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Climate Change and Sustainable Food Security

Editors
P K Shetty
S Ayyappan
M S Swaminathan

NATIONAL INSTITUTE OF ADVANCED STUDIES
Indian Institute of Science Campus, Bangalore-560 012

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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Krishi Bhavan, New Delhi - 110 001

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Preface

India has undergone a series of ups and downs in agricultural production with the climatic conditions playing havoc in the years of abnormality. We faced many droughts in 18th and 19th centuries without much know how to counterfeit their impacts. With the launch of Green Revolution (GR) in the late middle years of 20th century, India has improved its position in food grain production with technological interventions. The States of Punjab, Haryana and Western Uttar Pradesh could make use of GR technologies like high yielding varieties of rice and wheat, use of synthetic fertilizers and pesticides, irrigation facilities etc. and made enormous progress in food production. Currently, agroecosystems are facing the problems of over-exploitation of natural resources, decline in soil fertility, ground water level and agricultural productivity. Hence, ensuring sustainable food security is the need of the hour.

As per the statement of Minister of State for Agriculture and Food Processing Industries, Government of India (March, 2013), India's productivity of rice (3590 kg/ha) is lower than China (6686 kg/ha), Bangladesh (4219 kg) and Myanmar (4081 kg). Whereas India's productivity of wheat (1661kg) is lower than China (4838 kg) in 2011. China performed better in the productivity of coarse grains (5470 kg) and pulses (1533 kg) when compared to India which stood at 1591 kg and 699 kg respectively. India's per hectare production of pulses is the lowest when compared to its six neighbours - Bangladesh, Bhutan, China, Myanmar, Nepal and Sri Lanka. Besides all our efforts to enhance agricultural productivity through a huge network of institutions, we are still lagging behind due to numerous problems that are inherent in our system. At present, our aim should be to enhance the agricultural productivity without causing much damage to the natural resources and production environment. This calls for a stringent action to evolve varieties and technologies/innovations which can enhance the production/productivity of agricultural crops under changing climatic scenarios. This is possible through some innovative techniques like inducing C_4ness in rice, developing multiple resistant cultivars through MAGIC (multiparent advanced generation intercross), development of super hybrids, application of GIS/Remote sensing technologies, nanotechnology, crop modeling etc.. All the new generation technologies require policy support for their development as well as adoption for harnessing their full potential benefits. At the same time, the institutions involved in research, extension activities, development departments, banking, planning and execution should all come together and work in coherence to make this a successful venture.

This book contains lead papers from distinguished experts, policy makers and dedicated researchers. Efforts are made to compile the latest information on present agricultural scenario in India in comparison with other developed and developing nations and also the major problems faced by Indian agriculture, types of innovations required in research, policy and institutional set up to meet the ever increasing demands for food and nutritional security. It also emphasizes the steps to be taken up by various stakeholders involved in the agricultural production scenario to make agriculture a profitable proposition, without causing much damage to the natural environment. It also covers the important measures to be adopted for creating interest among youth for agriculture and to improve their livelihood security through various interventions by public and private sectors.

We hope that this book would be of immense use to researchers in planning their future line of research, for policy makers to take rational decisions on Indian agriculture which would benefit farmers as well as consumers by protecting the soil and environmental quality, for students and general public to have a wealth of information on agriculture in India. It must be mentioned here that while the scholarly papers included in this volume do help enrich the readers' understanding on the issues related to the climate change and sustainable food security, the views expressed by the authors in their respective papers are their own and the editors do not necessarily subscribe to them.

We thank all the contributors to this volume. Our special thanks are due to Dr.V.S. Ramamurthy, Director, National Institute of Advanced Studies (NIAS) Bangalore, Dr. Ajay

Parida, Executive Director, M. S. Swaminathan Research Foundation (MSSRF) Chennai, Dr. Parveen Arora, Adviser (Sc-F), Department of Science & Technology, Government of India (GOI), New Delhi, Dr. A. Arunachalam, Principal Scientific Officer to Director General, ICAR, GOI, New Delhi for their support and encouragement at every stage of its preparation. We are very grateful to Ms. G. F. Aiyasha, Mrs. Mariyammal, Mr.Thomas K.Varghese and Dr. K. Manorama for their kind involvement and contribution.

P. K. Shetty
S. Ayyappan
M. S. Swaminathan

Foreword

One of the potential threats to agriculture is the impact of climate change in attaining sustainable development of agriculture coupled with food security. Climate change phenomenon is now a global reality. India is one of the most vulnerable countries to climate change that is affecting agricultural production. Forecasts are made by the Indian Council of Agricultural Research using crop simulation models incorporating future projections. Climate change is projected to reduce timely sown irrigated wheat production by about 6% by 2020. In the case of late sown wheat, the projected levels are alarmingly high, to the extent of 18%. Similarly, a 4% fall in the yield of irrigated rice crop and a 6% fall in rain-fed rice are foreseen by 2020 due to climate changes. The warming trend in India over the past 100 years is estimated at 0.60°C. The projected impacts are likely to further aggravate yield fluctuations of may crops with impact on food security. It requires a serious attention on adaptation and mitigation strategies to overcome the problems of climate change.

Sustainable food security is further affected by persistent land degradation, land fragmentation, labour problem, over-exploitation of natural resources, etc. We need to focus on sustainable production systems by strengthening the ecological foundations. This requires a holistic approach by considering technological, biophysical, socio-economic, political and environmental factors. Food security and environmental sustainability can be attained by improved land and water management, adopting eco-friendly technologies and initiating good agricultural practices in different agro-ecosystems. Further, strategic research and technology in agriculture and adoption of sustainable practices are necessary to meet current and future threats to food security.

Ensuring sustainable food security is an important challenge for our nation as well as elsewhere in the world. We need to work towards a specific national policy to reach the goal of sustainable food security. I am glad to go through the book edited by Dr. P. K. Shetty, Dr. S. Ayyappan and Dr. M. S. Swaminathan on "Climate Change and Sustainable Food Security". The editors, who are eminent scientists themselves in the field of agriculture, have done a highly commendable work of putting together thought-provoking scientific papers contributed by several researchers in the field. The volume is a compendium of scientific papers covering different dimensions of issues associated with climate change and sustainable food security and ways to mitigate the problem. I profoundly appreciate their effort in bringing out this book which, I am sure, is the need of the hour, as it offers lot of pragmatic guidelines to the policy makers to improve Indian agriculture, besides serving as a very useful reference work for academicians and researchers engaged in studies on agricultural development. I heartily congratulate the editors and also the contributors of papers to this momentous volume

Shri. Sharad Pawar
Minister of Agriculture and Food Processing Industries
Government of India

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Climate Change and its Impact on Indian Agriculture

M. Rajeevan

Indian agricultural production and consequently, the country's Gross Domestic Product (GDP) show a strong link with the year to year variations of Indian summer monsoon rainfall. The Indian monsoon could be susceptible to the regional manifestations of global warming. The analysis of past climatic records from the country revealed significant warming trends in surface air temperatures including night temperatures and extreme precipitation events. All-India rainfall does not show any significant trends, however there are significant regional trends and sub-seasonal rainfall. The variations in monsoon rainfall and surface temperatures influence the food grain production in the country. The climate model projections based on IPCC AR5 CMIP5 models, reveal that surface air temperatures including night time temperatures are expected to further increase. The all-India rainfall is also expected to increase due to increased moisture availability. However, extreme rainfall events are also expected to increase in future.

The new climate projections based on the CMIP5 models should be used in future assessment of impact of climate change and adaptation planning. There is a need to consider not just the mean climate projections, but also the extreme projections in impact studies and as well in adaptation planning.

The Indian monsoon is one of the most dominant climate systems in the general circulation of the atmosphere. The country receives more than 80% of the annual rainfall during a short span of four months during the southwest monsoon season (June to September). The year to year variations in the onset, withdrawal and total amount of rainfall and distribution during the season have profound impacts on the agricultural sector. Thus, the

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capability to predict the Indian monsoon seasonal rainfall variability is significant to many sectors including agriculture. Apart from the challenges of coping with patterns of climate variability, there is also concern about how future climate change due to global warming may influence the Indian monsoon. There is now unequivocal evidence that the earth's surface has warmed during the past 100 years, which is mainly attributed to the anthropogenic activity. Changes in many components in the climate system, like precipitation, snow cover, sea ice, extreme weather events, etc., also have been observed. These changes, however, showed significant regional variations. Among the regional manifestations of global warming, the Indian summer monsoon also could be susceptible.

In this review paper, the aspects of climate change and its possible impact on Indian agriculture are discussed.

Climate variability and agriculture

Indian summer monsoon rainfall (ISMR) (monsoon seasonal (June to September) rainfall averaged over the country as a whole) is most remarkable for its great stability and reliability as the coefficient of variation is within 10% of historical normal. Fig 1 shows the year to year variation of ISMR. The time series data of ISMR since 1901 to 2012 shows no long term trends. However, there are regional changes which are statistically significant. In addition, ISMR exhibits significant multi-decadal variation with epochs of low and high rainfall (Figure 1). The recent period of below normal rainfall coming especially on the heels of a prolonged wet period, has raised some concerns whether climate change may now be weakening the Indian monsoon rainfall.

An analysis of surface air temperatures over the country showed a warming trend, which is similar to the warming of global surface air temperatures. Figure 2 shows the time series of annual average of surface mean temperature anomaly averaged over the country from 1901-2011. The anomalies are calculated from the long term normal of 1961-1990. The annual average surface temperatures have increased over the years with a trend of $0.56^{0}C/100$ years which is close to the global warming trend. There is a substantial increase in surface temperatures since mid 1970s. Further, surface temperature warming is noted over most of the country except over a few pockets over northwest India. It is further noted that night time temperatures have increased sharply during the recent years, highlighting the role of greenhouse gases. These warming trends of surface temperature also may have an impact on agriculture.

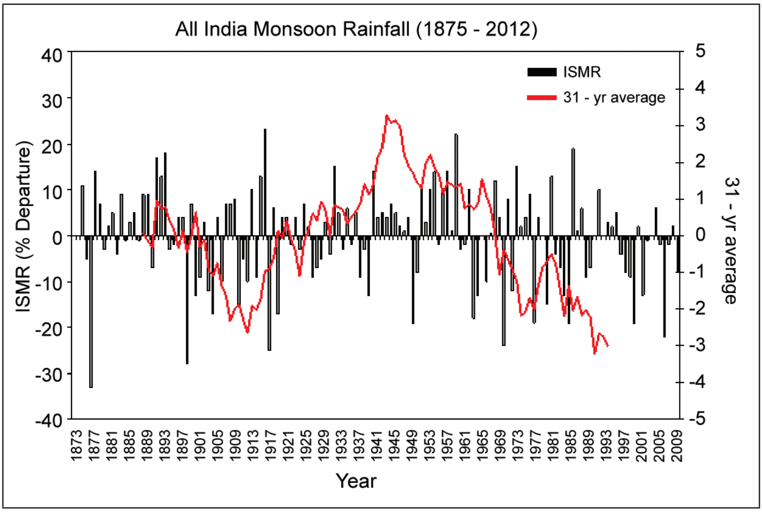

Figure 1: Time series of ISMR (% Departure) from 1875-2012 and 31-year running average of ISMR (continuous line).

Indian agricultural production and consequently, the country's Gross Domestic Product (GDP) show a strong link with ISMR (Gadgil and Gadgil 2006, Kumar *et al.*, 2004). In addition, temperature variations also play an equally critical role in crop production. The contribution of agriculture to the gross domestic product (GDP) has declined from 57% in 1950–51 to around 17% due primarily to growth in other sectors of the economy. There has been substantial growth in agricultural production due to technological developments. However, substantial year to variability about the trend is also noted. The year to year variability of weather and climate is primarily responsible for the year to year fluctuations in the agricultural production. The most striking feature of the variation of the crop yield with the anomaly of ISMR (Figure 3) is the asymmetry in response to deficits versus excess of ISMR.

It is seen that the magnitude of the impacts on crop yield increases rapidly with increasing deficits of ISMR. However, for positive anomalies of ISMR, the rate of increase of the impact on crop yield with ISMR is very small. This asymmetry in response to monsoon variability has important implications for the food security of the country. It implies that even when over a long period, the mean monsoon rainfall does not decrease, the negative impact of the deficit monsoon seasons cannot be made up by increases in crop yield in good monsoon seasons (Gadgil and Gadgil, 2006; Gadgil, 2012)

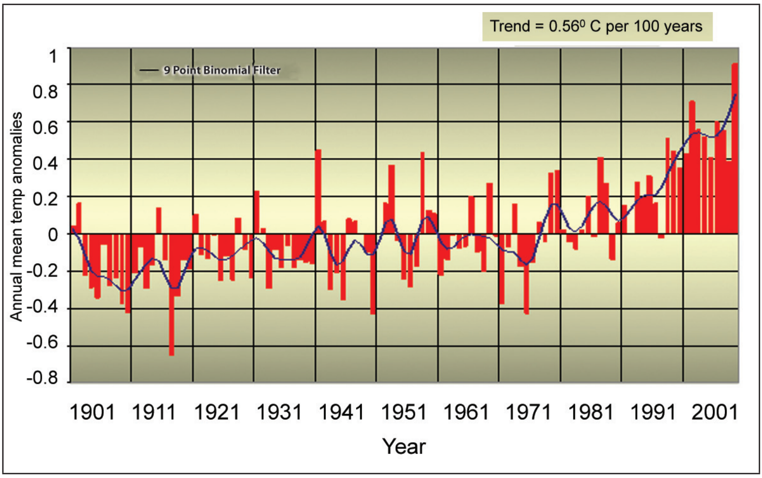

Figure 2: The time series of annual average surface air temperature anomaly averaged over the country from 1901-2011. The anomalies are calculated from the long term normal of 1961-1990. The smoothed variation using 9 point binomial filter is shown as a continuous line. The warming trend of annual temperatures is 0.56° C per 100 years.

When we consider crop production at an aggregate spatial scale, climate variability is more relevant than weather related impacts. Since variability in agricultural output is largely driven by the year to-year fluctuations in strength of the summer monsoon rains, it is important to examine how global warming and future climate change may affect the Indian monsoon climate. On agricultural perspective, in addition of quantum of rainfall, the length of the monsoon season, rainy days, length of weak/break monsoon spells, frequency of heavy rains etc are also important. Surface temperature variability also will play an important role in affecting agricultural production in the country (Kumar *et al.,* 2011).

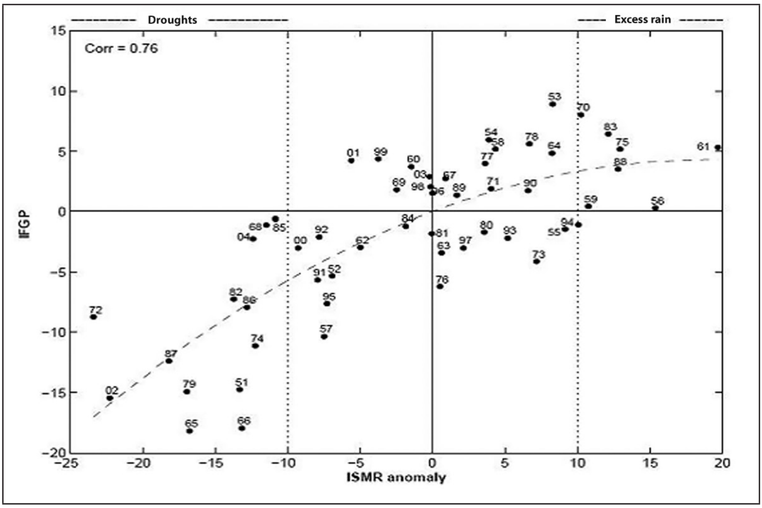

Figure 3: Relationship between ISMR anomaly and Food grain production in the country (Gadgil and Gadgil, 2006)

Projected climate change over India

The only way to understand the impact of global warming on the Indian monsoon and to assess future monsoon climate is to use climate models based on carefully constructed scenarios of emission of greenhouse gases. Previous studies (for example, Rupa Kumar *et al.,* 2006) examined the possible impact of the global warming on Indian summer monsoon using the output of different climate models. However, there are uncertainties in the regional climate projections due to the inaccuracies of the global climate models.

In a recent study, Kumar *et al.,* (2011) presented a comprehensive assessment of the present and expected future monsoon climate using observations and IPCC AR4 global climate model projections. The study suggested that monsoon seasonal rainfall over India in the latter half of the 21st Century may not be different in abundance to that experienced today. However, their intensity and duration of wet and dry spells may change appreciably. However, this assessment on precipitation has large uncertainty. On the other hand, Indian temperatures during the late 21st century will very likely exceed the highest values experienced in the 130-year instrumental record of Indian data. The assessment on temperatures has more confidence than for rainfall due to large spatial scale driving the thermal response of climate to greenhouse gases. The study revealed that monsoon climate changes, especially temperature could heighten human and crop mortality, thus posing a socio-economic threat to the Indian sub-continent.

The study made by Kumar *et al*. (2011) used the IPCC AR4 models. However, latest climate projections for the fifth assessment report of the IPCC are now available. These projections are made using the newly developed representative concentration pathways (RCPs) under the Coupled Model Inter-comparison Project 5 (CMIP5). For the IPCC AR5 projections, the scientific community has developed a set of new-emission scenarios termed as representative concentration pathways (RCPs), which represent pathways of radiative forcing and not detailed socio-economic narratives or scenarios. There are four RCP scenarios: RCP2.6, RCP4.5, RCP6.0 and RCP8.5. The naming convention reflects socio-economic pathways that reach a specific radiative forcing by 2100. For example, RCP8.5 leads to a radiative forcing of 8.5 Wm^{-2} by 2100.

Recently, Chaturvedi *et al*. (2012) examined the CMIP5 model projections on the future climate of the Indian monsoon. The study provides multi-model and multi-scenario temperature and precipitation projections for India for the period 1860-2099. They have used 18 CMIP5 coupled models to develop future projections. The study examined ensemble mean climate instead of individual coupled models as they found out that ensemble mean climate is closer to observed climate than any individual model. The salient results from this study are as follows:

1) Under the business-as-usual scenario, mean warming over India is likely to be in the range 1-7-2.0^{0}C by 2030s and 3.3-4.8^{0}C by 2080s relative to pre-industrial times.

2) All-India precipitation under the business-as-usual scenario is projected to increase from 4% o 5% by 2030s and from 6% to 14% towards the end of the century (2080s) compared to the 1961-1990 baseline.

3) The precipitation projections are generally less reliable than temperature projections.

4) There is consistent positive trend in frequency of extreme precipitation days (e.g., greater than 40 mm/ day) for decades 2060s and beyond.

Figure 4 shows the CMIP5 model ensemble-based time series of temperature and precipitation anomalies (historical and projections) from 1861-2099 relative to the 1961-1990 baseline for the RCP scenario (Chaturvedi *et al*, 2012).

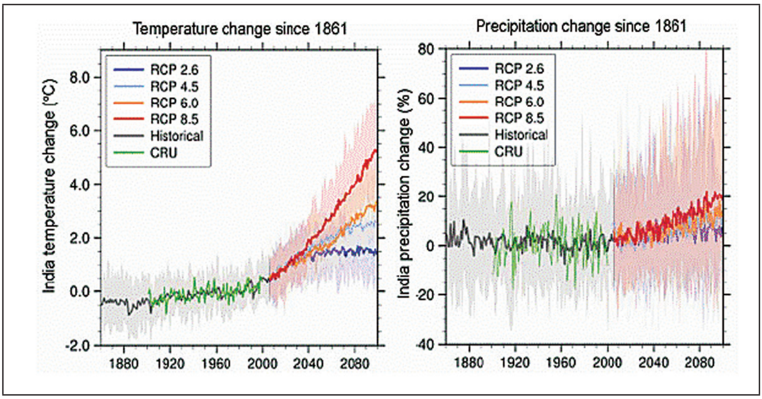

Figure 4: CMIP5 model based time series of temperature and precipitation anomalies (historical and projections) from 1861-2099 relative to the 1961-1990 baseline for the RCP scenario (Chaturvedi *et al*. 2012).

Figure 4 suggests that under RCP2.6 the ensemble mean temperature increases by approximately 2^{0}C over the period 1880s to 2070-2099 and 4.8^{o}C in RCP8.5. For RCP4.5 and RCP6.0, which represent the moderate scenarios, the projected increase in temperature ranges from 2.9^{0}C to 3.3^{0}C. All- India precipitation projections have larger uncertainties as evident from the large spread of the precipitation change projections in the figure, which ranges from -20% to 60% towards the end of the century. The model projections also suggest that all-India ensemble mean annual precipitation rise of 7%, 9.4%, 9.4% and 18.7% for RCP2.6, RCP4.5, RCP6.0 and RCP8.5 respectively by 2099 compared to the 1961-1990 baseline.

Figure 5 shows the percentage increase in the number of days when precipitation exceeds various thresholds. The period of 1861–1870 was selected as the reference period. The analysis projects consistently increasing trends in frequency of extreme precipitation days (e.g. 40 mm/day) for decades 2060s and beyond. The changes in extreme precipitation events have not emerged as a clear signal in 2010s in this model. The decline in heavy rainfall events in the 2050s is likely related to circulation changes on decadal variability in the model.

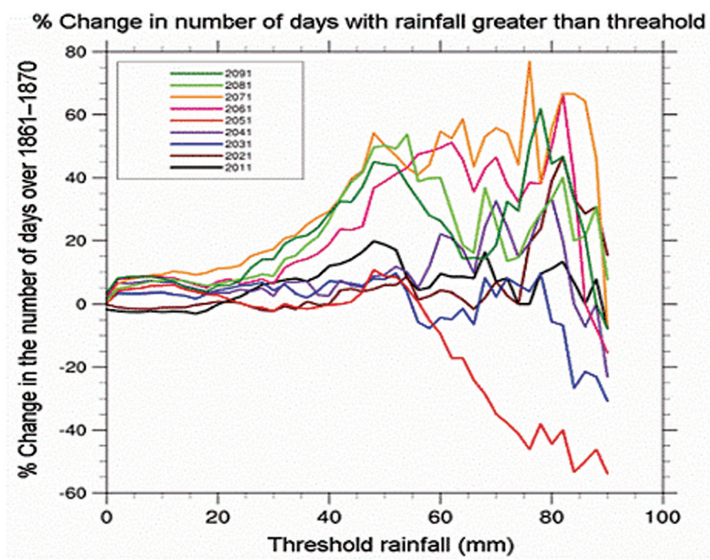

Figure 5: Projected change in the frequency of extreme rainfall days for future decades relative to the 1861–1870 baseline based on the MIROC-ESM-CHEM model for RCP4.5 scenario (Chaturvedi *et al,* 2012).

Impacts of climate change on agriculture

Agricultural sector is one of the sensitive areas which would be influenced by the projected global warming and associated climate change. In spite of the uncertainties about the precise magnitude of climate change on regional scales, an assessment of the possible impacts of changes in key climatic elements on our agricultural resources is important for formulating response strategies. Climate change may affect agricultural crops in four ways (Hulme, 1996). First, changes in temperature and precipitation will alter the distribution of agro-ecological zones. An increase of potential evapo-transpiration is likely to intensify drought stress, especially in the semi-arid tropics and subtropics. Second, carbon dioxide effects are expected to have a positive impact due to, greater water use efficiency and higher rate of photosynthesis. Third, water availability *(*or runoff*)* is another critical factor in determining the impact of climate change. A number of studies suggested that precipitation and the length of the growing season are critical in determining whether climate change positively or negatively affects agriculture. Fourth, agricultural losses can result from climatic variability and the increased frequency of extreme events such as droughts and floods or changes in precipitation and temperature variance. Higher frequency of droughts is likely to increase pressure on water supplies for numerous reasons ranging from plant transpiration to allocation.

Recently, Attri and Rathore (2003) used CERES-wheat dynamic simulation model and climate change scenarios projected by the middle of the current century. They found increase in wheat yield between 29–37% and 16–28% under rain-fed and irrigated conditions especially in different genotypes under a modified climate. An increase in temperature by 3^0C or more shall cancel out the positive effects of CO_2. Mall *et al*. (2004) used the CROPGRO-soybean model to simulate the impact of climate change on soybean production in India. Climate change scenarios for the selected regions of the Indian subcontinent were developed using the results from three climate models. For the crop growth model, the probable changes in surface air temperature during the growing season were estimated at the selected sites in the region following standard rationalization techniques. Probable changes in precipitation, cloudiness and solar radiation under the climate changes scenarios were not taken into consideration in this analysis in view of the significant uncertainties associated with non-linear, abrupt and threshold rainfall events projected by the climate models over the Indian subcontinent. In this study, all the GCM projected climate change scenarios (at the time of doubling of CO_2 concentrations) predicted decreased yields for almost all locations. Mean decline in yields across different scenarios ranged from 14% in Pune (West India) to 23% in Gwaliar (Central India). Decline in soybean yield is found to be less in west and south India as compared to other parts of the country. The mean yield was found to be significantly affected under UKMO climate model generated climate scenarios for both current and doubled CO_2 atmosphere.

These studies have indicated that the direct impacts of climate changes would be small on kharif' crops but kharif agriculture will become vulnerable due to increased incidence of weather extremes such as changes in rainy days, rainfall intensity, duration and frequency of drought and floods, diurnal asymmetry of temperature, change in humidity, and pest incidence and virulence. Rabi crop production may become comparatively more vulnerable due to larger increase in temperature, asymmetry of day and night temperature and higher uncertainties in rainfall. The impacts of the climate change on Indian agriculture would be small in near future, but in long run the Indian agriculture may be seriously affected depending upon season, level of management, and magnitude of climate change.

Night time temperatures above some threshold can have stronger negative impacts on rice yields compared to radiation and day time temperatures over India and other parts of south Asia (Peng *et al*, 2004). The recent studies highlight the importance of changing temperatures on the yields of major crops. The study by Kumar *et al*. (2011) suggested higher temperatures reduce the yields regardless of rainfall consistent with the findings by others. Not withstanding the positive benefits that may occur in crop yields under increasing CO_2 (Aggarwal and Mall, 2002), the substantial increase in temperatures could result in a net loss of productivity in the coming decades.

Conclusion

The analysis of past climatic records from the country revealed significant warming trends in surface air temperatures including night temperatures and extreme precipitation events. All-India rainfall does not show any significant trends, however there are significant regional trends and sub-seasonal rainfall. The variations in monsoon rainfall and surface temperatures influence the food grain production in the country. The climate model projections (based on IPCC AR5 CMIP5 models) reveal that surface air temperatures including night time temperatures are expected to further increase. The all-India rainfall is also expected to increase due to increased moisture availability. However, extreme rainfall events are also expected to increase in future.

The new climate projections based on the CMIP5 models should be used in future assessment of impact of climate change and adaptation planning. There is a need to consider not just the mean climate projections, but also extreme projections in impact studies and as well in adaptation planning.

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Sustainable Agricultural Productivity Growth, Food and Nutrition Security in India: An International Perspective

Shenggen Fan

Despite strong economic growth in recent decades, India is home to some 217 million undernourished people, or a quarter of all undernourished people globally (FAO, 2012). India also bears a high burden of child undernutrition, which is an especially important indicator of a country's overall human capital development. According to the United Nations Children's Fund (UNICEF), nearly half of preschool children in India are stunted and a similar number are underweight. As a result, India is likely to miss the Millennium Development Goal target of halving, between 1990 and 2015, the proportion of people who suffer from hunger.

Extensive prevalence of deficiencies in essential micronutrients such as vitamin A, iron, and iodine is also a challenge in India. Nearly a third of the population suffers from iodine deficiency. Iron deficiency is considered the leading cause of anemia globally and according to the World Health Organization (WHO). In India, 56 percent of adolescent girls and 85 percent of pregnant women in poorer states are affected by a high prevalence of anemia. Micronutrient deficiencies have the potential to weaken the mental and physical development of children and adolescents and to reduce the productivity of adults due to illness and reduced work capacity. The loss in productivity as a result of micronutrient deficiency is estimated to cost India the equivalent of 2.95 percent of GDP annually (FAO, 2012).

At the same time, more than 100 million people (or 11 percent of Indian population) are over-nourished. While undernourishment is prevalent throughout India, over-nutrition

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is most common in the urban areas. Over time, over-nutrition leads to obesity, which can lead to chronic and life threatening conditions such as diabetes, hypertension, and heart disease (Lauer, 2009). In addition to the burdens of undernourishment and malnutrition, many existing and future challenges threaten food and nutrition security, including continued population growth, scarcity and degradation of natural resources, and climate change.

Despite these challenges, there are reasons to be positive about the future. The experience of the Green Revolution in India and other Asian countries has shown that enormous progress can be made in feeding large numbers of people. Technological innovations as well as effective policies and institutions were critical for success during this period.

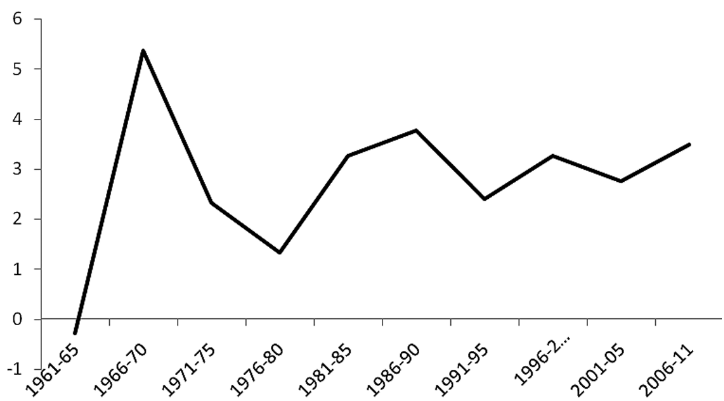
Moving forward, agricultural growth must be driven by productivity growth; environmentally sustainable; smallholder friendly with strong linkages to high-value markets; and explicitly associated to nutrition and health. In order to achieve sustained agricultural growth, India must promote more productive and smarter investments and eliminate inefficient subsidies. India should also learn from the experiences of other countries such as Brazil and China that have been able to sustainably accelerate agricultural growth (Gulati and Fan, 2007).

Agricultural growth has been crucial in feeding the country

Following independence in 1947, India designed and implemented various agricultural and industrial policies and strategies for achieving multiple goals such as economic self-sufficiency, industrialization/urbanization, and overall economic growth. The policies and strategies implemented include: central planning; price controls; nationalization of large enterprises; highly regulated international trade with high level of protection and restrictions for exports; taxation of agriculture; subsidies to urban and labor intensive industries; and state production monopolies in some sectors considered strategic (Nin-Pratt, Yu and Fan, 2010).

The performance of the agriculture sector in India, represented by the average annual growth rate of the value added in the sector since the early 1960s is shown in Figure 1. In the 1960s agriculture grew at an unprecedented rate with the average annual growth rate of the sector jumping from -0.3 percent in the early 1960s to 5.4 percent in the late 1960s – the highest increase seen for the sector so far. This came about as India increased its support for agriculture that began in the early 1960s by simultaneously increasing farmers' access to agricultural inputs such as high-yielding crop varieties, agricultural subsidies for fertilizers, irrigation, and electricity. However, India was unable to keep up this growth in the 1970s as the value of the sector grew by less than 2 percent during this time. This occurred as India experienced poor agricultural harvests coupled with an increase in domestic demand, oil price shocks, and deterioration of macroeconomic conditions, which resulted in major economic crises in the 1970s.

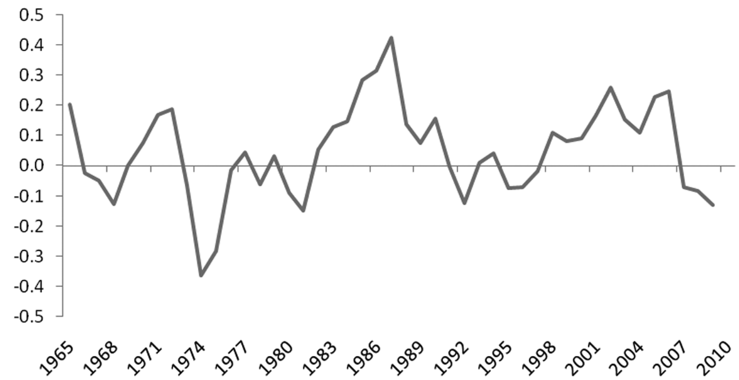
Figure 2 graphically summarizes the evolution of agricultural support policies implemented by India between 1965 and 2009 showing changes in the Nominal Rate of Assistance (NRA) – "the percentage by which government policies have raised/lowered gross returns to farmers above what they would be without the government's intervention" – to agriculture (Cervantes-Godoy and Dewbre, 2010). The NRA fluctuates around zero for India, with negative assistance seen between 1973 and 1980 when the country experienced economic down turns.



Source: World Bank (2012).

Figure 1: Average annual percentage growth in agricultural value added (%)

India was able to achieve higher growth in agriculture in the 1980s as the value of the sector grew at an average annual rate of 3.3 percent and 3.8 percent between 1981-85 and 1986-90, respectively (Figure 1). This came about as India recovered its support for the agriculture sector in the early 1980s by sharply increasing subsidies to farmers' inputs including fertilizer, irrigation, and electrical power, which determined the positive rates of assistance seen during this period (Figure 2). These, along with economy wide reforms in the 1980s (such as liberalization of trade on industrial goods and depreciation of the real exchange rate) resulted in higher agricultural growth seen in the 1980s (Nin-Pratt Yu, and Fan, 2010).



Source: Anderson, Kym, and Signe Nelgen (2012).

Figure 2: Nominal rate of assistance for all primary agriculture in India, value of production-weighted average (1965-2010)

India began to implement deeper and economy wide reforms in 1991, including the reduction of industry and trade regulations. However, no major changes were seen in agriculture specific policies as the sector faced many excessive regulations on private trading and market activities (Fan and Gulati, 2008). Agricultural assistance also declined during the 1991 economic crisis and reforms, and it recovered to positive rates of assistance only in late the 1990s (Figure 2). As a result, as shown in Figure 1, the average annual agriculture growth rate declined to 2.4 percent in the early 1990s. This rate recovered to about 3.3 percent in the late 1990s and stayed on a similar path as the country began to increase its support for the sector by increasing agricultural input subsidy and public spending in agricultural

R&D. The rate of assistance to agriculture saw a new reduction during the 2007/08 global food price crisis as India responded by banning export of staples such as rice and wheat while at the same time releasing government stock of these crops (Demeke, Pangrazio and Maetz, 2009). However, in the short-run this decline did not have much impact on the agricultural growth rate achieved in the late 2000s (Figure 1).

Another measure of the performance of the agricultural sector in India is its total factor productivity (TFP)—a measure of the efficiency of economic production and potential for future increases in output (Nin-Pratt, Yu and Fan, 2010). In this case it shows the relationship between growth of agricultural output and input, with TFP being raised when growth in output overtakes growth in input.

Similar to the trend observed for agricultural growth, India experienced the highest cumulative TFP growth in the early 1960s when the Green Revolution was underway. TFP growth slowly declined or stagnated for almost four decades afterwards – TFP declined by about 26% by the late 1990s compared to the levels seen in the early 1960s. Agricultural TFP began to grow again in the early 2000s and continued its slow growth afterwards and, by 2009, it grew by 17 percent from the levels seen in the late 1990s. During the decline in agricultural TFP in India, input subsidies were dominating government support for the sector- subsidies increased by about 90 times between 1966 and 1999 while public investment in agriculture steadily declined during the same time (Fan, Gulati and Thorat, 2008). The inability of subsidies to raise agricultural TFP in India shows the inefficiency of these policies compared to other public expenditures in agriculture such as in research and development (R&D). India began to invest more vigorously in agricultural R&D since the late 1990s that contributed to the reversal of the TFP decline in the 2000s. In the next section we identify areas of investment priorities for the Indian government in order to achieve sustainable and pro-poor increase agricultural productivity.

Future agricultural growth must come from productivity growth

India must achieve higher agricultural productivity growth in the future to address the persistent problems of poverty, food insecurity, and malnutrition. To do so, policymakers should scale up productivity-enhancing investments in agriculture and related sectors. Decisionmakers who allocate limited resources to support much needed smallholder-based agriculture in India must be informed of the impacts of different agricultural investments and subsidies on agricultural growth and poverty reduction in rural areas. This will help to design and implement policies that re-prioritize limited resources in order to increase the efficiency of limited resources in achieving the needed goals.

Table 1: Returns in growth and poverty reduction to investments and subsidies in India

	1960s-1970s	1980s	1990s
Returns in agricultural GDP (RPS per RPS spending)			
Roads	19.99	8.89	7.66
Education	14.66	7.58	5.46
Irrigation investment	8	4.71	4.37
Irrigation subsidies	5.22	2.25	2.47
Fertilizer subsidies	1.79	1.94	0.85
Power subsidies	12.06	2.25	1.19
Credit subsidies	18.77	3	4.26
Agricultural R&D	8.65	7.93	9.5
Returns in rural poverty reduction (number of poor reduced per million RPS spending)			
Roads	4,124.15	1311.64	881.49
Education	1,955.56	651.4	335.86
Irrigation investment	630.37	267.01	193.21
Irrigation subsidies	393.7	116.05	113.47
Fertilizer subsidies	90.07	109.99	37.41
Power subsidies	998.42	125.5	59.15
Credit subsidies	1,448.51	154.59	195.66
Agricultural R&D	642.69	409	436.12

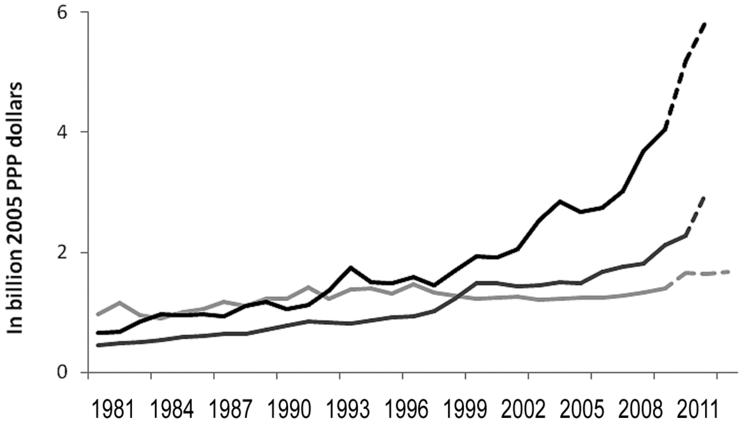
Source: Fan, Gulati and Thorat (2008).

Fan, Gulati and Thorat (2008) have investigated the efficiency of public expenditure in agriculture in order to achieve development goals in India. Table 1, which presents their findings, reports the returns to different types of government expenditures in each period, in terms of the impacts on agricultural GDP and poverty reduction. The authors find that in all the periods considered, agricultural research, education, and rural infrastructure are the three most effective public-spending items for promoting agricultural growth and poverty reduction. During the Green Revolution period in the 1960s and 1970s, India's investments in rural infrastructure and human capital were critical for successful outcomes. Initial subsidies in credit, fertilizer, and irrigation were also crucial to promote the adoption of new technologies among farmers, especially smallholders.

These findings have important policy implications. For the last three decades, we have seen a declining trend in public investments in agriculture in India and an increasing trend in investments in agricultural subsidies (Nin-Pratt, Yu and Fan 2010). The level of government subsidies to agriculture increased from around Rs. 20 billion in 1981 to Rs. 271 billion in 1999, an increase by 13 times in a span of two decades (Fan, Gulati, and Thorat 2008). Electricity and fertilizer subsidies have been particularly dominant followed by irrigation and credit subsidies.

While government spending has improved in recent years, trends suggest that it has not grown as fast as spending on agricultural input subsidies (Fan, Gulati and Thorat, 2008). Investments in input subsidies often come at the expense of more long-term capital investment in roads, rural education, and agricultural research that are needed to accelerate productivity. These subsidies also have to be replenished each year, which might not be fiscally sustainable in the medium to long term.

It is worthwhile to draw lessons for India from China's experience with boosting productivity growth as the two countries share some similarities in their development pathways. Both countries are large geographically and have large populations which remained poor during most of the twentieth century. Although China and India adopted very different political systems since the 1950s, they adopted similar development strategies (Nin-Pratt, Yu and Fan, 2010; Lal, 1995). However, during the onset of agricultural reforms in the late 1970s for China and the mid-1980s for India, the two countries followed different pathways. Unlike in India, agriculture played a central role in China's economic transformation as the country put in place crucial reforms such as freeing up rural markets and decentralization of agricultural production from collective to individual households (Nin-Pratt, Yu, and Fan, 2010).

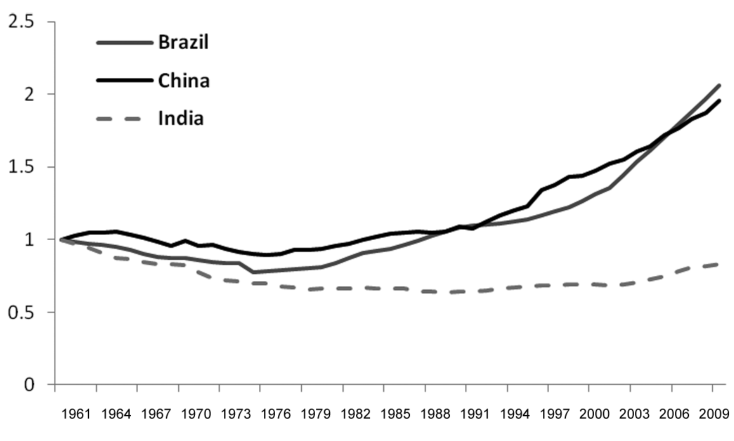


Source: Beintema *et al.* (2012).

Figure 3: Public Agricultural R&D spending in Brazil, China and India, 1981-2011

Brazil's commitment to achieve sustained public spending in agricultural R&D is also instructive emulating. Like China and India, Brazil also has large rural populations residing in geographical areas with diverse agro-ecological zones. Yet, India's agricultural support polices in the past two decades have differed from those implemented by Brazil and China. As Beintema *et al.* (2012) note, actions to improve agricultural productivity have been at the top of the agenda of these two countries. In recent years, Brazil and China have substantially increased their public investments in agricultural research (Figure 3). Between 2000 and 2008, China's public spending in agricultural R&D nearly doubled and it grew by an additional 50 percent just between 2009 and 2010. Although public agricultural R&D spending in Brazil has fluctuated in the last two decades, public investments in agricultural research have also risen in the last few years, growing by 20 percent between 2008 and 2011. In addition, it is noteworthy that Brazil's agricultural research system is one of the most well-established and well-funded systems across the developing world (Beintema *et al*, 2012).

India's success with accelerating agricultural research spending in the last few years is remarkable. Nonetheless, the performance of agriculture suggests that a reorganization of spending priorities, especially through cuts in inefficient subsidies, is required to accelerate agricultural productivity growth. Moreover, India needs to increase the proportion of its agricultural GDP that is invested in agricultural research. As Figure 4 illustrates, Brazil and China have been able to significantly raise TFP in the last few decades. Between the late 1990s and late 2000s, cumulative TFP in Brazil and China grew by 56 percent and 31 percent, compared to 17 percent in India. If a much longer horizon is considered late 1960s to late 2000s, cumulative TFP in India actually declined by 4 percent, compared to substantial growth of 115 percent and 87 percent in Brazil and China.



Source: Nin-Pratt (2012)

Figure 4: Agricultural total factor productivity index for Brazil, China, and India, 1961-2009

In addition to their strong commitment to agricultural research, both countries have launched policy and institutional reforms that propelled them ahead of the rest of the world in terms of agricultural productivity increases (Beintema *et al.*

2012). Such reforms include enhanced incentives for farmers, macroeconomic stability, improved rural infrastructure and market access, and relatively strong extension and rural education systems. Compared to Brazil and China, policy and institutional reforms in India have had a much less impact on agricultural productivity (Fuglie and Schimmelpfennig, 2010). In summary, to sustain long-term growth in agriculture and also to achieve a lasting solution to poverty, hunger, and malnutrition, the Indian government should cut subsidies and re-prioritize spending to scale up investments in agricultural R&D, rural infrastructure, and education.

Future agricultural growth must be environmentally sustainable

Going forward, India must work toward achieving a sustainable agricultural system. However, many challenges exist in trying to achieve this goal. The degradation and scarcity of natural resources, pollution resulting from agricultural production, food loss and waste, and food safety, both in terms of production and post-harvest handling, are critical issues that must be addressed in order to achieve sustainable agricultural growth in India.

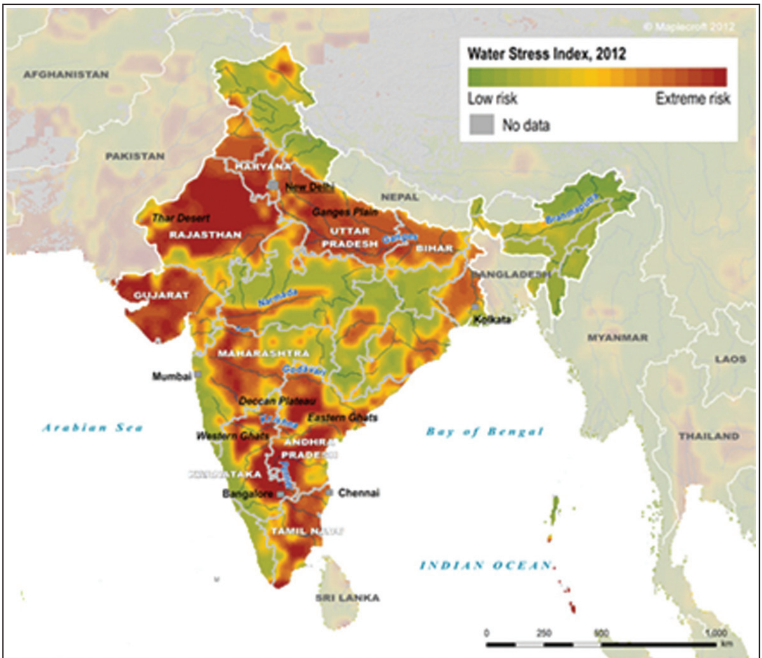
In terms of water scarcity, India faces severe water shortages with water availability per capita declining by more than 60 percent from 1962 to 2010 (Knight, Robins and Wai-Shin Chan, 2012). Figure 5 illustrates the extreme levels of water stress experienced across the Indian sub-continent. This results in uncertainty over crop yields and greater food insecurity unless concerted efforts are taken by government, the private sector, and non-governmental organizations to solve the water stress problem in India. India already accounts for 25 percent of all water used for agriculture globally, but water use efficiency can be greatly improved through institutional and management reforms of existing water systems.

The experience with water users' associations, participatory watershed schemes, and community based rain harvesting in some states in India can provide insights for future planning. Providing the right incentives to farmers is also crucial in promoting water saving. Improved crop yields can also lead to a more efficient use of scarce water resources and sustainable agricultural practices. For that, inputs other than water, such as credit and agricultural research on water saving and yield-improving technologies need to be deployed. Here India can also learn from China by strengthening its public institutions that provide public goods and services in rural areas and should make them cost-efficient (especially in power and water usage), which can lead to both fiscal sustainability and long-term growth (Fan and Gulati, 2008).

Regarding land degradation, it is estimated that nearly half of all land in India suffers from degradation due to various factors, including water and wind erosion, salinity, and soil acidity resulting from water logging. The majority of this degradation is the result of improper land use practices, including such factors as deforestation, increasing cultivation in areas of low potential or high hazard, improper soil conservation tactics and crop rotation, improper intensification of agro-chemicals like fertilizer and pesticides, and poorly planned irrigation systems, among others (Ministry of Environment and Forests, Government of India, 2009).

Investments should be made in enhancing farm productivity and improving resource-use efficiency, especially for smallholders, which create access to modern and improved inputs, including high-yielding and stress-resistant varieties. As with improved water-use technologies mentioned above, the government must incentivize the adoption of modern technologies through measures that decrease transaction costs, such as by increasing investment in rural infrastructure and modern financial products. Further, improving the dissemination of best practices, such as proper fertilizer usage and crop rotation, can help preserve areas currently being sown and promote the sustainability of arable land that is cultivated in the future.

Post-harvest food loss is also a concern for India. Nearly 30 percent of high-nutrient foods like fruits and vegetables perish as a result of limited infrastructure, such as cold storage facilities. Further, more than 30 percent of grain supplied through the public distribution system is lost during post-harvest handling due to factors like poor processing facilities (Venkat, 2012). In order to minimize the amount of high value commodities going to waste, the government should increase its support for the growth of agro-processing and cold storage facilities in the rural non-farm sector. In addition to food loss and waste reductions, these same investments, in combination with appropriate policies and regulations, can be used to improve the safety and quality of food products along the agri-food value chain.



Source: Maplecroft (2012)

Figure 5: Water stress in India

India should also promote win-win-win strategies in relation to climate change that involve investments and policies that promote climate change adaptation and mitigation—for example through improved land management and energy efficiency—alongside increased productivity. In this respect, increasing smallholder famers' access to biotic and abiotic stress-resistant high-yielding crop varieties will be crucial to reduce crop losses and promote sustainable intensification.

Future agricultural growth must be smallholder friendly, linking them to high value markets

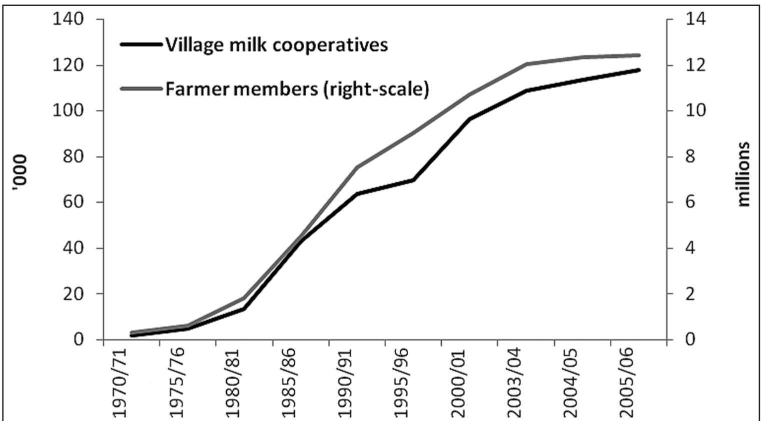
Indian agriculture is dominated by smallholders; the average size of land holding is about 1 hectare. Nearly 88 percent of the farm holdings own land less than 2 hectares and account for about 44 percent of the operated area (NSSO, 2006). They are efficient in production, but the high transaction costs that they face due to tiny marketable surplus make them inefficient in the entire supply chain. Since supply chains are also unorganized and inefficient, smallholders often receive less than 20 to 25 percent of the consumer prices. The problem is of multiple intermediaries and multiple handling that add to costs and wastage.

The challenge lies in linking smallholders with front and back ends of the supply chain and ensuring viable business opportunities for both farmers and agri-businesses. Establishing farm-firm linkages is not only about providing assured markets, reducing risk, and ensuring 'remunerative' prices, but also providing critical services such as credit, insurance, grading and inspection, technology extension, and market information. These institutional services can help elevate the scale at which smallholders can operate, raise their productivity and income, and mitigate the risks involved in participating in markets for high value horticultural, livestock, and fishery products (Gulati, Joshi and Landes, 2006).

The key issue that needs to be addressed is how smallholders can minimize transaction costs and reduce market risks. Experiences gained in developed countries and also in many developing countries in Southeast Asia, Africa, and Latin America have revealed that various forms of institutions, such as cooperatives, producers' associations and contract farming, have the potential to reduce transaction costs by vertically coordinating production, marketing, and processing (Warning and Key, 2000; FAO 2001; Narayanan and Gulati, 2002). There is a plethora of evidence from developing countries suggesting that farmers' incomes rise significantly with the adoption of value chain development. This happens by reducing the transaction costs and risks in food commodities and by improving access to better markets and higher prices. Once markets are accessible, farmers tend to diversify their production portfolio in favor of more remunerative and high-value food commodities. Well-functioning markets provide tremendous opportunities for smallholders to improve production and marketing efficiency, and contribute to higher incomes and poverty reduction. These innovative institutional arrangements also provide a platform for knowledge sharing, innovation, and value addition.

Thus, the impact of unlocking markets for smallholders through institutional innovations and strengthening value chains will immensely enhance their incomes and improve food and nutrition security. Studies have also shown that developing new markets increases the value of a nation's goods and services, thus adding to the growth of national wealth (Obi *et al.*, 2011).

In the Indian context, three aspects are critical for involving smallholders in sharing the benefits of emerging opportunities: (i) strengthening farm-firm linkage through innovative institutional arrangements such as contract farming, cooperatives, and producers' companies; (ii) developing the organized retail industry and ensuring smallholders' participation and enforcing food quality and standards to meet the requirements of global and domestic consumers; and (iii) strengthening the service and delivery systems to ensure regular supply of inputs, finance, and insurance services (Joshi *et al.*, 2007).



Source: Cunningham (2012)

Figure 6: Cooperative growth during and after operation flood, 1970 – 2006

The Indian experience with 'Operation Flood'—a national milk grid which linked millions of small dairy producers through cooperatives to domestic consumers is worth mentioning. The initiative, which began in 1970 and lasted until 1996, led to a 'white revolution' in the country, and today India, predominantly with smallholders, stands as the largest milk producer in the world with production over 110 million tones and a per capita availability of milk above 250 grams per day (Figures 6 and 7).

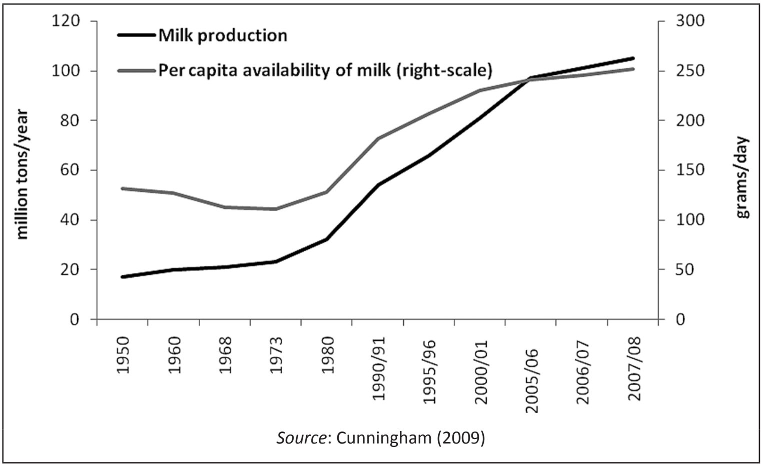


Figure 7: Production and per capita availability of milk in India, 1950-2008

Another example is that of the booming poultry industry in India as a result of contract farming. Domestic players such as Venkateshwara Hatcheries Limited, Saguna Hatchery, Godrej, and FieldFresh played key role in providing best technologies, ensuring supply of inputs and linking small scale producers to markets. Similarly, a number of large firms, engaged in organized retail chains, are contracting out fruits and vegetables production to farmers and farmers' associations.

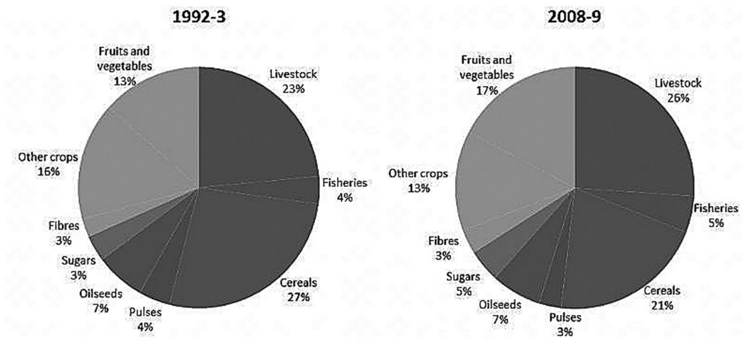
Studies show that the transaction costs of contract farmers were reduced by over 90 percent in dairy, 70-90 percent in vegetables, and 60 percent in poultry (Birthal *et al.*, 2005). The net revenue realization by contract farmers has been 2 to 4 times higher in dairy production and 1.2 times higher in poultry and vegetable production compared to that of non-contract farmers. In poultry, contract farming has helped in transferring as high as 88 percent risk from producers to the processors (Ramasawami *et al.*, 2003). Case studies also reveal that there has been more involvement of smallholders in these various models (Birthal *et al.*, 2005). Despite the significant benefits from innovative institutional arrangements which link farmers with high value markets, successes are confined to limited regions and commodities.

To overcome major hurdles in agricultural marketing and agro-processing, the Indian government undertook several steps to attract private sector investment in agri-food industry (Government of India, 2002). Among others, four major initiatives are: (i) amendment of the age-old Agricultural Produce and Market Committee Act in 2003, that was replaced by the Model Marketing Act, which promotes the role of the private sector in developing agricultural markets and links farmers with markets; (ii) allowed financial institutions to finance contract farming schemes and strengthened backward linkages; (iii) amendment of the company Act in 2002 to incorporate the concept of producer companies to promote Farmers Producers Companies, which can be run by the farmers and farmers associations; (iv) allowed 51 percent foreign direct investment in multi-brand retail in 2012, which is likely to improve the market efficiency, strengthen vale chain, reduce post-harvest losses, share benefits with producers and consumers, and guarantee food quality and safety issues. It is expected that these initiatives will modernize agricultural markets in India and enhance market access for smallholders to augment their incomes and improve food security.

Future agriculture growth needs to be explicitly linked to nutrition and health

Given that India is home to the largest number of undernourished and micronutrient deficient people in the world, agricultural development should play a critical role in improving nutrition and health outcomes. Agricultural growth strategies and investment policies need to be designed with a nutritional lens, identifying the likely trade-offs between implementing pro-nutrition growth strategies, poverty reduction, and targeted nutrition programs.

On the demand side, the recent dietary transition in India shows a troubling sign—calories from cereals, pulses, fruit and vegetables, milk and milk products, fish, meat and eggs declined or remained stagnant while calories from fats, beverages, and sweets increased, pointing to unhealthy shifts in diets in both urban and rural areas (Dubey and Thorat, 2012). Agricultural production patterns in India have been shown not only to respond to consumer demand, but also to strongly influence food consumption patterns especially when aided by further investments in public health and nutrition education.



Source: Kadiyala, Harris, and Gillespie (2012)

Figure 8: Share of value of output of agriculture, livestock, and fisheries in India

India's agricultural production is diversifying towards high value commodities with higher nutritional and monetary value (Figure 8). India is the world's largest producer of milk and second largest producer of fruits and vegetables. However, cereals continue to dominate agricultural policy debates in India as the recently passed National Food Security Bill shows (Kadiyala, Harris and Gillespie, 2012). Promoting diversification of Indian agriculture should, therefore, be a priority for policymakers in India as it plays an important role in diversification of the Indian food basket (Kadiyala, Gillespie and Thorat, 2012). This should, among other things, help to control for the high food price inflation that has been seen in India, especially of nutrient-rich, high-value food commodities, which tends to depress demand for these commodities.

The conditions under which the agricultural labor force in India work matter both for the success of efforts to sustainably increase agricultural productivity and the nutrition and health outcomes of farm households. India is seeing a feminization of the agricultural workforce as men are more rapidly shifting into nonfarm sectors. In 2004-05, around two-thirds of the female labor force in India was employed in the agriculture sector; in rural areas, this proportion was 83 percent. Yet, evidence to date suggests that Indian women employed in agriculture work very hard to the detriment of their nutrition status and that of their children (Galab and Reddy, 2012).

Women also face poor enforcement of property rights and institutional biases limiting access to land, markets, credit, inputs, extension, and other social services. Improving the status of women such as increasing their ownership and control of assets such as agricultural land and houses, and improving their access to education and health services should be a priority in order to ensure household dietary diversity and increase households' incentives to engage in agricultural productivity enhancing practices.

The push for technological innovations in India that improve nutritional status should also be developed along the whole agricultural supply chain from the development of more nutritious crop varieties all the way to the reduction of post-harvest losses. Biotechnology and biofortification, for example, have the potential to improve productivity and enhance environmental sustainability of specific crop varieties, but they need to be supported by effective and transparent regulatory institutions and systems so that timely and contextually relevant decisions can be made. Several efforts to conventionally breed beta-carotene-rich sweet potato and iron- and zinc-biofortified pearl millet are already underway in India. If India were to prioritize public research investment to ramp up the development of these technologies and effective supply chains, it would increase production and consumption of these nutrient-rich foods (Kadiyala, Gillespie, and Thorat, 2012). Smallholders in India should play a key role in forging links between agriculture and nutrition through the development and adoption of more nutritious staple and high-value food commodities. This should be accompanied by safety regulations to ensure more efficient post-harvest handling to reduce deterioration in the nutritional quality of foods and that agricultural intensification does not harm people's health.

Linking agriculture to health and nutrition outcomes in India also requires inter-sectoral cooperation that effectively exploits positive synergies among initiatives to improve nutrition and health through agriculture while reducing the tradeoffs (von Braun, Ruel and Gillespie, 2012). Achieving this requires better-integrated research and evaluation tools and incentives that promote policymaking processes and learning across agriculture, nutrition, and health sectors in India (Fan, Pandya-Lorch, and Fritschel, 2012). The TANDI initiative, which is facilitated by IFPRI with funding from the Bill and Melinda Gates Foundation, for example, builds a multi-stakeholder and cross-disciplinary agriculture-nutrition platform in India to identify key policy options and responses and is an important step in this direction.[1] Building datasets, ideally representative at the district level, that enable inquiry into the agriculture-nutrition links or disconnects and their variations across socioeconomic groups and regions, is also urgently needed (Gillespie and Kadiyala, 2012).

To address undernutrition and strengthen the link between agriculture and nutrition, principles of inclusiveness and equity should be the central organizing principle for the Indian agricultural sector. India can also learn from China in this respect. China's relatively egalitarian distribution of land, virtual lack of landlessness, and relatively equal access to health and education services set the stage for broad-based agricultural growth and significant reductions in poverty and undernourishment (Fan and Brzeska, 2012). India's agricultural growth that increases productivity and income of small and marginal farmers, as well as farm and nonfarm wage labor, should be leveraged to provide additional focus on inclusion of women and those from scheduled castes and scheduled tribes.

An integrated approach, which combines sustainable agricultural development and public health and nutritional interventions is also key (Kadiyala, Gillespie and Thorat, 2012).

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[1] The TANDI (Tackling the Agriculture-Nutrition Disconnect in India) initiative came about in January 2010 with a goal to better understand and address the failure of economic and agricultural growth to make significant inroads into reducing malnutrition in India. The platform brings together economists, nutritionists, and other stakeholders to address key knowledge gaps and drive a change in India's nutrition policy and program processes (Gillespie and Kadiyala, 2012).

Here India can learn from the experience of countries like Brazil. Brazil has one of the world's largest school feeding programs, which brings together agriculture, nutrition, and health, while at the same time making significant improvements to increase the inclusiveness of their social programs to reach poor and marginalized groups (Fan, Pandya-Lorch and Fritschel, 2012).

Conclusion

India must achieve higher agricultural productivity growth in the future in order to solve the persistent problems of poverty and food and nutrition insecurity as the country faces challenges such as continued population growth, scarcity and degradation of natural resources, and climate change. This paper reviews India's past agricultural policies and identifies areas of prioritization in order to sustainably grow the agricultural sector. India should reverse the declining trend in government investment in the agricultural sector as it holds much promise in reducing poverty and food insecurity. More specifically, the government should significantly increase its investment in agricultural research, education, and rural infrastructure as they are the three most effective public-spending items for achieving these goals.

Any agricultural development policy in India should also recognize the inextricable linkages between scarce resources such as water, land, energy, and food production that will be critical in sustainably meeting the growing demand for food. A more equitable land distribution for smallholder farmers along with support mechanisms to enable them to be productive on their lands and access markets—especially high-value markets—will be crucial. Smallholders in India should also play key role in forging links between agriculture and nutrition through the development of more nutritious staple and high-value food commodities. Safety regulations are needed to ensure that agricultural intensification does not harm people's health, and also to ensure more efficient post-harvest handling to reduce deterioration in the nutritional quality of foods. To address undernutrition, and strengthen the links between agriculture and nutrition, principles of inclusiveness and equity should be the central organizing principle for the Indian agricultural sector. Finally India should also learn from the experiences of countries like China and Brazil in their quest to eradicate poverty, hunger, and malnutrition.

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Indian Agriculture: The Way Forward

S. Ayyappan

Indian agriculture has witnessed transformation from an era of chronic food shortages during 1960s to food self-sufficiency and even surplus in some sectors, as a result of national research and development efforts directed towards generation of technologies (Green Revolution) provide critical inputs and develop relevant infrastructure. The annual foodgrain production has increased from about 50 million metric tonnes (mmt) in 1950-51 to over 250 mmt at present; the horticultural production has increased from 25 mmt to 241 mmt during the same period through science-led research interventions and development. The animal and fish sectors have also kept pace by recording annual production of over 120 mmt of milk, 65 billions of egg and 8.3 mmt of fish. 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. A significant contribution of science and technology-led output growth is the reduced cost of production in the range of 1.0-2.3% per annum during the past three decades in the case of cereals. As the largest private enterprise (~130 million farm families) of India, 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.

Agricultural research including education in India (National Agricultural Research and Education System, NARES) under the umbrella of Indian Council of Agricultural Research (ICAR), in one of the largest systems of research in the world, through 99 research institutes of 8 Zonal Project Directorates of the ICAR, 62 coordinated Research Projects, 17 network projects, 632 Krishi Vigyan Kendra, central universities and 65 Agricultural Universities.

P. K. Shetty, S. Ayyappan and M. S. Swaminathan (eds). *Climate Change and Sustainable Food Security*, ISBN: 978-81-87663-76-8, National Institute of Advanced Studies, Bangalore and Indian Council of Agricultural Research, New Delhi. 2013

The demand for food is constantly rising in view of ever increasing population (projected to be 1.5 billion by 2050) and improving per capita income. The trend in demand at national level indicates that by the year 2026-27, it is likely to rise by 1.3% per year for cereals, 3.0% for pulses, 3.5% for edible oil, 3.3% for vegetables, and 4-6% for fruits and livestock products over base year 2011-12 (Table 1).

Table 1: Estimates of Food Demand 2011-12 to 2026-27 (unit: million metric tonnes)

Commodity	2011-12	2016-17	2026-27	Compound growth rate %: 2026-27 over 2011-12
Cereals	218.86	235.67	265.24	1.29
Pulses	18.84	21.68	29.73	3.09
Edible oils	14.23	16.64	23.98	3.54
Sugar	23.70	26.50	32.95	2.22
Vegetables	139.17	161.01	226.39	3.30
Fruits	77.38	96.86	164.00	5.09
Meat and eggs	12.47	15.75	29.36	5.87
Fish	8.48	10.68	19.84	5.83

The use of high-input technologies of intensive agriculture over the five decades has resulted in soil degradation, nutrient depletion, surface and ground water depletion, poor drainage, problem soils and pollution in many areas of the high production zones. Variants of pests and pathogens as well as new pests and diseases have emerged. The other concerns at farm level are low input use efficiency, post-harvest management including processing, product development and value addition.

Recognising the various challenges for sustainable agriculture, the strategy is oriented to strengthen basic research to accelerate technology flow, train human resource at vocational, basic and higher education levels, integrate research in coordinated networks to accelerate technology generation and validation, and upscaling of technologies for translation, adoption and generation of profit in farm enterprises. This is now being viewed in an integrated 'farming system' perspective involving all forms of agriculture specific to the ecological regions of the country. In doing so, a definite focus is on the

Arid, Coastal, Hill & mountain, Irrigated and Rainfed systems integrating crop-animal/fish for maximizing productivity and farm incomes.

The fast-paced developments in science having applications in agriculture require higher skills and techniques and, therefore, capacity building deserves high priority. Modernization of research infrastructure, development of human resources and improvement in knowledge and skill of farmers are critical. Also, high priority should be accorded to build core competence in cutting-edge science and strategic research focused towards minimizing the vulnerability of the agricultural production systems. Acquisition of cutting-edge technologies and their dissemination will play a pivotal role. Owing to the increasing complexities in accessing and refinements in utilizing the 'next generation technologies', it becomes imperative to achieve self-reliance in the relevant areas such as biotechnology, information and communication technology, nanotechnology, geographical information system and robotics.

In the new 12^{th} Plan, a novel approach is contemplated in form of research consortia platforms which are proposed in critical areas such as agri-biodiversity management, genomics, seed, hybrids, conservation agriculture, input use efficiency enhancement, climate resilient agriculture, water &waste management, health foods, feed & fodder, fiber, biofortification, processing and post harvest management, diagnostics and vaccines, precision farming, farm mechanization, energy, nanotechnology, high value compounds/phytochemicals and agri-incubators. The core science institutions (public and private) related to disciplines concerned are integral part of the consortia platforms to make these the 'practical scientific solution providers' of the problems chosen. Further, core research areas like biology including molecular biology, genomics and genetically modified organisms (GMOs) along with the risk analysis prior and post-release and biotechnology, biophysics, chemistry, economics, evolution, space sciences and statistics have been prioritized on their scope to cover the gaps in research on complex issues such as drought and heat tolerance mechanisms in plant and animal systems, nutrient uptake efficiency and its management, allele mining, bioinformatics, host-pathogen interaction, weather prediction, development of fore-warning systems, molecular diagnostics and stem cell research in animals by roping in collaborations with other science agencies of the country.

The way forward is to ensure a holistic growth and vibrant research environment to increase agricultural productivity and farmers' profitability with minimum regional gaps. The new technological needs are knowledge and capital intensive and therefore, demand much higher investment. The research efforts require enhancement in budgetary allocation to 1% of the total Ag-GDP from present level of 0.6% that may gradually be enhanced to 2%. Appropriate supporting services, supplies and policies are vital links that enable us to meet our committed Development Goals. For making maximum impact of agricultural research for all round development and to make it an effective instrument to bring about inclusive growth of the economy.

Biosecurity, Sustainable Food and Nutrition Security

M. S. Swaminathan

The release of the "Science, Technology and Innovation Policy 2013" by the Prime Minister of India was a highlight of the Centenary Session of the Indian Science Congress held in Kolkata from January 3-7, 2013. This Policy introduces a new paradigm in our STI enterprise, viz., "science technology and innovation for the people". The Policy also calls for positioning our country among the top 5 global scientific powers by 2020. Sir Asutosh Mookerjee in his Presidential Address to the First Indian Science Congress in 1914 made the following remarks.

"What is of the greatest importance in our present condition – on the one hand, bring home to the commercial community the inestimable value of science as an essential factor of industrial regeneration, and, on the other hand, make the landed aristocracy realize that science enables us to solve difficult agricultural problems and thereby revolutionize agricultural methods."

Since the new STI paradigm calls for attending to the needs of the people, it may be worthwhile reminding ourselves that our position today in various global indicators relating to human development and nutrition is the following:

- National Family Health Survey (2005-06) Malnourished Children under 5 – *above 40 %*
- Low Birth Weight Children – *21 %*
- Union Planning Commission (2012) – *About 217 Million are undernourished*

P. K. Shetty, S. Ayyappan and M. S. Swaminathan (eds). *Climate Change and Sustainable Food Security*, ISBN: 978-81-87663-76-8, National Institute of Advanced Studies, Bangalore and Indian Council of Agricultural Research, New Delhi. 2013

- Global Hunger Index (IFPRI, 2012) – *65th position among 79 countries*
- UNDP Human Development Report (2012) – *134th position among 187 countries*
- Nutrition Barometer (Save the Children, 2012) - *Very Low Position*

It is obvious that we have to redouble our efforts in harnessing science for meeting the needs of our people in food and nutrition, water, sanitation, education, healthcare, shelter and energy. This was emphasized by the Prime Minister in his Opening Remarks at the Panel Discussion on "Science for Shaping the Future of India".

From Bengal Famine to Right to Food with home grown Food

2013 marks the 70th Anniversary of the Bengal Famine when about 2 million children, women and men died out of hunger. It also marks the determination of our country to confer on our people the Right to Food. This legislation is under the consideration of Parliament and is likely to become law before the end of this year. Thus India, which has over 18 percent of the world population and which was described in the early nineteen sixties as a country destined to lead "a ship to mouth" existence, has embarked upon conferring the legal right to food to all needing social protection against hunger. The right to food is to be implemented with home grown food.

Already, the State of Chhattisgarh in India has enacted a Food Security Act ensuring economic access to food to over 90% of its population. The Chhattisgarh Act includes the supply of pulses, iron and iodine fortified salt. The National Food Security Bill of India has the following important features:

- Women are recognised as the custodians of Household Food Security, by making them the recipients of the household Food Entitlement Card
- The Food Basket is enlarged to include nutri-cereals (Prof Swaminathan got the name "coarse cereals" changed to nutri-cereals) and other nutritious and climate smart "orphan crops"

- A life-cycle approach is adopted with reference to nutrition support, with special attention to the first 1000 days in a child's life, so as to avoid the birth of babies with a Low Birth Weight.
- Convergence and synergy is proposed among food and non-food factors of food security, namely clean drinking water, sanitation, toilets, environmental hygiene and primary health care.

The need for mainstreaming ecology in technology development and dissemination led to my replacing the term Green Revolution with "Ever-Green Revolution", which was defined as "increasing productivity in perpetuity without associated ecological or social harm". The scientific pathways which could lead to an Evergreen Revolution in agriculture have been studied and it is now possible to convert food security into sustainable food security.

Significant milestones in strengthening human security

Among significant milestones in addressing issues relevant to human wellbeing, it is important to mention three major events, which happened in 2012. These are

- **Rio +20 conference** held at Rio de Janeiro, Brazil, which addressed issues relating to "green growth". The Rio conference also suggested two major goals namely "Zero Net Land Degradation" and "Zero Hunger Challenge".
- **The climate convention conference** at Doha which unfortunately did not produce any significant new commitment on the part of industrialized countries. It is clear that the mean temperature may go up by 2 to 3 degree centigrade during this Century; also, sea level is likely to rise leading to a very large number of climate refugees seeking more safer locations to stay. Anticipatory research to meet these challenges is important.
- **The conference of parties to the global biodiversity convention** held at Hyderabad, India reemphasized the need for strengthening efforts in the areas of conservation, sustainable and equitable use of

biodiversity. This will involve putting a stop to habitat destruction and the introduction of invasive alien species. The Hyderabad conference christened as **"Biodiversity Summit"** helped to create greater public awareness of the urgent need to conserve biodiversity and to implement effectively our Biodiversity Act.

Price volatility

2012 was marked by extensive drought in USA, Eastern Europe, Central Asia and parts of India. Price volatility enhances the incidence of hunger, since over seventy per cent of the income of the poor goes to the purchase of food. We are now making the availability of food to all those needing social protection against hunger a legal right. This will require accelerated attention to alleviating agrarian distress and attending to the problems of our farmers, particularly those with small holdings. Total Factor Productivity, i.e., producing more with the same inputs, needs to be enhanced inorder to improve the economics of farming. The monsoon and the market are two major determinants of a farmers' wellbeing. We need more anticipatory research to meet the challenges arising from changes in precipitation, temperature and sea level. The zero hunger challenge requires hundred per cent access to adequate food all year round and the elimination of stunting in young children below the age of five. This will call for the hundred per cent increase in small holder productivity as well as the elimination of waste of food. Attention to food safety is equally important.

Womens' empowerment in agriculture needs special attention. For this purpose a Private Members' Bill was introduced in the Rajya Sabha. Similarly youth employment is necessary to ensure the future of our agricultural enterprises. This will call for improving the opportunities for market driven services in villages.

Stabilising population growth

Ultimately, the social impact of our scientific work will depend upon our ability to limit population growth. At the moment, it appears as though we will have to plan for a population of 1.5 billion by 2030. We must develop a Family Welfare Floor which lists the minimum essential steps needed to achieve our family planning goals. The following five catalytic interventions are particularly important:

- Delaying age at marriage.
- Delaying age at first pregnancy.
- Institutional delivery to bring down MMR.
- Promoting spacing between births.
- Improving the quality and adequacy of care of family planning and reproductive health programmes.

Mobilizing transformational technologies

Mobile telephony and other products of the ICT revolution need to be mobilized for conveying the needed information on weather, market prices, problems relating to health on the basis of a reaching the unreached approach. We can accelerate progress in adult literacy and healthcare through the use of e-medicine and e-education techniques. There are opportunities today for leap frogging in several areas such as healthcare, education and meteorological and market information. If India is to become one of the five global scientific powers by 2020, we should set-up more institutions for translational research, designed to convert scientific discoveries into commercial products and processes. There is need for more work on the development of vaccines both for human and animal diseases. The opportunities for combining scientific excellence and social relevance are immense.

We need a new breed of science communicators who can help to bridge the growing perception gap in relation to biosafety and nuclear power. The "science of science communication" needs greater attention. I would like to deal briefly with this urgent issue particularly with reference to nuclear power and genetically modified organisms.

Biosafety

The current concerns of biosafety and the impact of GMOs on bio- diversity will soon give way to an appreciation of the potential benefits that the new genetics can confer on humankind. Agricultural science and genetics together have fed the world and will continue to feed the world.

Recently, the Committee on Agriculture of Indian Parliament, headed by Mr Basudeb Acharia with 31 Members of Parliament drawn from both the Houses (Lok Sabha and Rajya Subha) and from all Political Parties has submitted a very detailed Report on "Cultivation of genetically modified food crops: Prospects and Effects" (Lok Sabha Secretariat, August 2012, 492 pp).

The Committee has unanimously recommended that *"till all the concerns voiced in the Report are fully addressed and decisive action is taken by the Government with utmost priority to put in place all regulatory, monitoring, oversight, surveillance and other structures, further research and development on transgenics in agricultural crops should only be done in strict containment, and field trials under any garb should be discontinued forthwith".* The Committee also suggested, *"What the country needs is not a biotechnology regulatory legislation but an all encompassing umbrella legislation on biosafety, which is focussed on ensuring the biosafety, biodiversity, human and livestock health, environmental protection, and which specifically describes the extent to which biotechnology, including modern biotechnology, fits in the scheme of things without compromising with the safety of any one of the elements mentioned above. The Committee, therefore, recommend to the Government with all the power at their command to immediately evolve such a legislation after due consultation with all stakeholders and bring it before Parliament without any further delay. In this context, the Committee would advise Government to duly consult the Norwegian Law, which emulates this spirit to a large extent".*

The Norwegian Act No.38 of 2nd April 1993, relating to the production and use of Genetically Modified Organisms focuses on biosafety, ethics and sustainable development without any adverse effects on the health and the environment. In my view, the suggestion that India should enact a comprehensive law on Biosafety on the lines recommended by the Parliamentary Committee on Agriculture is a sound one and should be acted upon immediately.

Nuclear power

Another recent example of the need for greater interaction between scientists and local communities is the concern expressed by the public in relation to the

Kudankulam and other Nuclear Power Plants. Nuclear power is environmentally benign since it does not add to the green house gas burden. On the other hand, there are concerns about the safety of the Nuclear Power Plants, particularly in the context of what happened at Chernobyl many years ago and Fukushima recently. The tsunami induced Fukushima tragedy has given a big setback to the spread of nuclear power plants. Nuclear waste disposal is another area which needs careful consideration. The situation observed at Kudankulam where technical experts and the general public have been living in different worlds, emphasizes the need for fostering continuous interaction between technical experts and the local communities. Such interaction and conversation should begin from the very early stage of the conception and construction of a nuclear power plant. Citizens' Consultative Councils will help to promote more enlightened and informed discussions on the issues involved. Parliament has recently approved an Atomic Energy Regulatory Authority Bill. The Bill provides for an autonomous and professionally credible and competent Regulatory Body. It is obvious that a Regulatory Body should not be under the control of the persons to be regulated, which was the case until recently. Ultimately, regulation alone will not be adequate for achieving public acceptance. Education and social mobilization through elected Local Bodies are equally important.

As frontier science progresses, more and more of such issues of public concern will grow. Nanotechnology will also create fears and apprehensions. The role of scientists in the area of public information and education will increase. We need a cadre of Science Communicators possessing both proficiency in science and mastery of communication. In this regard we need to appreciate the efforts of Prof C V Raman who used to deliver lectures for school students on topics like, "Why the Sky is Blue" or "Structure of Diamonds" with great clarity and lucidity. Our Universities should help in developing Science Communicators who can explain to the general public in local languages the significance of important scientific discoveries. Biodiversity, Biotechnology, Nuclear Technology and Nano-technology need priority attention in efforts designed to bridge the Scientist-Society perception gap.

Towards a biosecure agriculture

Our national preparedness and capability in the area of biosecurity are currently issues of widespread debate following the detection of H5N1 strain of avian influenza virus in a few small pockets in Maharashtra and Gujarat. Biosecurity has wider implications in the areas of biological warfare and bio-terrorism. This area is obviously a matter of serious concern to the National Security Council. In our country, agricultural biosecurity covering crops, trees and farm and aquatic animals is of even greater importance since it relates to the livelihood security of nearly 70% of the population, and the food, health and trade security of the nation.

The world is truly becoming a global village with reference to communication and transport. Disease causing organisms can spread fast through aeroplanes and farm trade. India is the transitory home for many migratory birds. Our country is also becoming a national village with reference to communication, transportation and trade. Therefore home quarantine assumes as much importance as international quarantine. Border movement of farm goods and animals in the case of neighbouring countries is another area of biosecurity significance.

The National Commission on Farmers is concerned with the impact of invasive alien species on the livelihood security of farm women and men. Therefore, it stressed in its very first report submitted in December 2004, the need for a thorough review of our present infrastructure and institutional framework in the area of agricultural biosecurity, including the WTO specifications of sanitary and phytosanitary measures.

The National Bureau of Plant Genetic Resources has been intercepting many alien invasive pests along with imported agricultural commodities. There is also the threat of new strains of wheat rusts. Hence, NCF has been holding Consultations on developing a National Agricultural Biosecurity System characterized by high professional, public and political credibility.

The major conclusion of such Consultations is that we urgenntly need a National Agricultural Biosecurity System with the following principal goals.

- To safeguard the income and livelihood security of farm and fisher families as well as the food, health and trade security of the nation through effective and integrated surveillance, vigilance, prevention and control mechanisms designed to protect the productivity and safety of crops, farm animals, fishes and forest trees.
- To enhance national and local level capacity in initiating proactive measures in the areas of monitoring, early warning, education, research, and international co-operation, and to introduce an integrated biosecurity package comprising regulatory measures, education and social mobilization.
- To organize a coordinated National Agricultural Biosecurity Programme on a hub and spokes model with effective home and regional quarantine facilities capable of insulating the major agro-ecological and farming systems zones of the country from invasive alien species of pests, pathogens and weeds.

Organisational structure of the National Agricultural Biosecurity System (NABS):

The NABS should have the following three mutually reinforcing components.

- **National Agricultural Biosecurity Council (NABC):** Chaired by the Union Minister of Agriculture, NABC will serve as a platform for convergence and synergy among the on-going and new programmes of different Ministries and Departments of the Government of India, as well as appropriate international and State Government Agencies and Private Sector Organisations. NABC should serve as an apex policy making and coordinating body and should pay particular attention to strengthening the national capacity in agricultural biosecurity as related to crops, farm animals, forestry and aquatic organisms. The existing infrastructure for sanitary and phytosanitary measures will have to be reviewed and major gaps filled. While in developed countries, any disaster arising from invasive alien species like H5N1 strain of the Avian Flu may be more of a human health problem, since hardly 2 to 3% of population are engaged in farming, agriculture is the backbone of the livelihood security system in rural India.

- **National Centre for Agricultural Biosecurity (NCAB):** This National Centre should have four wings dealing with crops, farm animals, living aquatic resources and agriculturally important micro-organisms. The major purpose of this Centre will be the analysis, aversion and management of risks, as well as the operation of an early warning system. NCAB will maintain databases relating to potential threats to Indian agriculture and human health security from alien invasive species. It will also serve as a watch dog agency helping to initiate **pro-active** action in the case of impending biosecurity threats. NCAB could provide the Secretariat for the National Agricultural Biosecurity Council. Further, it should work on the standardization of surveillance and control methods and help to introduce the latest molecular techniques like micro-arrays for disease diagnosis. NCAB should have considerable capacity in computer aided monitoring and early warning systems. The four different divisions of NCAB could be located in appropriate existing ICAR Institutes / Agricultural / Animal Husbandry and Fisheries Universities, such as the High Risk Animal Diseases Laboratory of ICAR at Bhopal

- **National Agricultural Biosecurity Network (NABN):** NCAB could serve as the coordinating and facilitating center for a National Agricultural Biosecurity Network designed to facilitate scientific partnerships among the many existing institutions in the public, private, academic and civil society sectors engaged in biomonitoring, biosafety, quarantine, and other biosecurity programmes. This will help to maximize the benefits from the scientific expertise and institutional strengths already available with the National Agricultural Research system, CSIR, ICMR, Ministry of Environment and Forests, Ministry of Science and Technology etc. The National Agricultural Biosecurity Network could have four mini-networks relating to crops and forestry, animals including migratory birds, living aquatic organisms and agriculturally important microbes.

Agricultural biosecurity compact:

The following are some of the other areas which require urgent attention from the proposed National Agricultural Biosecurity Council.

- Regulation: Review all existing Acts relating to biosecurity and identify and fill gaps in the existing regulatory framework. Based on such a review, develop a National Agricultural Biosecurity Policy for being placed before Parliament and the National Development Council.
- Education: Education holds the key to prevent unconscious and ill-informed introductions of invasive alien species. There is need for launching a Biosecurity Literacy Movement in the country. Human resource development is also exceedingly important. A course may be introduced in all Agricultural, Veterinary, Fisheries and Rural Universities, and Home Science Colleges on Agricultural Biosecurity. This should be done at the basic degree level. A Media Resource Centre should be established by the proposed National Centre for Agricultural Biosecurity to give timely and authentic information to mass media.
- Social mobilisation: Agricultural Biosecurity should be everybody's business and not merely that of a few government departments or academic institutions. It would be useful to train Grassroot Biosecurity Managers (atleast one woman and one male) in every Gram Panchayat and Nagarpalika. Towns and Cities require equal attention to enlist urban populations in the fight against biologically dangerous introductions and to create a well-informed public opinion in relation to agricultural risks and human health hazards.

Strategic partnerships:

A strong and effective National Agricultural Biosecurity System requires collaboration with neighbouring countries with whom we share a common border, as for example Bangladesh, Burma, Bhutan, Nepal and Pakistan. In addition, the proposed National Agricultural Biosecurity Council could foster appropriate regional and international partnerships in the fight against agricultural pandemics. Collaboration with SAARC and ASEAN nations will be particularly beneficial. Also, India should play an active role in the FAO Programme on Agricultural Biosecurity funded by the Government of Norway. Collaboration with Australia will be very beneficial, since Australia is developing a very well designed Agricultural Biosecurity system at the national level. Partnerships among the private, academic, civil society and public sectors as well as with the mass media should be promoted.

National Agricultural Biosecurity Fund:

NCF recommends the establishment of a National Agricultural Biosecurity Fund of about Rs. 1,000 crores with an initial contribution by the Government of India and appropriate international and bilateral donors as well as private sector companies. Such a Fund is urgently needed for the following purposes.

- Strengthening infrastructure for sanitary and phytosanitary measures.
- Upgrading facilities for plant, animal and fish quarantine and certification
- Establishing an off-shore genetic screening center for animals for the purpose of identifying genes for resistance to serious disease epidemics arising from invasive alien species, such as the H5N1 strain of the Avian Flu in poultry. Fortunately, there are unmanned islands in Lakshadweep which can be developed as off-shore Genetic Screening Centres. The present policy of killing indiscriminately all native breeds of poultry will be harmful since we may lose the wonderful opportunity of identifying genetic resistance to serious diseases. At the same time, off-shore screening in isolated areas under high security arrangements will help to avoid risks within the country.

Another purpose of a National Agricultural Biosecurity Fund will be to provide timely assistance to the affected farm families whose animals such as poultry have to be culled in national interest.

To sum up, it will be prudent to take immediate action in setting up a National Agricultural Biosecurity Council, National Centre for Agricultural Biosecurity and a National Agricultural Biosecurity Network. This will help to strengthen considerably our ability to prevent the outbreak of disease pandemics and to initiate timely and effective control measures, when needed. The proposed Agricultural Biosecurity Network could include also neighbouring countries, thereby forming strategic partnerships to prevent potential pandemics. Above all, a National Agricultural Biosecurity Fund will help to strengthen our infrastructure, introduce new molecular techniques of identification and verification, derive benefits from our animal genetic resources, and provide needed and timely help to the affected families.

Sustainable Food Security

Famines were frequent in colonial India and some estimates indicate that 30 to 40 million died out of starvation in Tamil Nadu, Bihar and Bengal during the later half of the 19th century. This led to the formulation of elaborate Famine Codes by the then colonial government, indicating the relief measures that should be put in place when crops fail.

The Bengal Famine attracted much attention both among the media and the public, since it occurred soon after Mahatma Gandhi's, "Quit India" call to the British in 1942. Agricultural stagnation and famines were regarded among the major adverse consequences of colonial rule. On the occasion of the 70th anniversary of the Bengal Famine, Parliament is likely to pass the National Food Security Bill which will be the world's largest social protection measure against hunger. How did this transition came about? I would like to pick up key factors which played a significant role in changing our agricultural destiny from the "ship to mouth" situation which prevailed during 1950-70, to the "right to food" commitment of 2013.

First, the Nehru era marked the developement of the scientific infrastructure essential for improving farm productivity, such as major and minor irrigation projects, fertilizer factories, agricultural universities, farm extension services and marketing facilities. To get the benefit from the investment in these areas, an Intensive Agricultural District Programme (IADP) was started in 1960-61. By 1963-64, IADP covered 15 districts. Unfortunately the impact of IADP on yield improvement was not upto expectation. My analysis showed that the package of practices missed one important ingredient, namely, a genetic strain which can respond to the rest of the package, particularly irrigation water and fertilizer.

It is this missing ingredient that helped to provide by undertaking a search for genes for non-lodging plant habit. Such a change in plant architecture helped the new strains to convert nutrients and water into grains and consequently they came to be referred to as high-yielding varieties. In 1962-63, it became clear that food self-sufficiency is an idea whose time has come. Keeping in view a plan was prepared early in 1963 titled "Five Years of Dwarf Wheats", outlining a road map for achieving a substantial rise in production by 1968. An important component of this Plan was launching a large Lab to Land programme in the form of national demonstrations in the fields of small and marginal faremrs. Agriculture is a risky profession and predictions are difficult. However, the strong public policy support extended by Shri C Subramaniam supported by Prime Ministers Lal Bahadur Sastri and Indira Gandhi, led to the fulfillment of our expectation that 1968 will mark a new beginning in our agricultural history. Indira Gandhi released a special stamp titled "the Wheat Revolution" in July 1968 to mark this event.

The second transformational factor was procurement of food grains from farmers at a minimum support price (MSP) fixed on the basis of the advice of the Agricultural Prices Commission. A small government programme titled "High Yielding Varieties Programme" became a mass movement owing to the enthusiasm generated among farm families both by the yield revolution and the opportunities for assured and remunerative marketing. Wheat production has continued to rise since 1968 and has now reached a level of 92 million tonnes. A third important factor was the synergy brought about among scientific know-how, political do-how and farmers' toil, often referred to as the "green-revolution symphony". While we can be legitimately be proud of our progress in the production of wheat and rice and other cereals and millets leading to the commitment of government of over sixty million tonnes of foodgrains for implementing the provisions of the Food Security Bill, there is no time to relax since dark clouds are gathering in the horizon.

There are three important threats to the future of food production and our sustained capacity to implement the provisions of the Food Security Bill. First, prime farm land is going out of agriculture for non-farm purposes such as real estate and biofuels. Globally, the impact of biofuels on food security has become an increasing concern. A High Level Panel of Experts on Food Security and Nutrition (HLPE) of the World Commission on Food Security (CFS), will be submitting a report shortly on Biofuels and Food Security. In this report, we are pointing out that if 10% of all transport fuels were to be achieved through biofuels in the world, this would absorb 26% of all crop production and 85% of the world's fresh water resources. Therefore, it will be prudent for all countries to accord food security the pride of place in the national land use policy.

The second threat comes from global warming and climate change. It is now clear that the mean temperature may rise atleast by 2 degrees centigrade during the next few decades. Adverse changes in temperature, precipitation and sea level are all causes for concern. Both anticipatory research to checkmate the adverse consequences of climate change, and participatory research with farming families for developing adaptation and mitigation measures will be important. A third threat comes from the proposal to provide cash instead of grain to those needing protection against hunger. Such a shift may lead to a loss of interest in procurement and storage by public agencies like the Food Corporation of India. Most of our farm families have small holdings and have very little holding capacity. They want to sell as soon as their crop is harvested. If procurement goes down, there will be distress sales and production will go down. We should remember that the green revolution has been sustained only by assured and remunerative marketing opportunities. The Public Distribution System will suffer if procurement by public agencies goes down. National and global price volatility will increase, adding to the misery of the poor. Government therefore should always remain at the commanding height of the food security system.

On the occasion of the 70th anniversary of the Bengal Famine, we should derive strength from the fact that we have so far proved the prophets of doom wrong. At the same time, we need to redouble our efforts to help our farmers to produce more food and other commodities under conditions of diminishing per capita availability of arable land and irrigation water. This will be possible if the production techniques of the evergreen revolution approach are followed and farmers are assisted with appropriate public policies to keep agriculture an economically viable occupation. This is also essential to attract and retain youth in farming. If agriculture goes wrong, nothing else will have a chance to go right.

New Innovations, Technologies and Practices Enhancing Agricultural Production and Productivity in India

K. Ramasamy

Agricultural sector in India plays a pivotal role in ensuring food and livelihood security and sustainable economic development. This sector over the years has been confronted with many challenges. The agricultural sector is also subject to degradation of the quality of natural resources hitherto available, vulnerable to erratic monsoons coupled with climate change and severe pressure from increasing population demand higher food production. Such burgeoning pressures also impact other sectors since agriculture has a main stake. Besides, policies addressing to agricultural sector need to accelerate the economic development satisfying both the producers and domestic consumers. Similar to developments in other sectors namely manufacturing and services, the technology development and practices in agriculture also created some cushions to postpone the yield stagnations. However, any future increase in food production to meet the demand must come from increase in productivity of crops subject to the various tangible and intangible constraints.

This paper attempts to bring various issues and challenges facing Indian agriculture, the innovations brought in along with technology support and extension and strategies to be adopted for enhancing agricultural production and yield in India. For the sake of comprehension, the issues discussed in this paper are confined to crops alone though the allied activities of agriculture like livestock and fisheries do contribute to overall agricultural development.

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Current status

The contribution of agriculture to the Gross Domestic Product (GDP) at constant price was estimated at 15.97 per cent (2011-12) as against 53.71 per cent during 1950's (Economic. Survey, 2011-12). However, the contribution to GDP in terms of actual value has been increasing. The role of agriculture sector is also more critical as it is the major provider of employment, supplier of food, fodder and raw materials to many industries.

Growth in agricultural crops depend on acreage and yield. Considering the limitations in the expansion of available area under cultivation, the long term growth in agriculture is possible only through drastic improvements in yield levels. An analysis on the growth rates in area, production and yield of the seven major crops cultivated in India would highlight limitations and challenges, (Table 1).

Table 1: Compound Growth Rates (%)

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

An analysis on annual growth rates in area, production and yield of seven major crops based on the actual figures reveal some interesting facts. These growth rates were estimated for three decades viz. 1980-81 to 1989-90, 1990-91 to 1999-2000 and 2000-01 to 2010-11. Rice being one of the major crops, had shown a declining trend in growth rates in area and production, more specifically 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 against 1980's. Contrary to these observations, maize had shown some positive signals with an 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. The hike in production was achieved mainly through an increase in yield from mere 473 kg/ha to 689 kg/ha.

Similar achievements could also been seen in the case of oilseeds where there is a positive growth in area, production and subsequently yield. Cotton, one of the major commercial crops showed mixed trend over the years. The 1980's 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 crop and its performance over the years observed to be somewhat unstable as the area under sugarcane declined during 1990's as against 1980's and later recouped during the periods from 2000-01 to 2010-11. However no substantial increase in growth in production and yield could be revealed in sugar cane. The above performance measures of the principal crops over the years could lead to important conclusions. Any increase in production resulted from more of yield gains rather than expansion in cultivated area. High production and productivity achievement obtained through "Green Revolution" earlier was the reason for achieving food security to a larger extent and the country has not witnessed a major technological breakthrough since then. This calls for action on several fronts and the precise mix varies from one agro climatic zone to the other (Planning Commission, 2011).

Demand – supply gaps

The trend in population growth projects India to emerge as the most populous country in the world. Under these circumstances, proper balance between demand and supply prospects of food items becomes critical to the country's food security concerns. Many studies have forecasted the demand and supply situations based on the current growth in population and income, price change and change in productivity levels.

An elaborative study conducted by Mittal, 2008 concluded that an increase demand for food is seen with low yield growths especially in cereals any surplus in cereal production in the country is likely to diminish in the years to come. This is more alarming in the case of edible oil and pulses and the policy focus is needed for productivity enhancement (Table 2). Negative signs in respect of total cereals, pulses, oilseeds and sugars indicate the demand for the commodity outstrips supply and thus imply a deficit of the commodity in future. The deficit however is projected to increase over the years particularly for the above food items. This is a challenge as well as an opportunity. Providing ample opportunities to domestic producers would no doubt increase the income, generate more employment and involve more number of additional stakeholders through handling, value addition, processing and marketing.

Table 2: Supply-Demand Gap for selected food item

(Million tonnes)

Gap (Supply minus Demand)		
Food Items	**2021**	**2026**
Rice	8.98	9.13
Wheat	27.33	32.04
Total Cereals	-2.94	-16.97
Pulses	-24.92	-39.31
Edible oils	-17.68	-26.99
Sugar	-39.67	-74.13

Source: Surabhi Mittal, Demand-Supply Trends and Projections of Food in India, Indian Council for Research on International Economic Relations, Working Paper No. 209, March 2008

High-low productivity regions

Increase in agricultural yield and the growth is however not uniform across the major producing states in the country. An analysis is done in this paper based on the individual state's share of production of various crops to the country and the area allocated to achieve these productions (Table 3). In case of rice, 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. There could be many limitations in West Bengal to achieve the yield that were obtained in Punjab.

Table 3: State wise share in Area, Production and Yield of Principal crops (2009-10)

1. Rice

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**

2. Wheat

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**

3. Maize

State	Area %	Rank	State	Production %	Rank	State	Yield (kg/ha)
Karnataka	15.01	1	Karnataka	18.02	1	Tamil Nadu	4686
Rajasthan	13.28	2	A.P	16.52	2	W. Bengal	3943
M.P	10.07	3	Maharashtra	10.93	3	A.P	3527
Maharashtra	9.61	4	Bihar	8.84	4	Punjab	3417
A.P	9.48	5	Rajasthan	6.85	5	Karnataka	2430
U.P	8.58	6	Tamil Nadu	6.84	6	Bihar	2341
Bihar	7.65	7	M.P	6.25	7	Maharashtra	2302
Gujarat	6.02	8	U.P	6.21	8	H.P	1839
Others	5.17	9	Others	3.88	9	J & K	1566
J & K	3.76	10	H.P	3.25	10	U.P	1465
H.P	3.58	11	Gujarat	3.19	11	M.P	1256
Tamil Nadu	2.96	12	J & K	2.91	12	Jharkhand	1169
Jharkhand	1.98	13	Punjab	2.84	13	Gujarat	1072
Punjab	1.68	14	W. Bengal	2.30	14	Rajasthan	1044
W. Bengal	1.18	15	Jharkhand	1.14	15	Others	-
All India	**100**		**All India**	**100**		**All India**	**2024**

4. Pulses

State	Area %	Rank	State	Production %	Rank	State	Yield (kg/ha)
M.P	21.22	1	M.P	29.36	1	M.P	871
Rajasthan	15.04	2	Maharashtra	16.16	2	Bihar	836
Maharashtra	14.50	3	U.P	12.97	3	W.B	826
U.P	10.91	4	A.P	9.75	4	Haryana	758
Karnataka	10.65	5	Karnataka	7.63	5	U.P	748
A.P	8.30	6	Rajasthan	4.87	6	A.P	740
Orissa	3.72	7	Gujarat	3.53	7	Jharkhand	709
Chhattisgarh	3.47	8	Chhattisgarh	3.33	8	Gujarat	705
Gujarat	3.15	9	Bihar	3.22	9	Maharashtra	702
Bihar	2.43	10	Orissa	2.72	10	Chhattisgarh	604
Tamil Nadu	2.30	11	Others	1.84	11	Orissa	461
Others	1.61	12	Jharkhand	1.53	12	Karnataka	451
Jharkhand	1.36	13	Tamil Nadu	1.39	13	Tamil Nadu	382
West Bengal	0.78	14	West Bengal	1.03	14	Rajasthan	204
Haryana	0.57	15	Haryana	0.68	15	Others	-
All India	**100**		**All India**	**100**		**All India**	**630**

5. Oilseeds

State	Area %	Rank	State	Production %	Rank	State	Yield (kg/ha)
M.P	26.06	1	M.P	30.69	1	Tamil Nadu	1898
Rajasthan	15.92	2	Rajasthan	17.71	2	Haryana	1645
Maharashtra	14.96	3	Gujarat	12.45	3	Punjab	1354
Gujarat	10.76	4	Maharashtra	11.31	4	M.P	1129
A.P	7.98	5	A.P	6.03	5	Gujarat	1109
Karnataka	7.71	6	Karnataka	4.04	6	Rajasthan	1066
U.P	4.18	7	Tamil Nadu	3.78	7	W.B	1065
Others	2.88	8	Haryana	3.53	8	Bihar	1042
W.B	2.63	9	U.P	3.28	9	U.P	753
Haryana	2.05	10	W.B	2.92	10	Maharashtra	725
Tamil Nadu	1.91	11	Others	2.08	11	A.P	724
Orissa	1.13	12	Orissa	0.69	12	Orissa	589
Assam	1.06	13	Assam	0.58	13	Assam	526
Bihar	0.53	14	Bihar	0.58	14	Karnataka	502
Punjab	0.24	15	Punjab	0.34	15	Others	-
All India	**100**		**All India**	**100**		**All India**	**959**

6. Cotton

State	Area %	Rank	State	Production %	Rank	State	Yield (kg/ha)
Maharashtra	34.50	1	Gujarat	33.25	1	Punjab	667
Gujarat	24.32	2	Maharashtra	24.39	2	Haryana	646
A.P	14.48	3	A.P	13.43	3	Gujarat	551
M.P	6.03	4	Punjab	8.35	4	A.P	374
Punjab	5.04	5	Haryana	8.02	5	Tamil Nadu	368
Haryana	5.00	6	Rajasthan	3.76	6	Rajasthan	345
Karnataka	4.51	7	Karnataka	3.61	7	Karnataka	323
Rajasthan	4.39	8	M.P	3.56	8	Maharashtra	285
Tamil Nadu	1.03	9	Tamil Nadu	0.94	9	M.P	238
Others	0.70	10	Others	0.69	10	Others	-
All India	**100**		**All India**	**100**		**All India**	**403**

7. Sugarcane

State	Area %	Rank	State	Production %	Rank	State	Yield (kg/ha)
U.P	47.36	1	U. P	40.08	1	Tamil Nadu	101452
Maharashtra	18.11	2	Maharashtra	21.95	2	Karnataka	90335
Karnataka	8.07	3	Karnataka	10.41	3	Maharashtra	84866
Tamil Nadu	7.02	4	Tamil Nadu	10.18	4	Gujarat	80519
A.P	3.78	5	Gujarat	4.24	5	A.P	74101
Gujarat	3.69	6	A.P	4.00	6	West Bengal	72522
Bihar	2.78	7	Uttarakhand	2.00	7	Haryana	72095
Uttarakhand	2.30	8	Haryana	1.83	8	Punjab	61667
Haryana	1.77	9	Bihar	1.72	9	Orissa	61238
M.P	1.49	10	Punjab	1.27	10	Uttarakhand	60854
Punjab	1.44	11	M.P	0.87	11	U. P	59251
Others	1.02	12	Others	0.59	12	Bihar	43422
Assam	0.65	13	Assam	0.36	13	M.P	40821
West Bengal	0.33	14	West Bengal	0.34	14	Assam	39077
Orissa	0.19	15	Orissa	0.18	15	Others	-
All India	**100**		**All India**	**100**		**All India**	**70020**

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

Similar analysis to other principal crops like wheat would indicate there are still untapped potential regions in the country to increase our production of the crops provided the constraints to production adequately addressed. 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. Yield performance in the different states and their respective positions to the total area are shown in Table (4). 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. Similar arguments can be placed in other crops. Thus there is need to indentify local constraints.

Constraints in production

The various constraints or limitations are responsible for poor performance in yield in some of the states. Among the states where there the highest yield levels had been achieved, a yield plateau could possibly be foreseen. Both the situations however need to be addressed as the former situation is an opportunity where as the latter situation is a threat. Thus the limitations to harness the yield potential are many. One can delineate such constraints as resource, technology and policy based. The resource based including land and irrigation limits the scale of operation in the country. For instance there has been only marginal increase in the net sown area over three decades (Table 5). As the area sown more than once has increased from 34.63 million hectares (1980-81) to 53.74 million hectares, it resulted in an increase of cropping intensity from 123 per cent to 138 per cent. With reference to irrigation coverage, the country's net irrigated area has increased from 38.72 million hectares to 63.20 million hectares during the above period. However, the percentage of irrigation coverage to the net area sown has increased from 28 per cent to 44.71 per cent. About 55 per cent of the gross cropped area is still not covered under irrigation inducing severe pressure on land. Besides, differences do occur in irrigation coverage among the various crops.

Table 4: State wise Yield performance (2009-10)

Food Items	National Average (kg/ha)	Above National Average	No. of States	Below National Average	No. of States
Rice	2125	Punjab (7), Tamil Nadu (9), A.P (5), Haryana (14) Kerala (17), West Bengal (1), and Karnataka (11)	7	U.P (2), Gujarat (16), Assam (8), Orissa (3), Jharkhand (15), Maharashtra (12), Bihar (6), Chhattisgarh (4) and M.P (13)	9
Wheat	2907	Punjab (3) Haryana (4) Rajasthan (5) and U.P (1)	4	W.B (11), Gujarat (8) Bihar (6), Uttarkhand (9), J&K (12), M.P (2), Jharkhand(15), H.P, (10) Maharashtra (7),Assam (16) and Karnataka (13)	11
Maize	2024	Tamil Nadu (12), W.B (15), A.P (5), Punjab (14), Karnataka (1), Bihar (7) and Maharashtra (4)	7	H.P (11), J.K (10), U.P (6), M.P (3), Jharkhand(13), Gujarat (8) and Rajasthan (2)	7
Pulses	630	M.P (1), Bihar (10), W.B (14), Haryana (15), U.P (4), A.P (6), Jharkhand (13), Gujarat (9) and Maharashtra (3)	9	Chhattisgarh (8), Orissa (7), Karnataka (5), Tamil Nadu (11) and Rajasthan (2)	5
Oilseeds	959	Tamil Nadu (11), Haryana (10), Punjab (15), M.P (1) Gujarat (4), Rajasthan (2), W.B (9) and Bihar (14)	8	U.P (7), Maharashtra (3), A.P (5), Orissa (12), Assam (13) and Karnataka (6)	6
Cotton	403	Punjab (5), Haryana (6) and Gujarat (2)	3	A.P(3), Tamil Nadu (9), Rajasthan (8), Karnataka (7), Maharashtra (1) and M.P (4)	6

Food Items	National Average (kg/ha)	Above National Average	No. of States	Below National Average	No. of States
S. Cane	70020	Tamil Nadu (4), Karnataka (3), Maharashtra (2) , Gujarat (6), A.P(5), West Bengal (14) and Haryana (9)	7	Punjab (11), Orissa (15), Uttarkhand (8), U.P (1), Bihar (7), M.P (10) and Assam (13)	7

Source: Own Compilation from Table 3

Note: Figures in parentheses denote respective position of the state in the country to the total area

Table 5: Land Use Pattern in India

(Million Hectares)

Sl No	Classification	1980-81	1990-91	2000-01	2008-09
I.	Geographical Area	328.73	328.73	328.73	328.73
II.	Reporting Area	304.16	304.86	305.18	305.69
1	Forest	67.46	67.81	69.53	69.63
	%	22.18	22.24	22.78	22.78
2	Not Available for Cultivation (A+B)	39.55	40.48	41.48	43.32
2A	Area Under Non-agricultural Uses	19.60	21.09	23.89	26.31
	%	6.44	6.92	7.83	8.61
2B	Barren & Un-culturable Land	19.96	19.39	17.59	17.02
	%	6.56	6.36	5.76	5.57
3	Other Uncultivated land excluding Fallow Land (A+B+C)	32.31	30.22	27.74	26.51
3A	Permanent Pasture & other Grazing Land	11.99	11.40	10.67	10.34
	%	3.94	3.74	3.49	3.38
3B	Land under Miscellaneous Tree Crops & Groves not included in Net Area Sown	3.58	3.82	3.44	3.40
	%	1.18	1.25	1.13	1.11
3C	Culturable waste Land	16.74	15.00	13.63	12.76
	%	5.51	4.92	4.47	4.17
4	Fallow Lands (A+B)	24.55	23.37	25.07	24.86
4A	Fallow Lands other than Current Fallows	9.72	9.66	10.29	10.32

Sl No	Classification	1980-81	1990-91	2000-01	2008-09
	%	3.20	3.17	3.37	3.37
4B	Current Fallows	14.83	13.70	14.78	14.54
	%	4.88	4.49	4.84	4.76
5	Net Area Sown (6 minus 7)	140.29	143.00	141.36	141.36
	%	46.12	46.91	46.32	46.24
6	Gross Cropped Area	172.63	185.74	185.34	195.10
7	Area Sown more than once	34.63	42.74	43.98	53.74
8	Cropping Intensity	123.05	129.89	131.11	138.01
III.	Net Irrigated Area	38.72	48.02	55.13	63.20
IV.	Gross Irrigated Area	49.78	63.20	76.19	88.42

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

The declining average size of holding is another major threat and limits the scale of operation. The average size of operational holding in India has come down steadily from 2.28 hectare in 1970-71 to 1.16 hectare in 2010-11. Such marginal size of holding with marginal rise in operational area would add more number of marginal and small farmers implying that there are nearly twice as many farms as four decades ago.

Developments in molecular biology, bio technology, nano technology etc. are expected to provide significant new opportunities for yield enhancement of various crops. These technical developments also pose new challenges like increased adaptation, capacity building, policy changes, regional and global cooperation.

Innovations, technologies and strategies

Several categories of innovations have been introduced to increase agricultural production and productivity in the country. The categories include mechanical innovations (tractors and farm implements), biological innovations (new varieties, hybrids, seeds etc.,), chemical innovations (fertilizers and pesticides), agronomic innovations (new management practices), biotechnological innovations and informational innovations that rely mainly on computer technologies. In crop improvement, biotechnology plays key role in improving agronomic traits and quality of food crops. Tools like genetic engineering, marker assisted selection, genomics etc., help us to improve many of the complex traits in plants.

One of the important applications of genetic engineering is to improve plant traits by over-expressing or suppressing specific genes associated with the phenotypic trait. Examples include improved yield, reduced vulnerability of crops to environmental stresses, enriching nutrient content in grains, development of "Golden rice" possessing increased beta-carotene accumulation in rice grains and rice grains possessing enriched iron content by over-expressing "Ferritin" gene(s). Few technologies are helping the farmers to have reduced dependency on fertilizers, pesticides and other agrochemicals. For example, *Bacillus thuringiensis* (Bt) is a soil bacterium that produces a protein with insecticidal qualities (Bt toxin). Crop plants have now been engineered to contain and express the genes for Bt toxin, to impart resistance against lepidopteran pests.

In case of oilseeds used mainly for production of margarine and other food oils can be modified to produce fatty acids for detergents, substitute fuels and petrochemicals. Banana trees and tomato plants have also been genetically engineered for production of vaccines from the fruits. Technologies are being used to engineer and adapt organisms to find sustainable ways to clean up contaminated environments. Elimination of wide range of pollutants and wastes from the environment is an absolute requirement to promote a sustainable development of our society with low environmental impact.

Another technique known as *in vitro* gene shuffling allows extremely rapid evolution of genes encoding new enzyme activities. Gene shuffling has been used to greatly improve the catalytic capabilities of an enzyme (GAT; glyphosate N-acetyltransferase) found in bacteria that naturally has a very weak ability to modify glyphosate herbicide (by addition of an acetate residue) to a form that is inactive in plants. This helped the scientists to develop herbicide tolerant crop varieties. Recent innovations in molecular biology help us to impart virus resistance in plants through a method called "RNAi mediated gene silencing". Through this technique, virus resistance has been engineered in papaya, tomato, banana, cucumber, tapioca etc.

Marker assisted breeding refers to physical detection of small DNA sub regions associated with complex traits in plants through methods viz., restriction fragment length polymorphisms (RFLPs), microsatellites (SSRs) etc., DNA markers are useful for backcrossing major genes (such as those conferring pest-tolerance) into proven high performing cultivars. They can aid selection for traits that are not easily assayed in individual plants. Introduction of unwanted genes, genetically linked to the desired trait (genetic hitchhiking) can be minimized and the time needed to obtain a plant with a high percentage (98 – 99 %) of the original desirable genetic background can be substantially reduced. Using this technology, popular rice varieties have been improved for their bacterial leaf blight resistance, blast resistance, submergence tolerance, drought tolerance and salinity tolerance etc.,

In the twenty first century, genome science (chromosome sequence decoding and computer assisted dissection of gene functions and structure) is increasingly used to assist plant breeders. One important approach is to compare gene arrangements in different species (comparative genomics) to take advantage of the greater ease of gene sequencing and faster progress with smaller more compact genomes such as those of *Arabidopsis thaliana* and *Oryza sativa* (rice), to provide clues for gene function and location in crop species with larger genomes. This has led to the development of Genome Wide Association Analysis in natural population to identify genomic regions/ genetic polymorphisms associated with agronomic traits.

Besides in the farmer's field through extension support many technologies have been developed and practiced. System of Rice Intensification (SRI) is a synergistic management technique involving four components of rice farming such as planting, irrigation, weed and nutrient management strategies. Besides, few more packages namely preparation of mat nursery, transplanting and weeding are also introduced. Modified mat nursery technique, mechanized planter and weeder are also developed. Mechanization of rice crop production in irrigated eco-system, integration of herbicidal and mechanical weed management for different rice ecosystems and rice production technologies for protected agriculture (precision agriculture, conservation agriculture) are the future strategies for improvement of productivity of rice in the country. In wheat production, the major constraints are biotic and abiotic stresses. Major issues in yield improvement through technology are breaking the yield barriers through exploitation of heterosis for developing hybrids.

In case of maize, nutrient applications are not matching to the crop's demand and hence there is ample opportunity to improve maize yield through better nutrient management optimum nutrient applications and fertigation technology to economize the fertilizer use and increase the efficiency. Improving the efficiency of water use through the use of sprinkler and drip technology for improving the yield and quality of maize, water logging during the rainy season is the major problem for which adequate drainage facilities should be arranged since the crop is highly sensitive to water logging. Moisture conservation measures for rainfed maize cultivation, providing supplemental irrigation through farm ponds and mobile sprinklers, skill manpower for hybrid maize development and seed production, technical and investment support to private enterprises to establish maize seed industry, technological interventions on low cost and efficient management practiceswould lead to substantial increase in maize production.

Through Integrated Scheme of Oilseeds, Pulses, Oil palm and Maize (ISOPOM), Maize Development Programmes are being implemented in 15 States viz. Andhra Pradesh, Bihar, Chattisgarh, Gujarat, J & K, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, U.P. & West Bengal. The main emphasis of the scheme is on transfer of modern crop production technology to the farmers' fields through front line demonstrations, field, Integrated Pest Management and seed mini kit demonstrations, capacity building for field officers and farmers, conference/ seminars/ workshops on Maize Development, use of improved implements, etc.

In case of cotton, machine picking is very important to minimize cost of cultivation and to complete the operations in minimum possible time. In view of this, focus is to identify varieties / genotypes suitable for machine picking, to find out appropriate spacing, dose and time of application of defoliant to cause leaf shedding to synthesis boll opening. In case of sugarcane crop, mechanization could offer more opportunities to cope with the labour scarcity and expansion of the area.

Conclusion

In lieu of severe pressure on natural resources and ever increasing demand for larger food and agricultural production arising due to high population and income growths, agricultural intensification is the main strategy for future growth of agriculture in the country. Besides developing technologies for promoting intensification, the country needs to emphasize development of technologies that will facilitate agricultural diversification particularly towards production of fruits, vegetables, flowers and other high value crops that are expected to increase income growth and generate effective demand for food.

Thus identification of need-based productive programs is very critical which can be explored through characterization of production environment which are so diverse. We have to develop demand-driven and location-specific programs to meet the requirements of different regions to meet the targeted growth in agriculture. Besides, because of the high variability in agro-climatic conditions, research has to become increasingly location-specific with greater participation or interaction with farmers. Private sector participation in agricultural research, extension and marketing is becoming increasingly important especially with the advent of biotechnology and protection being given to intellectual property. However, private sector participation tends to be limited to profitable crops and well endowed regions; the public sector research has to increasingly address the problems facing the farmers and the crops that are not subject to private sectors development plans.

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Transfer of Technology in Indian Agriculture: Challenges and Opportunities

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Agriculture accounts for 14% of GDP, about 11% of total exports, remains main source of raw material for large number of industries and provides employment to 57.4% of work force in rural areas. However, its GDP contribution has declined from 23.4% in 11th Plan to 19% in the 10th to 14.2% at the end of 11th Plan and average annual growth of the agriculture reported as 2.5%,2.4% and 3.3% in these plans respectively which fell short of the targeted growth rate of 4 per cent in the eleventh five year plan. The Crop sector has recorded average growth of about 1.8 to 2%, however, allied sectors like Horticulture, Animal Husbandry and Fisheries have registered output growth of 4.5 to 6%. Targeted Growth rate during 12th Plan is 4 per cent. The dependence of the population on Agriculture for self employment remained unchanged over the decade (2000-2010). Therefore, it calls for adequate coverage of small, marginal and farmers from weaker sections to obtain more inclusive and faster growth that has been prominently reflected in the Approach Paper to the 12th Plan

State wise growth trends and lessons

State wise growth trends calculated from CSO data showed that despite usual explanations for low growth like changing climate, soil degradation, stress on water resources, technology slowdown and policy constrains, some states have done exceedingly well, recording average annual growth of 4% and above during 11th Plan. The major States falling in this category are:Jharkhand (7.94%), Rajasthan (7.67%), Chattisgarh (6.74%) AndhraPradesh (5.38%), Assam (4.81%), Gujrat (4.11%), Maharashtra (6.63%), Karnataka (5.74%), Madhya Pradesh (5.43%), and other NE States like Mizoram (9.45%), Manipur (8.33%), Tripura (5.76%), Arunachal (5.56%) and Sikkim (4.83%).

P. K. Shetty, S. Ayyappan and M. S. Swaminathan (eds). *Climate Change and Sustainable Food Security*, ISBN: 978-81-87663-76-8, National Institute of Advanced Studies, Bangalore and Indian Council of Agricultural Research, New Delhi. 2013

The next category recorded average annual growth rate of 2-4%, they are: Haryana (3.44%), Orissa (3.35%), Meghalaya (3.34%), UttarPradesh (3%), Nagaland (2.85%), West Bengal (2.76%) and Uttarakhand (2.47%). The third category of the States recorded low growth rate of less than 2%.They are: Punjab (1.71%), Bihar (1.19%), Tamil Nadu (1.08%), Himachal Pradesh (1.07), Goa (1.03%), Jammu &Kashmir (0.68%) and Kerala (-0.4%).

Lessons emanated

It showed that action at state level matters a lot in determining performance of agriculture in a state. The slow moving States are required to give adequate focus on key growth drivers like: Technology, inputs , management of natural resources, investments, agricultural infrastructure, markets/price incentives, convergence and programme delivery and inclusive approach. There is a need to learn from better performing states and replicate relevant experience in low growth/ states particularly those with high potential. Agriculture diversification towards high value agricultural commodities like fruits and vegetables hold vast potential to accelerate growth and improve farm income in the country. Harnessing full benefit of diversification requires new institutional and contractual arrangements for production / marketing and ensuring that smallholders are not excluded from the process. Considering the costs and constraints of resources such as water, nutrients and energy, the genetic enhancement of productivity should be coupled with input use efficiency.

Sectoral challenges and opportunities

Shrinking land holdings and natural resource base

Predominance of smallholders in Indian agriculture is continuing to rise. Average size of land holding has reduced to 1.30 hectare . Small and marginal farmers now comprise 83% of total land holdings and they occupy about 41 per cent of area under all operational holdings. These farms have to be focus of agricultural development for their own sake, for future growth of farm sector and overall food security. Natural Resource base that sustain production is under serious strain. Land, water, soil health and biodiversity resources are shrinking and deteriorating and ground water going down even in irrigated areas as a result of overexploitation, in several parts of the country. Continuing imbalance in use of fertilizer has affected soil fertility and without enhancing soil health it is proving very difficult and costly to increase productivity gains. Long run sustainability of agriculture requires that land and water are used judiciously and efficiently.

Regional imbalance

It is widely acknowledged that there is lot of potential to raise agricultural output in the country across the States/ regions/sectors. Present level of productivity of most of the crops/sectors in a large number of States is awfully low as compared to the productivity which is attainable with already available technology, and as compared to other countries of comparable level. This potential is believed to be very large in the eastern and central regions. Regional imbalances in growth and productivity are surprisingly high and rainfed and dryland areas continue to be in disadvantageous position.

Food and nutritional security concerns and demand supply projections

India ranks at 67th as per Global Hunger Index (IFPRI). Half of the children (51%) are malnourished, over 55% married women suffer from anaemia and 30% adults suffer from protein – calorie deficiencies. Food availability to BPL and supply/distribution in disadvantaged areas and food quality / standards are other major concerns. Horticulture, milk, poultry and nutri-cereals provide an excellent opportunity on nutritional uptake however, the awareness and reach are still limited. It is well established that malnutrition particularly with reference to essential minerals is a major problem, which can be addressed by inclusion of coarse cereals and millets in the diet. These crops are grown in rain-fed areas and on marginal lands without adoption of recommended package of practices including input use. Thus to utilize the potential of extinct cultivars and make available improved varieties suitable to diverse farming situation it is pertinent to expand the umbrella of NFSM by including coarse cereals and millets in the 12th Plan

Demand for cereal is projected to reach 235 mt and demand for pulses is projected to reach 22 mt thus the demand for the total foodgrain is expected to reach 257 mt. by the year 2016-17 Supply projections for the same indicate that India is likely to have small surplus in cereals whereas, pulses will remain in short supply. Edible oil demand is projected to reach 16.64 mt which will require 59 mt of oilseeds. Even in the best production scenario India remains deficit in oilseeds. The deficiency in terms of oilseeds is expected to rise to 18 to 26 mt of oilseeds. Demand for sugar is projected to grow to 26.5 mt which can be met through sugarcane production of 279 mt. Available trend show that India will be having surplus of sugar during the 12th Plan. Demand for vegetables and fruits are anticipated to reach 161 and 97 mt.

Rainfed farming

Nearly 60% cultivable area would continue to be rain fed which is typically characterized by vulnerable natural resource base, inhabiting 40% population, giving 40% food grain output and sustaining about 60% livestock. Watershed has been taken up as a key intervention for development of such areas and as against target of 36.6 Million ha the area treated for watershed so far is about 19 Million ha, and thus provides vast scope for conservation agriculture. Climate change and adaptation issues are predominant in development of these areas. Though there are series of development programmes, however, when it comes to rain fed areas, the issues like convergence and programme delivery below of the block are observed to be very poor. Recent innovative programmes like NAIP &NICRA have initiated good number of initiatives and proved successful, they need to be internalized in future strategies. The general technology transfer models have not been able to make any perceptible dent in rain fed areas, perhaps, it calls for policy framework and delivery mechanism for such areas. The forthcoming National Mission on Sustainable Agriculture(NMSA) may have to establish a good equilibrium with IWMP and NRAA Pilots. In future, the strategic elements for harnessing growth potential of rain fed areas need to view conservation of natural resources, their sustainable use and enhancing productivity in an integrated manner . The resilience of the system has to be built in these areas along with capacities for adaptation to climate variability as the rain fed areas are ecologically fragile and highly vulnerable to vagaries of climate.

Livestock sector growth/productivity of dairy animals/small ruminants

Small holders and landless labourers own about 65-70% cattle, buffaloes, small ruminants, pigs and poultry mostly in rain fed and disadvantaged areas with low productivity. Enhancing productivity through genetic improvements, providing organized input/credit support services and marketing are required. Number of States are promoting para workers for their field programmes however, their technical competence need to be improved through organized training. This sector is facing serious feed fodder and health services concerns. There is need for door step delivery of health services at least preventive type. This is far more true in case of small ruminants. Animal husbandry extension services are either missing or they are very weak. Perhaps, the forth comming National Extension Mission should be able to strengthen the ATMA/KVK/Other stakeholder linkages down the line in such a way that it addresses integrated extension delivery and responds to the local situations as per the potentials. Rapid growth in livestock sub-sector is desirable for several reasons. This sub-sector employees about 21 million people. It is an important source of livelihood for smallholders and landless.

Productivity of dairy animals

There is considerable scope to enhance productivity of dairy animal through genetic enhancement. This require production of good quality semen from high genetic sources and in desired quantity. To achieve this, the existing semen stations should be strengthened and upgraded and /or new semen stations established to ensure at least 150 million doses of quality semen to cover 40% of the breedable cows and buffaloes. The larger strategy on this should be on field progeny testing for quality bull production. The AI services should be delivered at farmers' doorstep. Proposed Livestock Mission, the Dairy Entrepreneur Scheme and the World Bank funded National Dairy Plan (NDP) should be implemented in tandem and complement each other. Enhancing supplies of sexed semen will help livestock owners produce required number of males or females and contribute towards population optimization.

Small ruminants and health care

The smallholders and landless labourers together control about 71 per cent of cattle, 63 per cent of buffaloes, 66 per cent of small ruminants (goat and sheep), 70 per cent of pigs, and 74 per cent of poultry. There should be adequate focus on small ruminants (sheep/goats) and pigs covering aspects like breeding, feeding, health care, credit and extension support.

The extension arrangements for information dissemination in this sector are either weak or totally missing. Para vets and selected local community workers should be encouraged to take on extension role with proper training for this purpose Their training and capacity building arrangements should be taken up through Krishi Vigyan Kendras, ATMAs and through Private Sectors. Health care infrastructure in Animal Husbandry sector appeared to be in adequate, serious efforts are required to augment veterinary and health care facilities, may be through private sector investments or RKVY. It is also noticed that indigenous breeds of cattle and buffalos need high degree of investments and efforts for their conservation in local tracks with the support and participation of local communities, NGOs, traditional herd groups etc. The issue of production of progeny tested Bulls can be linked to these efforts.

Para vets and their capacity building

Small ruminants are playing very important role for livelihoods support systems to small, marginal and women from rain fed and tribal settings. Good number of States are promoting para vets and community volunteers , however, attention is required on their capacity building, these being crucial grassroots level functionaries directly interfacing with the farmers. There should be involvement of the State AHD Departments right from project formulation through implementation and ME, in innovative approaches for future up-scaling through selected KVKs/NGOs/Vet universities as programme partners. The outcome of the feasibility studies currently in progress under SAPPLPP in the states of Rajasthan and Madhya Pradesh may provide adequate context in this regard. Back Yard Poultry (BYP) is other area that needs serious attention as very important source of livelihoods for poorest of the poor in rural/tribal areas especially women folk. Linkage with GOI Schemes is essential in making good impacts. Training and Capacity building of selected KVKs/ Veterinary Universities could be taken up as a part of such interventions.

Development and management of fisheries and aquaculture

Globally India ranks second in total fish production and aquaculture next to China. There is huge potential in marine, inland and brackish water segments. This sector offers an excellent growth potential from present level of 8.44% to 12.8 Mill tones during the 12th Plan. However, the areas needing immediate attention are : by catch management, conservation of fish resources, replenishment of native stocks, fisheries infrastructure, value addition and treating aquaculture with agriculture. Weak fisheries marketing arrangements and strengthening fisheries extension which is either weak or non existing, need to be addressed urgently. FFDAs, Fish Cooperatives, entrepreneurs, KVKs, Fisheries Universities could play important role in fish extension. Areas that would require international collaboration are: quality fish seeds/feeds and certification, management of reservoir and larger water bodies, hatchery technology for valuable species, open sea cage culture, limited capacity to harness deep sea resources.

Increased investments and programme priorities

The projected investments in 12th Plan in Agricultural Development Programmes of DAC are 71,500 Crs, of Department of Animal Husbandry are 14,179 Crs and of DARE/ICAR are 25,553 Crs. The RKVY allocation has been proposed at 63,246 Crs as against 25,000 Crs during 11th Plan. An analysis of the Result Framework Documents (RFDs) underlines the following priorities

The DAC : increasing crop production and productivity to ensure food security, providing incentives to the States for higher public investments in agriculture and allied sectors, diversification for increased income generation, ensuring supply of agricultural inputs, soil health management, technology dissemination and encouraging private investments in agriculture sectors on PPP mode. The Flagship Missions (NFSM/NHM/NMSA/NMAET/NMOSOP and the RKVY constitutes major agenda of the 12th Plan.

The DARE/ICAR : Improved research in NRM and input use efficiency, utilizing frontier research in identified areas for better genetic exploitation, IP Management and commercialization of technologies, PHM, Farm mechanization and value addition, development of vaccines and diagnostics, monitoring of fish resources, higher education and frontline agricultural extension systems. Frontline Extension, Agricultural Education, Crop Science Research and Consortia Research Platforms forms major agenda for 12th Plan.

The DAHD&F : prevention and control of animal diseases, development of feed and fodder, increased fish production and welfare of fishers, development of poultry with focus on backyard and rural, development of small ruminants, genetic up gradation of livestock and conservation of indigenous breeds and increased milk production. The 12th Plan agenda includes NDP, Dairy Entrepreneurs Development Scheme, the NFDB, Livestock disease and Health control programme, National Livestock Mission, etc.

RKVY as major initiative and concerns

RKVY is a very major initiative of the GOI to incentivize the States for increased public resources in agricultural and allied sectors. It provided an outlay of Rs.25000 Crs during 11th Plan.and the projected outlay for 12th Plan is 63,246 Crs. The States are responding better as it provides flexibility to the States and provides wider coverage of allied sectors. However, the priority setting that is suppose to have basis on C-DAPs is not getting properly internalized. Also, there is need for district level mechanism to track the projects sanctioned across the sectors.Pre-screening of the projects, DPRs for the bigger projects and third party M&E were also suggested.

Agricultural extension and farmer empowerment

12th Plan working group recommendations

Agricultural extension covering crops and allied sectors is the prime responsibility of the States and it is expected that the States should drive the extension reforms process. The National Mission on Agricultural Extension and Technology may primarily support States' efforts in this direction. Further, it has been observed that the project formulation capacity of ATMAs needs to be augmented to draw the location specific extension plans. The MANAGE and SAMETIs should take leading role in driving the extension reforms at the National and State levels respectively. ATMAs and KVKs should lead the extension reforms process at the district level and below keeping in view the priorities reflected in the Comprehensive District Plans. Intensive use of ICT application, strengthening HRD / training infrastructure, empowerment of farmer groups, involvement of Farm Youths and Farm Women, field level linkages between various extension agencies and promotion of PPP arrangements in extension should also be focused. Progress on agricultural extension reforms should be put as one of the pre-conditions for release of RKVY funds to the States.

Reforms in extension planning and management

The Project Planning and Management (PPM) capability of ATMAs/KVKs and other institutions should be improved through (a) engaging a project management agency at the district level to formulate projects, access funding, train the staff and stakeholders and support service delivery, assist in project implementation and monitor project implementation; (b) improve PPM skills of ATMAs, BTTs and other institutions; and (c) leveraging the capabilities of ICT to the fullest extent for formulation and implementation of the Extension Mission. ATMA shall be the platform for convergence and service delivery of all schemes and programmes of agriculture development at the district level and below capturing priorities through C-DAPs. A convergence matrix may be prepared which will list out schemes and component wise allocations and activities. Every proposal for funding under existing schemes or new schemes should be accompanied by a convergence matrix relating to that department. Full potential of KVKs needs to be harnessed promoting them as knowledge resource centres addressing issues like enhancing contingency grants, farm developments, linkages with development units at district / block / villages, additional SMSs in critical areas, etc. The present extension system does not pay adequate attention to livestock, fisheries and fodder. As separate extension machinery for animal husbandry and fisheries are not going to be feasible in many states this function need to be integrated with ATMA with suitable backstopping from KVKs and private players.

Farmers empowerment

Empowerment of farmers and promoting farmers organizations should form the basis for sectoral growth. Aggregation of small and marginal producers, their training and capacity building, credit support and institutional back up would required to be streamlined in this process. This is absolutely essential to realize the advantages of decentralization process.

Extension reforms/strategies for effective technology transfer

Extension must empower farmers, farm youth and farm women.

Extension system must respond to the extension needs of farm women(feminization of extension services---both public and private)

Project planning and management capacities of ATMAs, KVKs, BTTs need to be improved enabling them to develop locally relevant extension interventions

ATMA must provide programme convergence platform at the district level and below

C-DAPs must provide holistic extension opportunity as opposed to crop centric extension.

Promote para extension workers and alternate sources of extension delivery, across the sectors and build their training and capacities

Promote intensive use of ICT/FFS, supported by systematic capacity building of field functionaries and farmers for this purpose.

Extension must address decentralized planning process and extension outreach in dis-advantaged areas like hill and mountainous, desert, chronic drought prone and tribal areas.

Proper sharing of Extension/training space by the stakeholders at local level.

KVKs to lead by locally relevant science based innovations/examples.

Involvement of PRIs and increase Community participation in extension programmes

Promote PPPs and agri Entrepreneurs

KVKs-ATMAs-OTHERS….Right equilibrium for locally effective extension

Promote best extension actor in given local situation

TOT in allied areas like Horticuture /AnimalHusbandry /

Dairy Development and Fisheries need to be systematically worked out involving both public and private extension resources.

Extension must capture & provide proper feedback analysis to the local research system so the research results respond to the location specific problems

Extension must Capture & Internalize successes of NAIP/ NICRA and globally proved best practices and apply them locally after due validation and assessment.

Field programmes must have inbuilt arrangements for extending influence of successes.

Extension agents both public-private must be oriented to NRM/Marketing/Mechanization

Flagship Missions should have strong TOT/Extension window with proper linkages down the lines up to field

R&D Convergence guidelines developed jointly by the DAC/ICAR must be properly understood, appreciated and implemented in true spirit by both ATMA/KVK systems

National Extension Mission to have an in built arrangement for extension innovations and action research in Extension as a local response.

Finally, Extension must drive and facilitate locally effective, regionally relevant & globally competitive growth of agriculture & allied sectors.

Sustainable Agriculture : Strategies and Approaches

Gopi N. Ghosh

In search of possible ways and viable means to maintain food security for 1.2 billion people we often talk about a second Green Revolution(GR). There are profound confusion on what it is all about – what are its essential elements - what are the pros and cons – so and on and so forth. However, one thing is clear; that it has to be different from the 1st GR in its fundamental approach and strategy and most importantly its impact.

Even as we contemplate arrival of a 'second GR' of sort, it may be worthwhile to conjecture what could essentially drive the same. With the arrival of Nargis in Lucknow, the world has stepped into the 7 billion mark. Thus with the ever growing demand for food, feed and clothes, food security remains to be the main concern. With impressive economic growth in emerging economies such as in India and China, food demand is going to grow – both in terms of quantity & of quality - as increasing income and urbanization look for diversified food baskets. With MDG is still being a distant dream in India, with persistent poverty and hunger all around, improved agriculture will continue to remain the most potent tool to address poverty.

As we witnessed recurrent volatility and soaring food prices across many nations since 2006-2008, food crisis has re-emerged to be an abiding concern – exacerbated as it is with climate change calamities like recurrent droughts and floods – at times with greater intensity. To talk of climate change, the ferocity and frequency of such weather-induced events will surely increase food system vulnerability with greater loss of livelihood assets and enhance farm risks – particularly to the poorly endowed regions populated by marginalized sections. Overall, the

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agrarian distress due to unsustainable farming conditions and increasing resource constraints manifests itself with more migration, increasing feminization and ageing farmers and many times, suicides. Farming is turning more into a compulsion for many rather than a preferred options – especially for the younger generations who like to move away from agriculture.

Critics of the GR also cite the bypassing of a significant section of people and areas from its area of influence. Rainfed agriculture, marginal ecosystems and the North East parts of India are said to have remained particularly 'unreached' from the GR– thereby making "inclusivity" as a major signpost of the 12th FYP. With no major technological breakthroughs since GR, therefore, the question of "what next" remains solidly engrossed in the minds of many planners and thinkers. Last but not the least, addressing the issue of sustainability in the context of rapid resource depletion, soil erosion, excessive tillage, fires, enhanced grazing, shrinking water resources and dwindling bio-diversity has been a formidable challenge.

Throughout the history of civilization, in search of meeting its ever-growing needs for food, feed and fibre, farmers selected higher yielding and more resistant cultivation plants, built structures to irrigate their fields, developed tools to improve farm operations, and used manure as fertilizer and sulphur against pests. In the 20th century, a paradigm shift from traditional farming systems was witnessed in management of natural resources and ecosystem services, to the application of biochemistry and engineering to crop production. Copying manufacturing, agriculture adopted increased levels of mechanization, standardization, labour-saving technologies and the use of chemicals to feed and protect crops. Great increases in productivity have encouraged higher and higher use of heavy farm equipment, fossil fuel, intensive tillage, high-yielding crop varieties, irrigation, extraneous inputs, and capital.

The strategies for intensification of crop production thus need to be revisited to inculcate a greater degree of sustainable systems and practices as described hereunder. Also, the scope of sustainability need not be confined only to the aspects of ecological sustainability of land, water, forest cover, or bio-diversity. It has to expand to the physical, human and fiscal resources –

understanding how the system, structure and institutions are also vulnerable – with greater focus on sustainability of small farms and their livelihoods and the sustainability of man-animal-ecosystem (one health).

FAO puts forth the idea of Save and Grow to address many of the problems current agriculture in the developing countries face. The central doctrine is that in order to grow 70% more food by 2050 with the shrinking resources for the projected 9 billion people, we must learn to save by increasing our efficiency, reducing unnecessary inputs- chemicals, energy and labor, save food by reducing the 30% of the food waste and save natural resources – water, biodiversity and land. Let us look at some of these avenues of Save and Grow.

Farming systems

The ecosystem approach to crop production regenerates and sustains the health of farmland. Farming systems for Sustainable Crop Production Intensification (SCPI) will be based on conservation agriculture practices, the use of good seed of high-yielding adapted varieties, plant nutrition based on healthy soils, efficient water management, integrated pest management, and the integration of crops, pastures, aquaculture, trees and livestock. Such systems are knowledge-intensive. Policies for SCPI should build capacity of farmers through extension approaches such as farmer field schools (FFS), and facilitate local production of specialized farm tools. Crop production intensification will be built on farming systems that offer a range of productivity, socio-economic and environmental options and benefits to producers and to society at large, including high and stable production and profitability; adaptation and reduced vulnerability to climate change; enhanced ecosystem functioning and services; and reductions in agriculture's greenhouse gas emissions and "carbon footprint".

Soil health

Soil health can be defined as: the capacity of soil to function as a living system. Healthy soils maintain a diverse community of soil organisms that help to control plant diseases, insects and weed pests, form beneficial symbiotic associations with plant roots, recycle essential plant nutrients, improve soil structure with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production. Agriculture must literally, return to its roots by rediscovering the importance of healthy soil, drawing on natural sources of plant nutrition, and using mineral fertilizer wisely.

Soils rich in biota and organic matter are the foundation of increased crop productivity. The best yields are achieved when nutrients come from a mix of mineral fertilizers and natural sources, such as manure and nitrogen-fixing crops and trees. Judicious use of mineral fertilizers saves money and ensures that nutrients reach the plant and do not pollute air, soil and waterways.

Policies to promote soil health should encourage conservation agriculture and mixed crop-livestock and agroforestry systems that enhance soil fertility. They should remove incentives that encourage mechanical tillage and the wasteful use of fertilizers and transfer to farmers precision approaches such as urea deep placement and site-specific nutrient management.

Crops and varieties

Farmers will need a genetically diverse portfolio of improved crop varieties, suited to a range of agro-ecosystems and farming practices, and resilient to climate change. Genetically improved cereal varieties accounted for some 50 percent of the increase in yields over the past few decades. Plant breeders must achieve similar results in the future by developing crops and varieties that are better adapted locally to ecologically based production practices. SCPI varieties will need to be adapted to less favoured areas, lower levels of inputs and varied production systems, produce food with higher nutritional value and desirable organoleptic properties, and help improve the provision of ecosystem services.

However, timely delivery to farmers of high-yielding varieties requires big improvements in the system that connects plant germplasm collections, plant breeding and seed production & delivery. It also requires increased support to PGR/AGR collection, conservation and utilization. Funding is also needed to revitalize public plant breeding programmes. Policies should help to link formal and farmer-saved seed systems as opposed to a few big multinationals that control global seed market, and foster the emergence of local seed enterprises that also include indigenous seeds.

Water management

Sustainable intensification requires smarter, precision technologies for irrigation, and farming practices that use ecosystem approaches to conserve water. Cities and industries are competing intensely with agriculture for the use of water. Despite its high productivity, irrigation is under growing pressure to reduce its environmental impact, including soil salinization and nitrate contamination of aquifers. Knowledge-based precision irrigation that provides reliable and flexible water application, along with deficit irrigation and wastewater-reuse, will be a major platform for sustainable intensification.

Policies will need to eliminate perverse subsidies on fuel, power, etc that encourage farmers to waste water. In rainfed areas, climate change threatens millions of small farms. Increasing rainfed productivity will depend on the use of improved, drought-tolerant varieties and management practices that save water. The scope for implementing SCPI under rainfed conditions will depend on the use of ecosystem-based approaches that maximize moisture storage in the root zone. To allay farmers' risk aversion, better seasonal and annual forecasting of rainfall and water availability (such as in APFAMGS) and flood management, are required both to mitigate climate change and to improve the resilience of production systems.

Plant protection

Plant pests are often regarded as an external, introduced factor in crop production; however, in most cases pest species occur naturally within the agro-ecosystem. Pesticides kill pests, but also pests' natural enemies and their overuse can harm farmers, consumers and the environment.

In well-managed farming systems, crop losses to insects can often be kept to an acceptable minimum by deploying resistant varieties, conserving predators and managing crop nutrient levels to reduce insect reproduction. Recommended measures against diseases include use of clean planting material, crop rotations to suppress pathogens, and eliminating infected host plants. Effective weed management entails timely manual weeding, minimized tillage and the use of surface residues. Pesticides become necessary, lower risk and more selective synthetic pesticides should be used for targeted control, in the right quantity and at the right time. Integrated pest management can be promoted through farmer field schools, local production of biocontrol agents, strict pesticide regulations, and removal of pesticide subsidies. Farmers awareness and skills are equally important in minimizing wrong use of unnecessary chemicals.

As an ecosystem-based strategy, integrated pest management affects the prospects for the effective management of pests through soil management. It applies an ecosystem approach, such as mulching, because water stress can increase the susceptibility of crops to disease, crop varietal resistance essential for managing plant diseases and many insect pests, and timing and spatial arrangement of crops to influence the dynamics of pest and natural enemy populations.

Policies and institutions

To encourage smallholders to adopt sustainable crop production intensification, fundamental changes are needed in agricultural development policies and institutions. First, farming needs to be profitable: smallholders must be able to afford inputs and be sure of earning a reasonable price for their crops. Some countries protect income by fixing minimum prices for commodities; - others are exploring "smart subsidies" on inputs for sustainability, targeted to low-income producers. Policymakers also need to devise incentives for small-scale farmers to use natural resources wisely – for example, through payments for environmental services and reduce the transaction costs of access to credit, which is urgently needed for boosting farm investment.

Major investment is needed to rebuild research and technology transfer capacity in developing countries in order to provide farmers with appropriate technologies and to enhance their skills through farmer field schools. Given the uncertainty of future demand and supply conditions, important factors that could draw major attentions towards small farmers policy package concern the areas of climate change, natural resource degradation, input and output pricing, reduction of food losses and changes in food consumption patterns, and market integration. The development of agricultural value chains must aim at enhancing smallholders' capacity for SCPI adoption and provide incentives.

The future of agriculture and food security is inalienably associated with the future of small holders. Revitalizing farmers institutions- Coop, SHG, FPO, Farmer's Associations, Producers Companies - is highly critical in offering the small holders required production services delivery and access to markets. Empowering farmers through proper education, skill and capacity building is important to ensure that they acquire knowledge, participate in the development process, adopt innovation and entrepreneurship having expanded their economic choices. ICT could play a great role in this regard.

India has progressively increased its food grain production since 1950. The consumption of insecticides has also kept on increasing. However the unique story that unfolds has been a sharp drop in insecticide consumption when the Finance Ministry Imposes 10% Excise Tax on All Pesticides at Factory Gate in 1993-94, citing "Polluter Pays" principle. This amply demonstrates that SCPI is very much possible with right policies and effective institutions at place. Further given the fact that most of the States (except Kerala which is a altogether different case and Maharashtra that produces cotton, sugarcane and other high value crops) are now producing the food grain they need for feeding their own people, the traditional food bowl (Punjab, Haryana and Western UP) concept needs a serious revisit. Along with the price incentive, infrastructure and investment that went on supporting such structure for decades, policy interventions must be directed towards diverting resources to incentivize and encourage rice production, in say Eastern India, and stop supporting rice production in Punjab – that overdraws its ground water to an abysmally unsustainable level.

Agricultural change is a complex process, which is non-linear and quite unpredictable, with multiple stakeholders. Thus, the social, political, technological, economic, and ecological dimensions of policymaking are immensely intertwined. The issues are not only interdependent and closely linked to each other, there seems to be no fixed solutions. Quite often, there are conflicting goals with equally plausible explanations making any meaningful policy interventions quite daunting. We need negotiated understanding, meaningful communication and synthesis of major issues, ideas and solutions to make a highly integrated and knowledge intensive agriculture. We need to engage local people and people's institutions for all such constructive dialogue on a continuing basis to create the future we want.

Enhancing Rice Productivity in India: Aspects and Prospects

R. K. Ellur, A. K. Singh and H. S. Gupta

Rice is the primary staple food crop of Asia, where 60% of world's population resides. It is the second most widely cultivated crop in the world after maize and is grown in 115 countries spanning a total area of 159.4 million hectare (MHa) with a total production of 696.3 million tonnes (MT) of paddy. However, 88.95% of the global rice area is concentrated in the Asian countries which contribute 90.4% to the global rice production and consumption. India ranks first with the total area under rice cultivation of 42.56 MHa (26.7% of the global area under rice cultivation) but ranks second with the total rice production of 143.96 MT (20.67% of the global production of rice). On the other hand in China rice is cultivated in 30.1 MHa. (18.8% of the global rice area) with a total production of 197.21 MT (28.3% of the global rice production).This is attributed to low average productivity of 3.38 t/ha in India, as against 6.55 t/ha in China. The status of top ten countries in terms of area, production and productivity of rice is presented in Table 1.

Rice in India

The area under rice cultivation has increased from 34.69 MHa in 1961 to 42 MHa in 2010, whereas there has been substantial increase in production from 53.49 MT during 1961 to 143.96 MT during 2010 (Table 2). However, the annual compounded growth rate of rice production has decreased from 3.55 per cent during 1981-90 to 1.74 per cent during 1991-2000.Amidst the growing production trends, the productivity of rice crop has to be further increased to produce 200 MT by 2030 to feed the ever increasing population and maintain food security.

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Table 1: Country wise area, production and productivity of paddy-rice.

Countries	Area (MHa)	Production (MT)	Productivity (t/ha)
China	30.12	197.21	6.55
India	42.56	143.96	3.38
Indonesia	13.25	66.47	5.02
Bangladesh	11.70	50.06	4.28
Vietnam	7.51	39.99	5.32
Myanmar	8.05	33.20	4.12
Thailand	10.99	31.60	2.88
Philippines	4.35	15.77	3.62
Brazil	2.72	11.24	4.13
USA	1.46	11.03	7.54

Table 2: Area, production and productivity of paddy-rice in India over years

Year	Area (MHa)	Production (MT)	Yield (t/ha)
1961	34.69	53.49	1.54
1965	35.47	45.88	1.29
1970	37.59	63.34	1.68
1975	39.48	73.35	1.86
1980	40.15	80.31	2.00
1985	41.14	95.82	2.33
1990	42.69	111.52	2.61
1995	42.80	115.44	2.69
2000	44.71	127.47	2.85
2005	43.66	137.69	3.15
2010	42.56	143.96	3.38

Rice is grown in almost all parts of the India. The five states of the country *viz.,* West Bengal, Punjab, Uttar Pradesh, Andhra Pradesh and Odisha contributes 60% of the total rice production of India. Considering the underground water depletion in Punjab, it is often opined that the rice cultivation in Punjab should be slowly phased out with an equally remunerative but less water requiring crop such as pigeon pea etc. However, it must be borne in mind that Punjab alone contributes more than 70% of the rice to public distribution system. Therefore, rice cultivation in Punjab is critical to India's food security. However, efforts should be made to develop mid early and medium duration varieties with high yield potential rice varieties which require less water. Highest area under rice cultivation is in the state of West Bengal (13% of the country's area under rice) and produces 16% to the total production, with an average productivity of 2.55t/ha. But, Punjab produces 13% of rice in 7% of the country's area under rice with the maximum productivity of 4.01 t/ha (Table 3). The state of Uttar Pradesh possesses second largest area under rice cultivation and produces 12% of the total country's production. Odisha although possess 10% of the total rice area, contributes only 8% to the total rice production with the very less average productivity of 1.58 t/ha.

Table 3: State wise area, production and productivity of paddy-rice in India in descending order of total production.

States	Area (MHa)	Production(MT)	Productivity (t/ha)
West Bengal	5.63	21.55	3.83
Punjab	2.80	16.88	6.03
Uttar Pradesh	5.19	16.24	3.13
Andhra Pradesh	3.44	15.83	4.60
Orissa	4.37	10.39	2.38
Tamil Nadu	1.85	8.51	4.61
Assam	2.50	6.52	2.61
Chattisgarh	3.67	6.18	1.68
Karnataka	1.49	5.55	3.73
Haryana	1.21	5.45	4.52
Bihar	3.21	5.41	1.68
Maharashtra	1.47	3.28	2.23
Jharkhand	1.00	2.31	2.32
Gujarat	0.68	1.94	2.86
Madhya Pradesh	1.45	1.89	1.31
Kerala	0.23	0.90	3.84
Others	1.75	5.04	2.88

Table 4: The list of yield and yield related genes cloned in rice.

Trait	Gene Cloned	Causal Mutation	Chro	Reference
GN	Gn1a	Deletion	1	Ashikari *et al.* 2005
GN	DEP3	Deletion	6	Qiao *et al.* 2011
GN	Ghd7	Deletion	7	Xue *et al.* 2008
GN	Ghd8/DTH8	Frameshift	8	Yan *et al.* 2011 and Wei et al. 2010
GN	DEP1	Premature stop	9	Huang *et al.* 2009
GW/ GF	GIF1	Premature stop	4	Wang *et al.* 2008
GW/ GF	FLO(a)/FLO2	Substitution	4	Qiao *et al.* 2010 and She *et al.* 2010
TN/ GN	EP3	Substitution	2	Piao *et al.* 2009
TN/ GN	LRK1	Over-expression	2	Zha *et al.* 2009
TN/ GN	MOC1	Inserted	6	Li *et al.* 2003
TN/ GN	PROG1	Substitution	7	Jin *et al.* 2008 and Tan *et al.* 2008
TN/ GN	IPA1/ WFP(OsSPL14)	Substitution	8	Jiao *et al.* 2010 and Miura *et al.* 2010
GW/ GS	GW2	Premature stop	2	Song *et al.* 2007
GW/ GS	GS3	Premature stop	3	Fan *et al.* 2006
GW/ GS	SRS3	Substitution	5	Kitagawa *et al.* 2010
GW/ GS	GS5	Substitution	5	Li *et al.* 2011
GW/ GS	qSW5/GW5	Deletion	5	Shomura *et al.* 2008 and Weng *et al.* 2008
GW/ GS	EP2/DEP2/ SRS1	Deletion	7	Zhu *et al.* 2010, Li *et al.* 2010 and Abe *et al.* 2010
HI/ GN	APO1	Substitution	6	Terao *et al.* 2010 and Ikeda *et al.* 2007
GS/ GN	SP1	Deletion	11	Li *et al.* 2009

GN – Grain number, GW – 1000 grain weight, GF – Grain filling , TN – Tiller number, GS – Grain size, HI – Harvest Index

Although, Globally India has largest area under rice cultivation, it conspicuously stands at 59^{th} position in terms of productivity. It is a matter of concern that India's rice productivity is even lower than the countries like Bangladesh, Myanmar, Vietnam, Srilanka etc. having similar ecologies. Therefore, there is a need to have critical analysis of production constraints, challenges and opportunities for rice research and development in the country.

Rice ecosystem in India

Rice is cultivated across India in varying climatic, topological (from below mean sea level to as high as 2000m) and hydrological conditions (Upland and lowland). It is cultivated in different ecosystems *viz.,* Irrigated ecosystem, Rainfed lowland ecosystem, rainfed upland ecosystem, deep water ecosystem, coastal ecosystem and hill ecosystem.

Irrigated ecosystem

In 2006-07, the total area under irrigated ecosystem was 24.5 MHa, which accounts to 56% of the total area under rice cultivation of the country. In the states of Haryana, Punjab, Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Uttarakhand, Himachal Pradesh and Gujarat, the area under irrigated rice cultivation was more than 63%, with a maximum of 99.9% in Haryana. The productivity of the rice grown in this ecosystem is >3.5 t/ha. However, the irrigated ecosystem suffers heavily from biotic stresses such as insect pests (Stem borer, leaf folder, BPH), diseases (BB, blast, sheath blight and false smut) and abiotic stresses such as salinity stress.

Rainfed upland ecosystem

Rainfed ecosystem can be sub divided into the rainfed upland and rainfed lowland ecosystems. The total area under rainfed upland ecosystem is 4MHa, which is mainly concentrated in the eastern and north eastern states of the country *viz.,* Assam, Bihar, Eastern M.P, Orissa, Eastern U.P, West Bengal and North-Eastern Hill region accounting to 9% of the total area under rice cultivation. Owing to poor availability of the irrigation facilities, the rice crop in this region is cultivated in uncertain conditions of resource availability and therefore is highly prone to biotic stresses due to weeds, blast disease etc. coupled with abiotic stress such as drought.

Therefore, the average productivity of paddy-rice in rainfed upland conditions is as low as 700 kg/ha.

Rainfed lowland ecosystem

Rainfed lowland ecosystem (14.0 MHa) accounts to 32% of the total area under rice and is concentrated in the flood affected eastern states of India *viz.,* Assam, West Bengal, Bihar, Orissa, eastern Madhya Pradesh and eastern Uttar Pradesh. In this ecosystem, the crop suffers either from drought or submergence and is usually grown in the standing water. The average productivity of paddy-rice in this ecosystem is 1.35 t/ha.

Deep water ecosystem

A total of 1.3MHa is in deep water ecosystem and is concentrated in the states of Odisha, West Bengal, Bihar etc. The initial phase of the crop is under rainfed dryland conditions and in the later phases, it suffers from flooding with a water depth of more than 50cm to 100cm for a period of more than a month. The average productivity of the paddy-rice grown in this ecosystem is 900kg/ha.

Coastal and hill ecosystem

The area under coastal saline rice in the country is estimated to about 1 million ha, which accounts for 2.3% of total area under rice in the country. Rice in coastal area is grown in states of West Bengal, Odisha, Andhra Pradesh, Tamil Nadu and Kerala. The average yield in coastal saline area is ~45% lesser than the national average productivity. Similarly, the total area under rice in hill ecosystem is estimated to about 1 million ha which accounts for 2.3% of total area under rice in the country spanning the states of Jammu and Kashmir, Uttarakhand and North Eastern Hill states. In this region, the crop suffers from cold injuries, drought stress with very short span of cropping seasons.

In all, 56% of the total area under rice cultivation is under irrigated ecosystem and remaining 44% of the paddy-rice area is under fragile ecosystems *viz.,* rainfed lowland, rainfed upland, coastal and hill ecosystems. The productivity in the fragile ecosystem is ~ 40 to 50% lower than that of the irrigated ecosystem. Therefore, in order to improve the national productivity of the rice, genetic improvement program has to be strengthened to develop high yielding varieties suitable for fragile environment which has been described as a sleeping giant. Considering the potential of eastern India, Ministry of Agriculture, Government of India has launched a highly focused programme of Bringing Green Revolution in Eastern India (BGREI) in various abiotic stress prone areas such as flood, drought, submergence and sodicity. The programme aims at enhancing productivity in the fragile ecosystem and therefore various interventions have been made which includes promotion for large scale adoption of hybrid rice technology among the farmers.

Production constraints

Biotic stresses

Diseases

Rice suffers from several diseases caused by bacteria, fungi, virus and nematodes. Bacterial Blight (BB) is one of the most important diseases caused by the gram negative non spore forming bacteria *Xanthomonas oryzae* pv. *oryzae.* The yield reduction of 10-20% was recorded under moderate infection, while the reduction of up to 50% was recorded under severe BB infection (Mew, 1988).

Rice Blast is considered as the most notorious diseases of rice caused by *Magnaportha oryzae* Anamorph, *Pyricularia oryzae* (Couch and Kohn 2002). The occurrence of Blast disease was first reported in China as early as 1637 and the first incidence of blast disease in India was reported in 1913 (Website 1) and its incidence has been reported from more than 85 countries (Kato *et al.* 2001). It infects all aerial parts of the plant resulting in yield losses of over 50% (Scardaci *et al*, 1997).

Sheath Blight is the ubiquitous disease of the rice caused by the fungi *Rhizoctonia solani* Kuhn. Sheath Blight causes major losses to crop worldwide (Ou 1985) and in India, yield loss of up to 54.3% has been reported (Chahal *et al*, 2003). Brown spot of Rice is caused by the fungi *Helminthosporium oryzae,* which was responsible for the occurrence of great Bengal famine in 1942 which caused yield losses of 50 to 90% leading to death of 2 million people.

Insect pests

Rice crop is the host to large number of insect pests which cause severe yield losses. Yellow stem borer, brown plant hopper (BPH) and gall midge are considered most destructive insect pests in rice which cause yield losses of 25-30%, 10-70% and 15-60%, respectively (Website 3.).Yellow stem borer (*Scirpophaga incertulas*) is found in all the rice ecosystems of the country and causes dead heart at vegetative stage and white ear head at reproductive stage. BPH (*Nilaparvata lugens*), is the destructive phloem-sap-sucking insect pests of tropical and temperate rice in Asia which causes hopper burns and also transmits viral diseases such as ragged stunt virus (RSV) and grassy stunt virus (GSV). The BPH was considered minor pest before 1970s, however, after its epidemic outbreak during 1973 causing an estimated losses of $12M, it assumed an importance of major pest.

Abiotic stresses

Drought

In India, 47% of the total paddy-rice growing area is located in rainfed ecosystem (19.3MHa), which contributes to less than 25% of the total rice production. The major constraint in this ecosystem is drought and submergence. The entire area of rainfed upland and the part of rainfed lowland is considered as potential drought prone region for rice cultivation. In Asia, it is estimated that 23 MHa of the rice growing area is potentially drought prone, of which, 59% is located in India (Pandey and Bhandari, 2009). Drought not only declines the total production status of the country, but is also associated with the different types of economic impacts such as inflation, unemployment, poverty, food insecurity, poor health etc. In India, much of the drought prone area is located in the eastern states *viz.*, Odisha, Jharkhand, Chhattisgarh etc. Under severe drought stress conditions, the annual yield losses in India have been estimated to 40%, which accounts to losses of US $800 million (Pandey, 2007).

Submergence

Submergence is the second most important abiotic stress after drought. Of the 14MHa area in the rainfed lowland ecosystem, 3MHa is submergence or flood prone, where plants are completely submerged for 1-2 weeks or so, resulting in partial or even complete crop failure. Submergence prone area is located in the eastern states of India viz., West Bengal, Odisha, Bihar, Jharkhand and eastern UP etc.

Salinity stress

Salinity is the situation where the soil is characterized by high concentration of soluble salts and possesses the ECe of 4 dS/m or more. Globally, 2% of the total area under the dryland agriculture is salt affected while, 20% of the total area under the irrigated agriculture is salt affected (USDA-ARS, 2008). In Asia, 21.5 MHa of rice growing area is affected by salinity stress (Pandey *et al,* 2010). In India, the salt affected area is 8.6 MHa, with 5.2 MHa of saline soils and 3.4 MHa comprising of sodic soils, spread across coastal, upland and irrigated ecosystems.

Opportunities for setting up new yield ceiling

Breeding by design

Improving the productivity of the crop is the prime objective of any plant breeding program. However, yield is governed by polygenes and has low heritability. Therefore, indirect selection for the yield by selecting for the yield attributing traits which have high heritability was advocated and practiced in the conventional varietal development programs. Further, in order to accelerate the breeding process and improve the production potential of crop plants by precise manifestation of the genetic make-up of the genotype, understanding the genetic basis of the yield and yield related traits is essential. Therefore, globally, several QTL mapping experiments were undertaken and more than 3,000 QTLs governing yield and yield attributing traits have been mapped. Of these 20 QTLs have been successfully cloned (Table 4) and characterized (Bai *et al,* 2012). With the availability of such an information on the genomic regions governing the yield and yield attributing traits, the *in silico* design of superior genotypes is possible (Peleman and van der Voot, 2003), based on which, marker assisted selection would lead to pyramiding of favourable yield QTLs to develop a designer rice genotypes with superior characters and unprecedented yield gains.

Unveiling yield QTLs from wild and weedy progenators/ landraces

During the process of domestication, strong selection pressure had been exerted to select for the domestication related traits *viz.,* non-shattering, loss of germination inhibition, compact plant type etc. These selected mutants were propagated and utilized for cultivation year after year which had progressively narrowed down the genetic base of the population. With the advent of systematic plant breeding methodologies, selective hybridization to mobilize favourable alleles into a certain genotype led to the development of high yielding varieties. However, potential reserves of unlocked sizeable variability are present in the wild progenitor species and primitive landraces, which have been inadvertently ignored during the domestication process (Tanksley and McCouch, 1997). In order to unveil this great deal of genetic potential from wild species, the traditional approach is through phenotype evaluation for the trait of interest, followed by utilization in the hybridization program to incorporate the trait into the crop improvement program (eg. The BB resistance gene *Xa21* was introduced into the modern rice varieties from *O. longistaminata*).

As a presumption the high yielding varieties are expected to carry many if not all of the QTLs enhancing the yield and low yielding varieties are expected to carry inferior alleles. With the development of genotyping techniques and advances in QTL mapping experiments, it was revealed that the inferior parents may also possess superior alleles at one or more loci, which are not visualized by simple phenotypic evaluation. With the same proposition, Xiao et al. (1998) utilized *O.rufipogon* in a QTL mapping experiment and 51% of the identified QTLs along with two rare yield QTLs *viz.,yld1.1* and *yld2.1*, each of which explained the phenotypic variance of ~17% were contributed by the inferior parent *O. rufipogon*. This unveiled the genetic potential of wild species and several mapping experiments involving wild relatives were conducted. The mapping populations viz., RIL, F_2 etc. are well suited for QTL mapping experiments involving cultivated genotypes as parents of mapping population. However, there are several drawbacks with these populations when unadapted wild parents are used. The undesirable QTL alleles from the unadapted parent occur in high frequency and minimizes the ability to generate meaningful data on yield and other traits and also poses problem in detecting the epistatic interactions. Therefore the concept of Advanced Backcross–QTL method was proposed, which overcomes all the above said drawbacks as well aids in simultaneous varietal improvement along with QTL mapping (Tanksley and Nelson, 1996). Septiningsih *et al*. 2003 utilized the BC_2F_2 population generated by the cross IR64/*O. rufipogon* and mapped QTLs for yield and yield attributing traits which demonstrated that 1/3rd of the QTL alleles originating from *O. rufipogon* had beneficial effect for yield and yield components in the IR64 background. Similarly, in India, Marri *et al,* (2005) generated AB-QTL mapping population using *O. rufipogon* and the *indica* rice restorer line KMR3. Two novel QTLs *viz., yld2.1* and *yld8.1* for yield contributed by *O. rufipogon* were identified, which explained the phenotypic variance of 50.47 and 4.67%, respectively.

Indica/Japonica hybridization for development of New Plant Type (NPT)

The heterosis was considered to be the function of genetic distance between the two genotypes. Therefore, the hybrids generated by *indica/indica* crosses and *japonica/japonica* crosses were estimated to yield much lower as compared to *indica/japonica* crosses. However, owing to the hybrid sterility due to post zygotic reproductive isolation in plants, the estimated heterosis could not be realized. The genetic analysis revealed as many as seven loci conditioning hybrid sterility. With the identification of the wide compatibility gene from the genotypes *Dular* and *Keta Nanga*, the *indica/japonica* crosses with complete fertility were produced. Among the identified wide compatibility loci, S5 locus has been functionally characterized and its molecular mechanism has been well studied. The S5 locus has upto 5 ORFs, of which the three ORFs *viz.,* ORF3, ORF4 and ORF5 were found to regulate the fertility in indica/japonica hybrids. During female sporogenesis, the action of ORF5 and ORF4 from indica and japonica respectively causes endoplasmic reticulum (ER) stress. In such a case if ORF3 of Indica is also present, it prevents ER stress and produces normal gametes. However, if the ORF3 of japonica is present, cannot prevent ER stress, resulting in premature programmed cell death and finally leading to embryo-sac abortion. This understanding aids in precise manifestation of genotypes for successful utilization of indica/japonica crosses in hybrid breeding program (Yang *et al*, 2012).

In order to reduce the growing gap between the demand and production of rice, the concept of new plant type (NPT) was proposed (IRRI, 1989). The ideotype of NPTs were aimed at following characters viz., reduced tillering (9-10 for transplanted conditions), no unproductive tillers, 200-250 grains per panicle, dark green and erect leaves, vigorous and deep root system, growth duration of 110-130 days, multiple disease and insect resistance and higher harvest index. In order to accomplish this, the temperate *japonica* lines possessing sturdy stem, deep root system, less tillers and high grain number were crossed with semi dwarf *japonica* lines. Further, these lines were improved for biotic stress resistance, grain filling traits and yielding abilities by crossing with the indica lines. These improved lines were called as NPT-IJ lines and few of the promising lines have been reported to yield 1.5 to 3 t/ha more than the traditional rice varieties. Several NPT lines were also developed at Indian Agricultural Research Institute, New Delhi and to understand the genetic basis of the yield and yield related traits, the NPT line Pusa 1266 was crossed with high yielding *indica* rice genotype Jaya and a RIL population consisting of 310 inbred lines were generated. Composite interval mapping identified 112 QTLs affecting 12 traits spread over 12 linkage groups were identified, of these 11 QTLs were detected across three locations and 23 QTLs across two locations. Further, Fifteen QTL hotspots (clusters) were identified on eight chromosomes often for correlated traits such as plant height, panicle length, flag leaf, spikelets per panicle, filled grains per panicle and spikelet setting density. Co-location of multiple traits indicates that selection for beneficial allele at these loci will result in a cumulative increase in yield due to the integrative positive effect of various QTLs (Marathi *et al*, 2012).

Hybrid Rice

Major breakthrough in breaking the yield ceiling was achieved in late 1970s by the deployment of dwarfing genes in wheat and rice and by heterosis breeding in maize, sorghum, pearl millet, sunflower etc. In last three decades, major success has been achieved in increasing the yield of rice, particularly in China, by development of hybrids. In India, a systematic hybrid rice-breeding program was initiated in 1989 with the launch of a special project on "Promotion of Research and Development Efforts on Hybrids in Selected Crops" by ICAR. With the concerted efforts through the network mode involving 12 centers across the country, till date 59 rice hybrids based on CGMS system have been released for commercial cultivation. Among these, 31 hybrids are contributed by public sector research institutes and 28 hybrids were contributed by private sector. Despite these developments, the area under rice hybrids during Kharif 2012 was~2 million hectares. Poor adoption of the hybrid rice technology is attributed to the low level of heterosis;

low hybrid seed yield on seed parent; poor grain and cooking qualities; and susceptibility to biotic stresses.

Strategies for enhancing level of heterosis:

i. Development and use of NPT based CMS and restorer lines for development of heterotic hybrids

Most of the commercially cultivated rice hybrids in India are genetically half sibs as they are based on common female parent IR58025A and thus there is no quantum improvement of heterosis over time. Therefore, development of genetically diverse CMS and restorer lines with superior combining ability is essential. Incorporation of new plant types (NPT) in the breeding program would improve the genetic base of the CMS and restorers lines as well as yielding ability. At Indian Agricultural Research Institute, New Delhi, series of NPT lines have been developed from *indica/japonica* crosses, which can be used for development of genetically diverse CMS and restorer lines for their eventual utilization in development of heterotic hybrids.

ii. Identification and mapping of heterotic QTLs and their pyramiding in parental lines for enhancing levels of heterosis

The superiority of hybrids over pure line varieties has been well established by the improvement in the production and productivity of rice upon adoption of hybrid rice technology in China. Mapping of the heterotic QTLs using the heterotic hybrids would reveal the genomic regions governing heterosis phenomenon. Such heterotic QTLs upon validation can be mobilized into a common background to breed for super parental lines which can be used for developing heterotic hybrids.

iii. Identification of novel genes for heterosis by whole genome expression profiling

With the availability of the array based platforms, whole genome expression profiling of the parental lines of the superior hybrids would reveal the molecular basis of heterosis phenomenon. Heterosis is one of the genetic phenomena which have been most successfully utilized across the crops while understanding little about the molecular mechanism. With the identification of genes governing the heterosis phenomenon, such genes can be mobilized into the genetic background of target genotypes to develop superior parental lines for hybrid development.

iv. Enhancing seed yield on parental lines

Poor panicle exertion in the CMS line due to adverse effect of male sterility inducing cytoplasm (WA) reduces seed yield on female parent. Therefore, GA_3 application is done to improve the panicle exertion thereby improving the out crossing and increasing the seed setting on CMS lines. Alternatively, the rice gene *'Eui'* encoding cytochrome P450 monooxygenase which deactivates the bioactive gibberellins and regulates the plant height (Zhang *et al,* 2008) as well as elongation of uppermost internode has been identified. Incorporation of *'eui'* into the genetic background of CMS lines would eliminate the need for GA3 application and thus increasing the hybrid seed yield and reducing the cost of hybrid seeds.

Sustaining the production potential

Biotic stress tolerance

The management practice adopted in rice to overcome disease and insect pest incidence is by application of pesticides. However, exploitation of the genetic resistance is considered to be the most feasible and eco-friendly approach to combat the diseases and insect pests. Several BB resistance sources *viz.,* TKM 6, BJ1, ARC 18562, *Chogoku* and *Sigadis* (Singh and Singh, 2003); blast resistance sources *viz.,* Tetep & Tadukan; Brown plant hopper resistance sources *viz., Rathuheenathi*, PTB33, IR26, IR32, IR60 & IR64 have been identified in the rice germplasm and widely used in the crop improvement programs to incorporate the resistance genes into the new varieties. As for example, in India the variety TKM 6 was used extensively in the early breeding programs and therefore, most of the present day Indian rice varieties possess *Xa4* gene. However, mapping of the genes would aid in understanding the genetic basis of resistance and therefore helps in precise utilization in breeding programs. With the identification of molecular markers spanning across the rice genome, the task of mapping the genes onto the chromosome was simplified. Presently, more than 38 genes governing resistance to BB, 104 genes and 345 QTLs governing blast resistance and 21 genes governing brown plant hopper resistance have been identified and precisely mapped. Among which, 7 BB resistance genes and 19 blast resistance genes (Sharma *et al,* 2012) have been cloned and characterized. Further, the gene linked molecular markers have been used to incorporate resistance genes in the breeding programs.

However, most of these resistance genes were identified in the unadapted rice genotypes. With the availability of molecular markers linked to gene(s) of interest as well as the availability of high density genetic maps, marker assisted backcross breeding (MABB) has become feasible offering great opportunity to transfer as well as to pyramid desirable genes into an otherwise agronomically superior cultivars. MABB has accelerated the breeding process along with increased precision. Although, PAU, Ludhiana pioneered in MABB by incorporating the BB resistance genes *xa5, xa13* and *Xa21* in the rice variety PR106 (Singh *et al,* 2001), first successful MAS bred rice variety "Improved Pusa Basmati 1" carrying resistance genes *xa13* and *Xa21* in the genetic background of elite Basmati rice variety "Pusa Basmati 1" was produced at IARI, New Delhi. Further, several rice varieties have been developed for BB (Sundaram *et al,* 2008; Joseph *et al,* 2004; Gopalakrishnan *et al,* 2008; Bhatia *et al,* 2011); Blast (Hittalmani *et al,* 2000; Singh *et al,* 2012; Singh *et al,* 2012 etc) and Sheath blight resistance (Singh *et al,* 2012).

Abiotic stress tolerance

Drought

To produce one kilo gram of rice, 3,000 liters of water is consumed by the rice crop. Therefore, in the scenario of depleting natural resources and increasing population, improving the inherent capabilities of plant system to produce more grains per unit of water is essential. Direct selection for grain yield under drought was reported to be the most promising approach to improve yield along with drought tolerance (Atlin *et al,* 2004; Venuprasad *et al,* 2007, 2008) as against selection for the secondary traits (Atlin and Lafitte, 2002). The conventional breeding methods of selection, hybridization and identification have yielded several drought tolerant popular rice varieties *viz., Nagina22, Vandana, Abhishek, Anjali, Dular, Annada,* MTU17 etc. Although, these varieties are drought tolerant, the yielding ability is relatively poor as compared to the high yielding rice varieties suited for irrigated conditions. Therefore, in order to incorporate the drought tolerance trait into the genetic background of high yielding rice varieties, understanding the genetic basis and molecular mechanism of this complex trait is essential. To identify the genomic regions governing drought tolerance, several QTL mapping studies were undertaken. The QTLs *Dty1.1, Dty2.3,* *Dty3.2, Dty4.1* and *Dty12.1* were reported to be the major QTLs found across the drought tolerant genotypes.

Submergence tolerance

Submergence has a dramatic effect on growth and yield of rice crop. It causes a reduced oxygen supply and thereby inhibition of respiration. Rice, which has interconnected gas spaces called aerenchyma, is one of the few crops species that has the ability to germinate and grow in waterlogged soils. However, under complete submergence conditions most rice cultivars cannot survive for more than a week, but the submergence tolerant *indica* type rice varieties, such as FR13A, can survive up to two weeks. The QTL mapping study revealed that, a major QTL, *Submergence1* (*Sub1*) mapped on chromosome 9 is linked to the submergence tolerance of FR13A. This locus possessed cluster of three genes (*Sub1A*, *Sub1B*, and *Sub1C*) that encode putative ethylene response factors (ERFs). However, functional validation studies confirmed that the allele *Sub1A-1* is responsible for submergence tolerance (Xu *et al,* 2006). SUB1A protein is accumulated in presence of ethylene during submerged conditions and triggers expression of ethanolic fermentation genes but repressing genes responsible for cell elongation and carbohydrate metabolism (Perata and Voesenek, 2007).

Salinity Tolerance

With the expansion in irrigated area, the salt stress problems are accentuating dramatically. Salinity stress hampers the crop growth as well reduces the potentiality of the crop. The salinity stress is due to higher uptake of Na^+ from the plant roots.

The excess salts damage the cell wall and lyse cytoplasm leading to electrolyte leakage and thereby causing plasmolysis. It also causes accumulation of electron-dense proteinaceous particles, citrate, malate, inositol, proline levels leading to reduced germination and seedling growth with substantial reduction in photosynthesis (Yeo *et al,* 1985; Lutts *et al,* 1995; Garcia *et al,* 1997) and ultimately hampering the crop yield. Therefore, it is important to eliminate cytosolic Na+ by transporters and maintain the balance of Na+ and K+ ions (the cellular Na+/K+ ratio). Various salt tolerant rice genotypes *viz.*, Pokkali, *Porteresia coarctata*, Nona Bokra etc were identified and have been utilized in dissecting the salt tolerance mechanism. Several QTL mapping experiments were undertaken globally, to identify QTLs responsible for variations in Na+ and K+ content. Lin *et al.* (2004) mapped a major QTL *qSKC1*, explaining the phenotypic variance of 40.1% in the salt tolerant *indica* rice variety Nona Bokra. Further, functional characterization revealed that *SKC1* encode a HKT-type transporter, a selective transporter for Na+ and is preferentially expressed in the parenchyma cells surrounding the xylem vessels (Ren *et al,* 2005). Additionally, a major QTL '*Saltol*' explaining 43% of the variation for seedling shoot Na–K ratio (Bonilla *et al,* 2002) was reported in the RIL population generated from the cross IR29 x Pokkali. Subsequently, a highly salt tolerant RIL, FL478 was promoted as an improved donor for breeding programs, which carried a small (< 1 Mb) region carrying alleles from the salt tolerant parent, flanked by alleles matching the salt sensitive parent IR29 alleles (Kim *et al,* 2009). Further, the region of exploitation of *Saltol* locus is likely, just one component of a multifaceted strategy to improve rice yields on salt affected soils. It primarily functions by regulating the uptake of Na+ and K+ and thereby manifesting the Na-K concentration in shoot. Since, salt tolerance is the complex trait, additional QTLs may be needed to contribute to other mechanisms for seedling stage tolerance, such as those controlling sequestration of sodium in vacuoles to provide increased tissue tolerance, by storing salts in old tissues and roots, and by triggering the mechanisms involved in protection against reactive oxygen species and chlorophyll degradation (Blumwald *et al,* 2000; Ismail *et al,* 2007; Moradi and Ismail 2007).

The donors for the drought tolerance QTLs (eg. Nagina 22, Brown Gora, Dular, Birsa Gora etc.), submergence tolerance genes (eg. FR13A) and salinity tolerance QTLs (FL478, Pokkali, Nona Bokara etc.) are unadapt rice cultivars. Therefore, marker assisted backcross breeding for precise incorporation of these major QTLs/genes would improve the yield under drought stress conditions in otherwise drought susceptible genotypes. The first MAS bred drought tolerant aerobic rice variety released in India was MAS946-1. Further, IRRI-India drought breeding network has yielded a drought tolerant genotype Sahbhagi Dhan which was released in India during 2009. Similarly, *Sub1A* locus has been transferred into mega rice varieties such as IR64, Swarna and BPT 5204 through marker assisted backcross breeding. The improved versions of these varieties with submergence tolerance have been tested at national level and Swarna with submergence tolerance has been released in Uttar Pradesh.

Nutritional deficiencies in soil

Amidst the multitudes of abiotic stresses caused to rice crop in rainfed conditions, the soils are poor in essential nutrients required for exuberant crop growth and productivity. Therefore, external application of fertilizers containing nitrogen (N), phosphorous (P) and potassium (K) is of prime importance. P is the indispensible major element for the normal plant growth and is considered as the nutrient which is least available. The only source for production of P fertilizer is phosphate rock. However, the source of P fertilizer is concentrated in only few countries *viz.,* Morocco, China, USA etc. and it is expected that P reserves will be depleted in 50 to 100 years (Cordell *et al.* 2009). Therefore, development of rice genotypes with high productivity under low phosphorous conditions is essential. In order to understand the genetic and molecular basis of phosphorous starvation tolerance in rice, the tolerant '*aus*' type genotype for P deficiency 'Kasalath' was used in QTL mapping experiments. The only P tolerance QTL *Pup1* (Phosphorous uptake 1) mapped on chromosome 12 was reported to confer tolerance to P deficiency under field conditions in Japan (Wissuwa *et al.* 1998 and Ni *et al*. 1998). Further, sequencing of *Pup1* locus in Kasalath showed presence of ~90kb transposon rich indel. Additionally, screening of rice germplasm with *Pup1* specific molecular markers revealed that putative protein kinase gene *OsPupK46-2* as the most closely associated gene for tolerance to P deficiency. Based on the semi quantitative RT-PCR and quantitative RT-PCR between the contrasting NILs with and without *Pup1* allele confirmed that the *Pstol1* (Phosphorous starvation tolerance 1), a cytoplasmic serine/threoinine protein kinase is the candidate gene underlying the *Pup1* locus. *Pstol1* being protein kinase, it cannot regulate the expression of genes, however causes regulation of transcription factors through phosphorylation. Eventually, over-expression of the *Pstol1* in the two rice varieties IR64 and Nipponbare enhanced the grain yield by more than 60% under P deficiency conditions as well enhanced the root growth thereby facilitating increased uptake of other nutrients such as nitrogen and potassium (Gamuyao, 2012).

Innovative approaches for rice improvement

Development of C_4ness in rice

The photosynthetic efficiency of the C_3 plants (eg. rice) is limited owing to the inability of photosynthetic machinery present in leaves to fill the large number of spikelets in the modern varieties (Caemmerer *et al*, 2012). In Rice, Rubisco is the primary enzyme involved in CO_2 fixation during photosynthesis. However, Rubisco has the affinity towards both CO_2 and O_2 leading to carboxylation and oxygenation reactions, respectively. 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. To overcome these inefficiencies of Rubisco, several organisms including C_4 plants, have adapted specialized mechanism of concentrating CO_2. In C_4 plants, the CO_2 is fixed in the mesophyll cells of the leaf tissue to produce C_4 acids and are decarboxylated in the bundle sheath cells. This increases concentration of CO_2 in the bundle sheath cells and inhibits the oxygenase activity of the Rubisco, thereby improving the photosynthetic efficiency. C_4 plants have elevated photosynthetic capacities at warmer temperatures as against C_3 plants, and possess 1.3–4 times higher water use efficiency (WUE) and nitrogen use efficiency (NUE) than in C_3 plants (Long, 1999; Sage and Pearcy, 2000; Kocacinar *et al*, 2008; Ghannoum *et al*, 2011). Higher WUE and NUE reduce the costs involved in agronomy as well as delay the drought stress (Sage and Zhu, 2011). In order to simulate the C_4 mechanism in rice, the genes determining the C_4 biochemistry as well as anatomy have to be incorporated. Installing the C_4 mechanism into rice would improve the photosynthetic efficiency as well as improve WUE, NUE and may also possess drought tolerance capacity.

Biological nitrogen fixation

Symbiosis is a well-known phenomenon existing between the legumes and the rhizobia for their mutual benefit. The process of endo-symbiosis initiates with the release of root exudates containing flavonoids which triggers activation of NodD transcription factor in the rhizobia. Further, lipochito-oligosaccharide Nod factors are perceived by the plant to induce root nodulation. Root nodules are the specialized organs which accommodates the bacteria (Oldroyd *et al*, 2009). The *Nif* genes present in the Rhizobia provides the inherent capacity to fix the atmosphoric nitrogen into the plant assimilatory form.

The first approach towards establishing the BNF in rice could be engineering rhizobium to recognize and infect rice plant and establish the symbiotic association and simultaneously modifying the plant system to ensure release of flavonoids and establishment of NOD factor recognition mechanism to develop the root nodules to provide environment for oxygen sensitive nitrogenase enzyme required for fixing nitrogen. However, in Rice, Rhizobium has not been reported to form symbiotic association, whereas mycorhhiza establishes symbiotic association with Rice. There exists a partial similarity between the genetic program associated with the rhizobial and mycorhhizal symbiosis (Reddy, 2012).It was established that the orthologs of *CASTOR/POLLUX, CCaMK* and *CYCLOPS* genes present in the rice genome were associated in establishing mycorrhiza-rice symbiotic association and further their functional validation in legumes established that they were functionally conserved (Banba *et al,* 2008 and Yano *et al,* 2008). Further, the nodulation specific genesNSP1 and NSP2 were also found to be functionally conserved in rice (Yokota *et al,* 2010). Also, the nodule initiation takes place using the hormones common to all plants. Therefore, it is reasonable to assume that rice possess some common symbiotic genes and therefore engineering may be less difficult than that previously anticipated. Further research is required to understand the mechanism of formation of infection thread through which the rhizobium gains entry into the root system.

The other approach of establishing the BNF is through direct engineering. To develop a plant system which can biosynthesize nitrogenase enzyme and metal co-factors required to fix atmospheric nitrogen, a complete pathway comprising of several *nif* genes has to be incorporated (Beatty *et al,* 2011). The nitrogenase enzyme being sensitive to oxygen, should be produced in a specific organelle with low oxygen concentration. Currently, it is proposed that either chloroplast or mitochondria can be targeted as they are the sources for the supply of ATP and reducing power required for the nitrogenase activity. Although there are no efficient mitochondrial transformation protocols, mitochondria would be the best choice for targeting nitrogenase as it contains efficient oxygen consuming respiratory enzymes (Beatty *et al,* 2011). Therefore, nuclear transformation of the *nif* genes and further targeting the gene products to the mitochondria is possible. This approach of BNF not only reduces the cost involved in nitrogen fixation, but also safeguards the environmental health.

Pathway manipulation for increasing the yield

The identification of source for dwarfing gene in rice and wheat, the crop geometry was manipulated and eventually led to the improvement in the harvest index for better crop stature and yield. The tailoring of crop geometry had improved the yielding ability which led to the green revolution in the late 1970s. However, with the stagnating yields since last decade, it is of great concern to identify and harness the unexploited genetic potential. Manipulation of biochemical pathways to improve the carbon flow, grain filling properties and maintaining the source-sink equilibrium to improve the photosynthetic efficiency is the promising approach. The rice plants grown in atmosphere containing high CO_2 concentration produced increased levels of photsynthates, but total grain filling and grain weight remain unchanged as compared to control conditions. Conversion of photosynthates into the starch was considered limiting and it was considered that the sink strength in rice is limited. Further, knock down studies demonstrated that conversion of Glucose-1-phosphate to ADP-glucose, catalyzed by the enzyme pyrophosphorylase (AGPase), is a rate-limiting step (Lin *et al,* 1988). The enzyme AGPase was found to be activated by 3PGA and inhibited by Pi. The *Escherichia coli glg*C triple mutant (TM) gene, which encodes a highly active and allosterically insensitive AGPase was expressed in the rice chloroplast, which showed 13 fold increase in AGPase activity, improved the starch synthesis and ultimately found to improve the grain weight upto 11% (Sakulsingharoj *et al,* 2004).

Therefore identification of genes encoding Pi and 3PGA insensitive AGPase from the rice germplasm lines or from unrelated species and incorporation into the rice varieties through marker assisted selection or through transgenic would improve the starch accumulation to increase the seed weight and ultimately improve the yield.

Basmati rice – a scented pearl

Basmati rice is cultivated for centuries in the foot hills of Himalayan mountain ranges in north-western India comprising of seven states namely Punjab, Haryana, Himachal Pradesh, Delhi, Uttarakhand, Jammu and Kathua districts of Jammu & Kashmir and 27 districts of western Uttar Pradesh. Basmati is the prized possession of Indian sub-continent which is blessed with the harmonious combination of specific kernel dimensions, appealing aroma, texture of cooked rice, high volume expansion during cooking owing to its linear kernel elongation with minimum breadth-wise swelling, fluffiness, palatability, easy digestibility and longer shelf-life (Singh *et al.* 1988). The traditional Basmati rice varieties viz., Type 3, Basmati 370, Basmati 386, Taraori Basmati, although had excellent grain and cooking quality traits, but, suffered from several undesirable traits such as, tall plant height with weak stem, temperature and photoperiod sensitiveness, longer duration and low yielding ability. In late sixties, Dr. M. S. Swaminathan, conceptualized the idea of combining typical Basmati quality of traditional Basmati varieties in high yielding background. The first breakthrough in Basmati rice breeding came in 1989 with the release of Pusa Basmati 1, the world's first semi-dwarf, photoperiod insensitive and high yielding Basmati rice variety. Following the success of Pusa Basmati 1, several Basmati rice varieties *viz.,* Pusa Basmati 1121, Improved Pusa Basmati 1, Pusa Basmati 6 and extra long grain aromatic rice varieties namely, Pusa Sugandh 2, Pusa Sugandh 3, Pusa Sugandh 5 and a hybrid Pusa RH10 were developed, wherein the duration of Basmati rice varieties have been reduced from 160 days to 115-140 days with enhancement of productivity from 2.5 tons/ha to 6-8tons/ha.

Currently, Pusa Basmati 1121 is the variety of choice for the Basmati growing farmers, which was released during 2003. Pusa Basmati 1121 is attributed with cooked kernel of up to 22mm, with an exceptionally high cooked kernel elongation ratio of 2.5 along with volume expansion of more than four times. The exceptional grain and cooking quality attributes attracted the consumers in the international markets and led to quantum jump in the Basmati rice export earnings from Rs. 1993 crores in 2003-04 to Rs. 15,449 crores in 2011-12. Owing to the increased demand from the consumers and high remuneration to farmers, there has been wide spread adoption of this variety and during Kharif 2011, 1.35 MHa of 2 MHa (67%) area under Basmati rice was planted with Pusa Basmati 1121 (APEDA, 2011).

All these Basmati rice varieties are susceptible to BB, Blast, Sheath Blight, BPH, Salinity stress etc. Importantly, no resistant sources were available in the Basmati germplasm. Of late, with the availability of molecular markers, several marker assisted backcross breeding (MABB) programs were launched which provided a great opportunity for precise transfer of desirable donor segment by minimizing the linkage drag into the current parent. At IARI, MABB was effectively utilized to incorporate BB resistance genes (*xa13* and *Xa21*) into the genetic background of Pusa Basmati1 (Joseph *et al,* 2004 and Gopalakrishnan *et al,* 2008) and PRR78 (the restorer parent of aromatic rice hybrid Pusa RH10) and Pusa6B (the maintainer line of hybrid Pusa RH10) (Basavaraj *et al,* 2009 and 2010); Blast resistance genes (*Pi54* and *Piz5*) into the genetic background of PRR78 and Pusa6B (Singh *et al.* 2012).Currently, the pyramiding of genes for resistance to BB (*xa13* and *Xa21*), blast (*Piz5* and *Pi54*) and BPH (*Bph18*, *Bph20* and *Bph21*) into Basmati rice varieties viz., Pusa Basmati 1121 and Pusa Basmati 6 is under way (Singh *et al,* 2011). In addition, a major QTL for salt tolerance (*Saltol*) is being transferred to Pusa Basmati 1121, which is widely grown in Haryana, the state having problem of salinity owing to underground brackish water. Molecular breeding has helped in improving Basmati rice varieties for resistance to biotic and abiotic stresses.

Technological options to meet the future demand for rice

In order to meet the food requirement of the ever increasing population of India, the paddy-rice production has to be increased to 162 MT by the year 2015, 171 MT by 2020, 178 MT by 2025 and 185 MT by 2030 (Kumar *et al,* 2010). To meet this requirement, the productivity of the rice crop has to be substantially increased. Therefore, several technological options have to be explored to meet the challenge increasing rice production in the country.

Hybrid rice technology

Hybrid rice technology is the most promising and feasible options to increase the rice productivity. Considering the demand of 178 MT of rice by 2025, the rice production must be increased by 2 MT per year for next 15 years. Hybrid rice technology can provide an additional average gain of 1t/ha as compared to the pureline rice varieties. Under the National Food Security Mission (NFSM), launched by the Ministry of Agriculture, Govt. of India, it has been projected to cover 20% of the total rice area under hybrids by 2015, which amounts to hybrid coverage of approximately 8.8 MHa, thereby giving an additional paddy production of 8.8 MT, which is equivalent to 5.80 MT of rice. However, looking into the current coverage under hybrid rice (approximately 2 MHa during Kharif 2012), the projected target of 8.8 MHa by 2015 seems to be highly unlikely. Therefore, the targets as well as strategies need to re-visited in order to popularize hybrid rice technology. Efforts should be made to cover 8.8 MHa under hybrids atleast by 2020. Therefore, the magnitude of yield advantage in hybrids needs to be enhanced substantially while improving grain and cooking quality and reducing the cost of hybrid seed.

Enhancing productivity of *boro* rice

In India, the highest area under rice cultivation is in the state of West Bengal (5.63 MHa), which produces 21.55 MT of paddy with an average productivity of 3.83 t/ha as compared to the paddy productivity of 6 t/ha in Punjab. The lower productivity of the state is due to submergence / flooding during *Kharif* season. However, the area under *boro* rice cultivation in West Bengal is 1.41 MHa. (25%), which produces 7.11 MT of paddy with an average productivity of 5 t/ha, as against 6 t/ha in Punjab. Development of varieties especially suited for *boro* cultivation in West Bengal can therefore increase the production by 1.4 MT. Similar gains can be made from other areas where *boro* rice is cultivated.

Improvement for biotic stress resistance

Several research programs have been funded by the Department of Biotechnology, ICAR-NAIP etc. across the country, to incorporate the disease (BB, Blast, Sheath Blight etc) and insect pest (BPH, Gall midge etc.) resistance genes into the genetic background of local popular rice varieties (Pusa Basmati 1, Pusa Basmati 1121, Pusa Basmati 6, Samba Mahsuri, MTU1010, Sampada, Akshayadhan, PAU201, PAU3105-45, CO43, ASD16, Tellahamsa, VL Dhan207, VL Dhan 85 etc.) to overcome the losses incurred due to biotic stresses and decrease the utilization of pesticides during rice cultivation. With the availability of the improved versions of these multiple biotic stress resistant varieties, the losses due to biotic stresses can be minimized and an extra of ~10mt can be produced.

Improvement for abiotic stress tolerance

Similar to the research programs for overcoming biotic stress, the network projects on marker assisted breeding for incorporation of abiotic stress tolerance in rice has been funded by DBT-IRRI, NAIP-ICAR etc. The QTLs governing salt tolerance (*Saltol*), submergence tolerance (*Sub1*), drought tolerance (*Dty1.1, Dty2.3, Dty3.2, Dty4.1* and *Dty12.1*) etc. are being incorporated into the region specific most popular rice varieties of India *viz.*, Pusa Basmati 1121, Pusa Basmati 6, ADT 43, ASD16, MTU1010, Samba Mahsuri and Swarna. Submergence tolerance genotypes alone are expected to gain an extra of 1-2 t/ha. Therefore, in all ~10MT of extra paddy can be produced with the development of such improved rice varieties for abiotic stress tolerance.

Conclusion

Rice is the staple food for more than half of the global population. Nearly 90% of the world rice is produced and consumed in Asia. India is the second largest grower of rice (44 MHa) with an annual production of 143MT and 3.3 t/ha productivity. The demand for rice in India is estimated to increase to 185 MT by 2030. The increased production has to come from limited resources in terms of land, water and labour. Therefore, the use of cutting edge science and technology in rice improvement is inevitable. With sequencing of rice genome, availability of dense linkage map with large number of markers and high throughput genotyping platforms, it has become feasible to use molecular marker assisted selection for precision breeding in rice. However, the potential of transgenic technology in terms of nutritional enhancement, pathway manipulation, C4ness, biological nitrogen fixation, which cannot be tackled through molecular breeding, is yet to be realized in the near future and needs intensive efforts.

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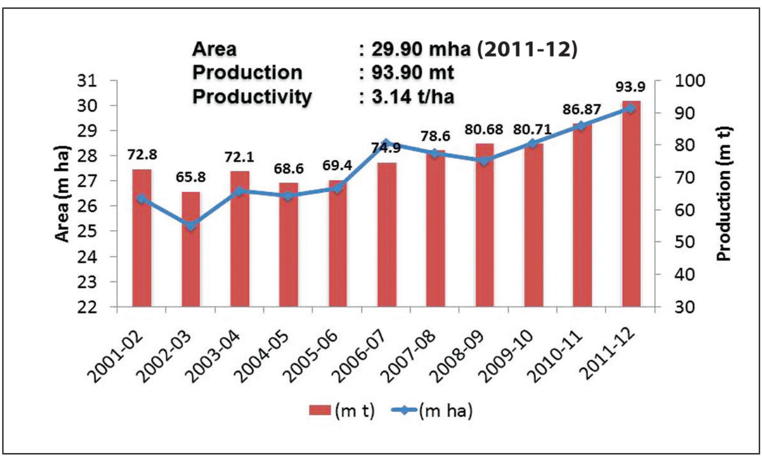
Research, Policy and Institutional Dynamics in Enhancing Wheat Production and Productivity in India

Indu Sharma, Ravish Chatrath and R. Sendhil

Wheat (*Triticum* spp.) is the second most important cereal in India after rice, contributing substantially to the national food security by providing more than 50% of the calories intake. Globally, wheat is the leading source of vegetable protein in human food, having higher protein content than either maize (corn) or rice, the other major cereals. The country has witnessed a significant increase in total foodgrain production to the tune of 257.44 million tonnes (mt) with a major contribution of rice with 104.32 mt and wheat with 93.9 mt during 2011-12 (4th Advance Estimates, DAC, GoI, 24th September, 2012). The scenario for the past ten years has clearly indicated that the wheat production in the country has soared ahead despite marginal increase in the crop acreage (Table 1).

Table 1: Area production productivity of wheat (2001-12)



P. K. Shetty, S. Ayyappan and M. S. Swaminathan (eds). *Climate Change and Sustainable Food Security*, ISBN: 978-81-87663-76-8, National Institute of Advanced Studies, Bangalore and Indian Council of Agricultural Research, New Delhi. 2013

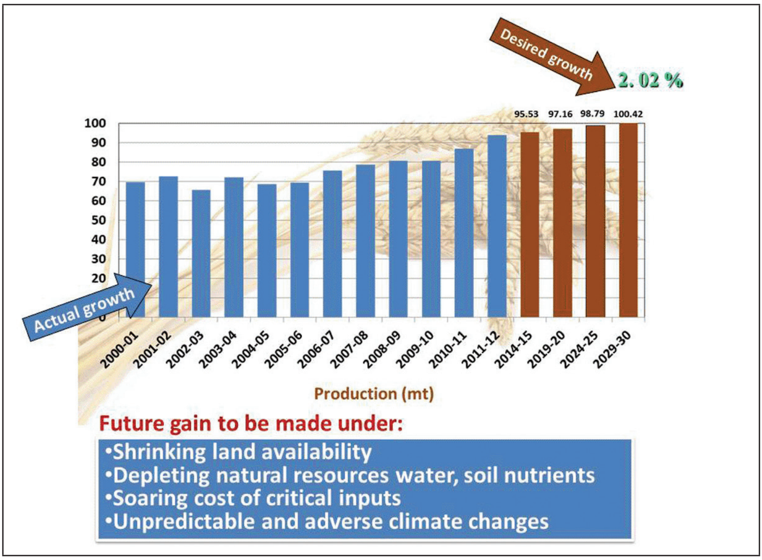
The production during 2011-12 has been a gargantuan figure of 93.9 million tonnes which was an increase of nearly 7.5% increase in production over last year's production of 86.87 million tonnes. Wheat cultivation in India traditionally been dominated by the northern region of India wherein states of Punjab and Haryana have been prolific wheat producers. About 92% of the wheat is produced in six states viz., Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan and Bihar. Among them Uttar Pradesh with 30.3 mt is the highest producer of wheat followed by Punjab (17.2 mt) and Haryana (12.7 mt). Contribution from Punjab and Haryana is due to high productivity (4.9 to 5.0 tonnes/ha), while the contribution of other states such as Uttar Pradesh and Madhya Pradesh is due to relatively large area (~50% of the total area) covered by the crop.

Following factors have played a significant role in the record production of wheat in 2011-12:

1. Exceptionally prolonged cool weather throughout the wheat season and especially during grain development stage.
2. Marginal increase in area from 29.2 million hectare in 2010-11 to 29.9 million hectare in 2011-12.
3. Containing yellow rust incidence in north India through active surveillance, issuing timely advisories and enhancing spread of rust resistant varieties. Awareness programme for agricultural department and farmers resulted timely application of fungicide which played an important role.
4. Proactive role of state extension machinery under the umbrella of National Food Security Mission (NFSM).

The establishment of the multilocational wheat programme in 1960 followed by the advent of dwarf wheat were important milestones that brought about systematic developments in wheat research and resulted in the real breakthrough in wheat productivity and production. Since then, the coordinated programme on wheat has released 399 wheat varieties, comprising bread wheat (335), durum (54), dicocccum (5) and triticale (5), for cultivation under different production conditions in all the wheat growing zones. 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.

Table 2: Wheat production targets by 2030



While commemorating our milestone accomplishments it is important that the future food and nutritional security of the country is also kept in the forefront. The wheat production target (Table 2) to be achieved by 2030 is set at 100 million tonnes (Vision 2030, Directorate of Wheat Research, 2011). However, there are several other challenges that are faced in achieving this target. The population is increasing in a geometric progression leading to an increased demand of wheat but there is no possibility of further increase in area due to growing urbanization, climate change; vulnerability to disease incidences; dwindling water resources, micro-nutrient deficiencies and soil health deterioration. Therefore, the need to produce more wheat has to be met with fewer resources in a sustainable and cost effective manner. The demand for wheat is also increasing due to changes in food consumption habits and preferences for processed products by the urban and rural population.

In order to achieve the set target it is of prime importance to do a SWOT analysis

Strengths

- Strong coordinated set-up
- Strong research and development support
- Genetic diversity
- Suitable varieties for diverse agro-climatic conditions
- Suitable climatic conditions for growing all types of wheat
- Repository of wheat rusts pathotypes at Flowerdale, Shimla
- Facility of off-season nursery at Dalang Maidan for advancement of generation and evaluation against wheat rusts under natural conditions
- International linkages

Weaknesses

- Absence of procurement based on quality
- Slow transfer of technology by the State Governments
- Poor commercialization initiatives
- Inadequate linkages between public and private sector

Opportunities

- Bridging yield gaps
- Focus on harnessing higher wheat production from states having low productivity – UP, MP, Bihar, Gujarat, Rajasthan and eastern parts
- Strong domestic demands from processing and baking industries

- Use of new biotechnological and bio-informatics tools
- Opportunities of outsourcing high throughput marker analysis
- India situated geographically at advantageous location for wheat export
- Value addition

Threats

- Global climate change
- Deteriorating soil health
- New diseases and insect pests
- Water scarcity
- Patent regulated genetic flow
- Volatile global price and export import restrictions
- Population pressure – reducing arable area due to urbanization

Researchable issues

It is a matter of great concern that for the last several years plateau in wheat productivity is being observed and thus the major challenge is to break the yield barriers. Yield jump as observed in 60s owing to technology breakthrough seems to be unattainable now. There is need to follow an approach for gradual gain in yield in order to develop new genotypes that are responsive to high input management and capable of yielding beyond 7t/ha. Pre-breeding efforts need to be taken up with a greater zeal by involving synthetics, Chinese materials, winter wheat etc. The wealth of Indian landraces and germplasm needs to be dissected for identification of genes of interest. The development of hybrids in wheat is another promising approach to break the yield barriers and to get the quantum jump. The expected onslaught of climate change is also a worrisome aspect and breeding strategies have to be reoriented to take care of the biotic and abiotic stresses. The threat of new races of rust, especially yellow rust in north India needs an enhanced focus. Similarly water becoming a scarce commodity and temperatures soaring high during grain formation will necessitate development of drought and heat tolerant wheat cultivars. The new biotechnological interventions like developing transgenics for abiotic stresses, genomic selection and high throughput support for marker analysis including GBS (genotyping by sequencing) along with precision phenotyping could provide the necessary boost in enhancing the yield potential. Enhanced photosynthesis and possibilities of converting C_3 wheat to C_4 are the areas that need a long term focus.

Managing the natural resources is an important challenge especially in the highly productive rice-wheat cropping system (RWCS) which is predominant in the Indo-Gangetic plains. This has put a tremendous pressure on the land leading to a decline in the total factor productivity and depletion of soil organic carbon. The problem is further aggravated by burning of rice and wheat crop residues by farmers especially that of rice under RWCS in north western parts. Nutrient mining, imbalanced fertilisation and over-exploitation of water resources are the other factors responsible for decline in total factor productivity. Addition of organic matter to soil through green manuring and crop residue recycling, balanced fertilisation, integrated nutrient and water management, diversification/ intensification of rice-wheat system by including pulses, oilseeds and vegetables crops are some of the possible remedial measures to improve soil productivity and hence, total factor productivity. Research in resource management has to be focused on developing and fine-tune the package of practices and varieties specific to resource conservation technologies (RCTs) - zero tillage, bed planting, laser leveling, need based application of nutrients (N) using leaf colour charts. To ensure sustainability of RCTs the long term effect of tillage and residue management options on soil properties, pest dynamics and productivity of wheat needs thorough investigation. Emphasis on conservation agriculture is paramount to address the issue of climate change and ill-effects of residue burning. It is a high time to focus on integrated rice-wheat research towards development of varieties with efficient input use and developing specific wheat varieties suitable for different tillage options that are increasingly becoming popular in the RWCS.

The most serious constraints in wheat production are a host of biotic stresses. Among the major biotic stresses, control of rusts and foliar blight are more critical for achieving higher yields. India in particular has not faced any rust epidemic since last three and half decades because of proper deployment of rust resistance genes in wheat breeding programmes. However, keeping in view the recent incidences of yellow rust in the foothills of northern India, survey-surveillance, crop health monitoring and tackling new races of rust, eg., 78S84 race of yellow rust and Ug99 race of stem rust, has to be prioritized. Likewise attention has been drawn towards incidence of wheat blast in Brazil. Host resistance – identification of new and diverse sources of resistance with emphasis on multiple disease/pest resistance has been strengthened. Over past five years there has been a significant increase in number of rust resistance genes that are being used in the breeding programme. Creating national repository of pathotypes of different rust pathogens and integrating molecular tools for understanding variability in pathogens are assuming greater importance. It is also important to devise eco-friendly management of diseases and pests as well as to promote IPM. Karnal bunt has assumed greater importance in wake of the foreseeable export potential of wheat. Other problems like powdery mildew, and pests (aphids, termites, etc.) are also receiving due attention in the wheat improvement programme. The entire plant protection strategy is moving towards the integrated pest management mode and focus on surveillance, biological control and other eco-friendly methods.

Wheat is the main source of energy and nutrition in human diet. Therefore, increasing the levels of micronutrients (such as Fe and Zn) in grains through biofortification and their enhanced bioavailability will have impact on health of large part of population specially children and pregnant women. Wheat is also unique in the sense that large number of diverse end-products such as chapati, biscuit, bread, noodles, macaroni and other pasta products are made from it. Varieties have been identified which are specific to end-product use. Work has been initiated on understanding genetic aspects related to gluten strength and extensibility, noodle quality, dough and pasta colour, yellow pigment content, micronutrient content, anti-nutritional factors in the grain and genes related to starch biosynthetic pathway to manipulate starch properties for improving quality and yield.

The 100 million tonnes target by 2030 could be a realistic one only if we concentrate on the short term strategies which give more emphasis to the effective transfer of available technologies to the farmers. This means taking stock of the situation at the grass-root level and bringing in remedial measures which impede wheat production growth. Wheat production in some states in India is faced with large gaps in potential and realized yield. Some of the gaps can be filled up through development of infrastructure facilities, while the production related barriers can be effectively overcome through adoption of appropriate interventions and technologies. However, with the available technologies it seems possible to bride this gap, especially under irrigated conditions. The analysis (2007-08 to 2011-12) shows that it is possible to harvest additional 14.3 million tonnes of wheat (Table 3).

Table 3: Wheat area under irrigation, yield gap and estimated additional production 2007-08 to 2011-12

State	Yield Gap (q/ha)	Area under wheat ('000 ha)	Area Irrigated (%)*	Estimated additional Production ('000t)
Uttarakhand	8.12	388	56.17	176.97
HP	4.64	359	19.81	33.00
J&K	5.13	285	29.11	42.56
UP	5.55	9533	97.78	5173.36
West Bengal	4.35	322	73.95	103.58
Assam	5.66	52	100.00	29.43
Bihar	5.25	2158	91.73	1039.26
Jharkhand	8.74	112	85.82	84.01
Punjab	3.77	3512	98.55	1304.83
Haryana	2.11	2491	99.28	521.82
Rajasthan	6.17	2539	99.43	1557.63
Gujarat	3.26	1174	89.80	343.69
MP	9.79	4207	83.84	3453.08
Chhattisgarh	11.88	103	71.13	87.04
Maharashtra	4.01	1101	74.80	330.24
Karnataka	5.37	263	53.64	75.76
India				14280.50

** Wheat area under irrigation is for the year 2008-09*

Policy support

Policy interventions for enhancing wheat production can be targeted at government, researchers, farmers, private sectors, extension agents and institutions. Since wheat is the second most important staple crop of India grown to feed the millions, government has to play a major role in streamlining the wheat production. The government needs to increase the Minimum Support Price (MSP) to raise the crop acreage. Under remunerative price, farmers tend to allocate more area than the usual acreage devoted to a particular crop. Further, incentives for procurement should be given by the respective state governments like Punjab and Haryana where local taxes in procurement are exorbitant amounting to 14.5 % and 10.5 % respectively. Though MSP is applicable across the country, only few states in India implement it. Efforts should be made to implement the MSP in all states. In regions where MSP is not followed, government should come forward and take the responsibility of paying the difference between the actual price received by farmers and MSP (deficiency price payment) so as to sustain the wheat production in the country.

Currently Indian wheat is procured in bulk irrespective of the quality or grades. Wheat varieties should be procured based on the grades, good quality wheat (Grade A) should fetch a premium price and the subsequent grade (Grade B) should fetch a price lower than Grade A or MSP, whichever is higher. Premium price for quality wheat particularly durum based products will increase the export demand as well as domestic production. For this, an effective regulated quality standards system (grading and standardisation at the procurement centre) and its awareness among the farmers and other stakeholders is needed at this hour so as to facilitate trade through value addition. Creating avenues for additional demand through value addition will induce wheat production in home country.

Further, inclusion of private sector becomes mandatory for efficient function of the markets so that farmers are left with the option of selling the produce at their goodwill. There is a dire need for Public Private Partnership (PPP) in research and development. Though, majority of the varietal development programmes are from the public sector organizations, private sector should equally contribute in those programmes and create competitiveness in research domain.

To avoid the losses at field level, continuous monitoring of the crop preferably through remote sensing techniques is advocated. This will help to take appropriate measures to manage the impact of the encountered problem in a large scale. Nevertheless, farmers should adopt technological improvements which are demonstrated through Frontline Demonstrations (FLDs) for reducing the existing yield gap in wheat production. Considering the depleting natural resources, the following demonstrated improved technologies of conservation agriculture *viz., z*ero and reduced tillage should be adopted to reap better yield. Climate change being global issue, suitable strategies like timely sowing, timely application of inputs and other resource services, decision support system for weather parameters and expert system should be exploited to enhance wheat production.

There is a need for mechanisation particularly in labour scarce areas. For instance, combine harvester will reduce the field wastage and lead to increased productivity. In addition to this, suitable policies for institutional support such as timely availability of credit, subsidies to venture any new operation like drip irrigation, farm mechanization and seed production. To mention, NFSM offers subsidy to purchase machineries like pump set for irrigation. Timely availability of credit from credit lending institutions will help the farmers to procure the right input at right time. Obviously, farm operations carried out at appropriate time will have significant impact on wheat yield.

Market intelligence has to be strengthened with faster flow of information across all quarters like sending bulk SMS, pre-recorded voice calls, toll free number for clarifications, electronic display boards in major markets showing the futures prices so that farmers can decide the acreage devoted to the crop well in advance and plan for marketing accordingly.

Government should create export demand by relaxing export restrictions and extend export subsidies at time of surplus production and stock. With the current high wheat production in the country the Government should be proactive towards export. Estimates show that global wheat production in 2012-13 could be lower by as much as 40 mt from the previous year's production of 694 mt. The decline is on account of lower yield in EU and Kazakhstan followed by deteriorating prospects in the southern hemisphere, Australia and Argentina. So, the big question is: where will export supplies come from? Nearly 45 % of global wheat stocks will be held by China and India. At this stage India has a win-win situation as China being the world's leading producer, is not an exporter, but an importer of wheat. With 94 mt historic production and 38 mt of record procurement by Food Corporation of India and state agencies, there is a huge inventory waiting (49.81 million tonnes) to be liquidated. Earlier the government took several policy measures during 2006-2011 to ward off the adverse impact of global food crisis. These included (a) imports of 7.9 million tonnes of wheat; (b) ban on exports of wheat; (c) ban on futures trade in wheat; (d) permission to private traders to import wheat and wheat flour at zero duty; (e) imposition of stocking limits on traders or bulk buyers; (f) hike in Minimum Support Price (MSP) to encourage production and for built-up of public stocks; and (g) raise in norms of buffer and food security stocks (most of the measures have been withdrawn). However, with wheat production touching new heights embargo on export was lifted a year ago and wheat shipments from the country have crossed 3 mt. With recent spurt in export prices due to shortage of wheat supplies in world market and weak rupee, export prospects have brightened. The country has to utilise the opportunity to liquidate the excess wheat and make export earnings.

Institutional support

International linkages: The wheat programme of the country has developed strong symbiotic linkages with international partners that have helped India and the collaborating institution as well. The longest and most productive linkage in the world has been between India and the International Maize and Wheat Improvement Center (CIMMYT) that dates back to 1963 when Dr. Norman E. Borlaug visited the subcontinent as a guest of Government of India. The linkages have facilitated germplasm enrichment, human resource development and screening of Indian wheat materials in Kenya and Ethiopia for Ug99 race of stem rust. India was one of the first countries to become involved in collaborative projects commissioned by the Australian Centre for International Agricultural Research (ACIAR) in 2007 on marker assisted wheat breeding involving bioinformatics and molecular biology, water use efficiency, drought and roots, rust and other biotic stresses, waterlogging and other abiotic stresses and industrial quality. Similarly, collaboration with Durable Rust

Resistant Wheat (DRRW) Project at Cornell University, USA has helped in survey and surveillance and molecular studies of wheat rust. Long term collaboration is being developed with other international institutes like Kansas State University, University of Nottingham (BBSRC), INRA, France and many more.

National linkages: The Directorate of Wheat Research through its coordinated setup of 31 centres has strong linkages with many SAUs and agricultural research institutes. Other important institutes collaborating in wheat research are IARI (New Delhi) and its regional stations, VPKAS (Almora), NIASM (Baramati) and ARI (Pune). Fruitful collaborations with these SAUs and institutes have collectively resulted in enhancing wheat productivity of the country.

Thus, it can be concluded that the Indian wheat programme with its strong multi-disciplinary team across the country along with the synergy between research, developmental and extension activities, can achieve the projected demand leading to food and nutritional security of our nation.

Enhancing the Productivity and Production of Pulses in India

C. L. Laxmipathi Gowda, S. Srinivasan, P. M. Gaur and K. B. Saxena

Pulses are major sources of proteins among the vegetarians in India, and complement the staple cereals in the diets with proteins, essential amino acids, vitamins and minerals. They contain 22-24% protein, which is almost twice the protein in wheat and thrice that of rice. Pulses provide significant nutritional and health benefits, and are known to reduce several non-communicable diseases such as colon cancer and cardio-vascular diseases (Yude *et al,* 1993; Jukanti *et al,* 2012). Pulses can be grown on range of soil and climatic conditions and play important role in crop rotation, mixed and inter-cropping, maintaining soil fertility through nitrogen fixation, release of soil-bound phosphorus, and thus contribute significantly to sustainability of the farming systems .

India is the largest producer and consumer of pulses in the world. Major pulses grown in India include chickpea or bengal gram (*Cicer arietinum*), pigeonpea or red gram (*Cajanus cajan*), lentil (*Lens culinaris*), urdbean or black gram (*Vigna mungo*), mungbean or green gram (*Vigna radiata*), lablab bean (*Lablab purpureus*), moth bean (*Vigna aconitifolia*), horse gram (*Dolichos uniflorus*), pea (*Pisum sativum* var. arvense), grass pea or khesari (*Lathyrus sativus*), cowpea (*Vigna unguiculata*), and broad bean or faba bean (*Vicia faba*). More popular among these are chickpea, pigeonpea, mungbean, urdbean and lentil. In general, pulses are mostly grown in two seasons: (i) the warmer, rainy season or kharif (June-October), and (ii) the cool, dry season or rabi (October-April). Chickpea, lentil, and dry peas are grown in the rabi season, while pigeonpea, urdbean, mungbean, and cowpea are grown during the kharif season. Among various pulse crops, chickpea dominates with over 40 percent share of total pulse

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production followed by pigeonpea (18-20%), mungbean (11%), urdbean (10-12%), lentil (8-9%) and other legumes (20%) (IIPR Vision 2030).

Though India is the world's largest producer of pulses, it imports a large amount of pulses to meet the growing domestic needs. During 2009-10, India imported 3.5 million tons of pulses from the countries like Australia, Canada, and Myanmar. Thus, India is the largest importer, producer and consumer of pulses. On the other hand, India is also the largest pulses processor, as pulses exporting countries like Myanmar, Canada and Australia do not have adequate pulses processing facilities.

Large shares of pulses import, including desi chickpeas, pigeonpea, mungbean, urdbean, and kidney bean come from Myanmar. Importers favor Myanmar because it offers varied pulses with qualities similar to those produced in India, low freight rates, and relatively fast delivery. Canada and Australia are major suppliers of dry peas and kabuli chickpeas to the Indian market, each supplying about one-third of India's pulses imports. Most kabuli chickpeas come from Mexico, Australia, Canada, Turkey and Iran. Nepal and Syria account for the largest shares of Indian lentil imports.

It has been estimated that India's population would reach 1.68 billion by 2030 from the present level of 1.21 billion. Accordingly, the projected pulse requirement for the year 2030 is 32 million tons with an anticipated required growth rate of 4.2% (IIPR Vision 2030). India has to produce not only enough pulses but also remain competitive to protect the indigenous pulse production. In view of this, India has to develop and adopt more efficient crop production technologies along with favorable policies to encourage farmers to bring more area under pulses.

Area, production and yields of pulses in India

India ranks first in the world in terms of pulse production (25% of total worlds production) (FAOSTAT 2010). Madhya Pradesh, Maharashtra, Uttar Pradesh, Andhra Pradesh, Karnataka and Rajasthan are the major states growing pulses in India. These six states contribute 80% of total pulse production and area (Directorate of Economics and Statistics, Department of Agriculture and Cooperation, 2010).

More than 90% of lentil area is covered by Madhya Pradesh and Uttar Pradesh states which contribute more than 70% of country's production during 2010 (Directorate of Economics and Statistics, Department of Agriculture and Cooperation, 2010). Pigeonpea is mainly grown in Maharashtra, Karnataka and Andhra Pradesh states (>60% area in India) with 60% of production (1.4 million tons) coming from these three states. Madhya Pradesh has the highest area (38%) under chickpea, followed by Maharashtra (16%), Karnataka (12%), Rajasthan (11%), Andhra Pradesh (8%) and Uttar Pradesh (8%). Andhra Pradesh leads in the total pulse productivity with an average increase of 81-100% in the yield of two major pulses, chickpea and pigeonpea in the past two decades (1991 to 2010). This significant increase has surpassed the national average increase in the total productivity.

Average yield of pulse crops in India is low compared to the world average. However, the average yield of pulse crops in the country has increased gradually over the period and is 690 kg ha^{-1} in 2010-11 which is 56% higher compared to yields during 1950 (Figure 1). Interestingly during 2010-11, India produced 18.1 m ton of pulses from 26.3 m ha with a productivity of 690 kg ha^{-1}, which is the highest of all time. Yield of kharif pulses ranges between 393 and 512 kg ha^{-1}. But, the yield of Rabi pulses ranges between 654 and 756 kg ha^{-1}. Mostly pulses are grown as rainfed or with limited irrigation, but due to the availability of improved high yielding varieties farmers are growing pulses as an irrigated crop.

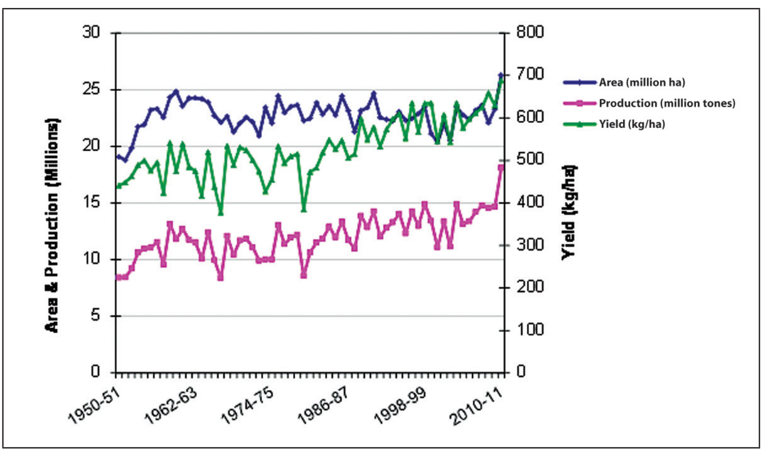

Figure 1: Area production and productivity of pulses in India

Net daily pulses availability for Indians has increased slightly from 32g per capita in 2000 to 37g per capita in 2009. Percentage share of pulses in net food grain availability has also increased slowly from 7% to 8.33% during this period. These data show that the availability of pulses has increased in the past decade with the increasing emphasis on development of improved varieties and supportive policies of the Government in India. over a period of 60 years (Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation 2010).

The expansion of irrigated agriculture in northern India has led to displacement of pulses by wheat, rice, and maize in large area. Area under pulses declined from 10.12 million ha to 8.16 million ha (about 20%) in north India (Figure 2). On the other hand, area of pulses increased from 11.34 to 15.01 in central and south India during the same three decades. Among pulses, chickpea area has decreased by more than 50% in north India, considering the base year 1971-75.

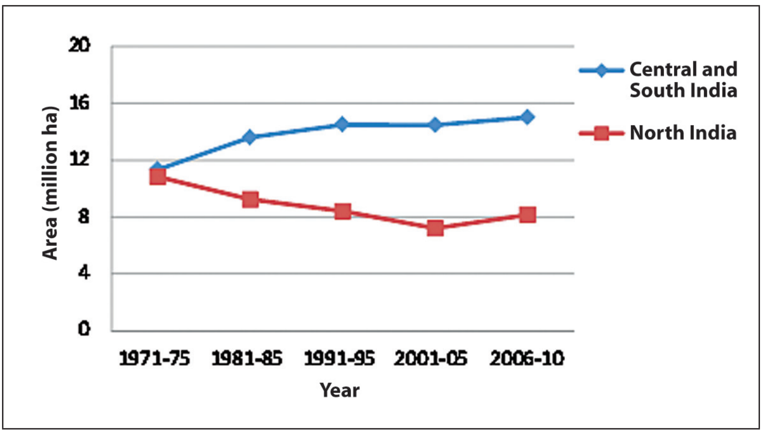

Figure 2: Shift in area of pulses from Northern India to Central and Southern India

There has been a major shift in chickpea area (about 3.0 million ha) from northern India (cooler, long season environment) to southern India (warmer, short season environment) during the past four decades. The short-duration varieties developed through ICRISAT and Indian NARS partnership have played a key role in expanding area and productivity of chickpeas in central and southern India. Among all major pulses of northern India, chickpea suffered maximum loss of 63% area (from 4.98 million ha in 1971 to 1.85 million ha in 2010), mainly due to replacement by wheat.

Constraints to pulse production

a. Production constraints

Production of major pulses is constrained by both biotic and abiotic stresses. For example, pod borers (*Helicoverpa armigera*), fusarium wilt, root rots, ascochyta blight and botrytis gray mold are some of the major biotic constraints to increasing the productivity of chickpea. The major constraints to productivity in pigeonpea are biotic stresses such as pod borer, pod fly, Fusarium wilt, and sterility mosaic disease. Similarly, pod borer, aphids, cutworm, powdery mildew, rust and wilt are the major pests and diseases affecting lentil production in India. The richness of legumes in N and P, makes them attractive for insect pests and diseases (Sinclair and Vadez, 2012).

Most of the pulses in India are grown in low fertility, problematic soils and unpredictable environmental conditions. More than 87% of the area under pulses is rainfed. Drought and heat stress may reduce seed yields by 50%, especially in arid and semi-arid regions. Another major problem is salinity and alkalinity of soils which is high both in semi-arid tropics and in the Indo-Gangetic plains. With recent changes in the global temperatures the grain yield is likely to be drastically affected by temperature extremities. Poor drainage/water logging during the rainy season causes heavy losses to pigeonpea on account of low plant stand and increased incidence of phytophthora blight disease, particularly in the states of UP, Bihar, West Bengal, Chhattisgarh, MP and Jharkhand.

b. Socio-economic constraints

Even though India is the largest pulses producer in the world, it imports large amount of pulses from rest of the world. Farmers in India treat pulses as secondary crops. Until recently the government also gave less importance to pulses compared to the staple cereals. In general farmers' access to inputs is limited, both because of low purchasing power and accessibility to markets to sell the excess produce of pulses. Because of this situation, the farmers give first priority to staple cereals and cash crops for allocating inputs and the second priority to pulses. As a result, pulses continue to be grown on poor soils with low inputs. In addition, there is lack of policy support and post-harvest innovations related to pulse crops. Availability of quality seed of improved varieties and other inputs is one of the major constraints in increasing the production of grain legumes (David *et al*, 2002).

Strategies to improve pulse productivity and production

There are a few available technologies that can increase the productivity and production of pulses. A few examples are given in this paper, mostly from chickpea and pigeonpea where the authors have experience. Similar technologies are available for most major pulses grown in India.

a. Short-duration, high-yielding varieties

Matching crop maturity duration to available cropping window, including soil moisture availability, is a major strategy to avoid drought stress. Hence, emphasis in crop improvement programs has been to develop high-yielding, short-duration cultivars which escape terminal drought. These short duration varieties provide opportunities for inclusion of a given crop/variety in the cropping systems with a narrow cropping window or new production niches.

Development of short-duration and wilt resistant chickpea varieties has led to the adoption of chickpea new niches of southern India, and in rainfed rice-fallow lands (Gowda and Gaur, 2004; Gaur *et al*, 2008). For example, early-maturing, chickpea varieties, particularly JG 11, KAK 2, JAKI 9218, and Vihar have brought a chickpea revolution in Andhra Pradesh state of India, where the production has recorded 9-fold (95,000 to 884,000 tons) increase over the past 10 years (2000-2009), as a result of a 5-fold increase in area (102,000 to 602,000 ha) combined with a 2.4 fold increase in yield levels (583 to 1407 kg ha^{-1}) (Gaur *et al*, 2012). The key factors for this significant increase in chickpea area and production in central and southern India are: (i) Introduction of high yielding, short-duration, Fusarium wilt resistant varieties adopted to short-season, warmer environments of southern India; (ii) High adoption of improved cultivars and production technologies ; (iii) Successful Introduction of commercial cultivation through mechanized field operations and effective management of pod-borer; and (iv) Availability of grain storage facilities to farmers at local level at affordable cost. Andhra Pradesh was once considered beyond the limits of chickpea cultivation, due to warm and short-season environment, but now has the highest average yield (1.4 tons ha^{-1}) levels in India. More than 80% of the chickpea area in Andhra Pradesh is occupied with improved short-duration cultivars (JG 11, KAK 2, JAKI 9218, and Vihar) (Gaur *et al*, 2012).

b. Improved varieties with drought tolerance

The drought tolerant varieties can provide cost-effective long-term solutions against adverse effects of drought. Returns to investment in breeding for drought tolerance are likely to be higher compared to those in other drought management strategies. A wider dissemination of drought-tolerant material would provide sustenance to the livelihoods of farmers who are more vulnerable to shocks of crop failure. On the other hand even though the potential economic benefits of drought-tolerance breeding research are attractive, farmers may not benefit from it if appropriate institutional arrangements are not in place for multiplication and distribution of seeds of improved varieties. This is more so in the case of large seeded pulses whose seed requirement is very high.

Marker-assisted back-crossing (MABC) approach has been successful in many crops including cereals (Varshney *et al,* 2006) and legumes (Varshney *et al,* 2010). Root traits, particularly rooting depth and root biomass, are known to play an important role in avoidance of terminal drought through more efficient extraction of available soil moisture. A genomic region that contained QTL for root traits and several other drought tolerance related traits was identified in chickpea. MABC was initiated at ICRISAT to introgress this major genomic region in three cultivars (JG 11, Chefe and KAK 2) in collaboration with the national programs in India, Kenya, Ethiopia, Tanzania. Recently, as a part of Accelerated Crop Improvement Program (ACIP) of Department of Biotechnology (Government of India), several marker-assisted breeding programs have been initiated, including MABC (marker-assisted back-crossing) to incorporate drought tolerance in to high yielding varieties.

c. New niches

Pulse crops have great diversity of maturity durations that enable their cultivation in many niches and different production systems to increase production. A few examples are given below, but there are many more in other crops and niches that can be exploited successfully.

(i) Chickpea in rice fallows

The Indo-Gangetic Plains (IGP) spread over South Asia's four countries-Bangladesh, India, Nepal and Pakistan- is agriculturally one of the most important regions of the world. About 14.3 million ha of the rice area in IGP remains fallow during the winter season. These rice-fallows offer a huge potential for expansion of the area of rabi pulses such as chickpea, lentil and grasspea. Large-scale on-farm trials conducted by several State Agriculture Universities in five states of India (Chhattisgarh, Jharkhand, Orissa, West Bengal and eastern Madhya Pradesh) have clearly shown that short-duration varieties of chickpea and lentil can be successfully grown after rice harvest, and with reasonably high yield levels of 1 to 2.5 ha^{-1}. For example, short-duration desi and kabuli chickpea varieties were found suitable, and the farmers preferred the *kabuli* varieties ICCV 2, KAK 2 and JGK 1 in most areas as they fetch high market prices. More recently, a heat tolerant chickpea variety JG 14 has been found to be highly adapted to late-sown conditions in the rice fallow area in the states mentioned above.

(ii) Pigeonpea in rice-wheat cropping systems

Rice–wheat cropping system is popular in the Indo-Gangetic Plain region of India. However, continuous mono-cropping of cereals has lead to depletion of soil fertility and increased incidence of pests and diseases, and is posing a serious threat to sustainability of the entire rice-wheat cropping system. The inclusion of legumes in rice–wheat cropping system would greatly help restore soil fertility and reduce other associated problems. Several on-station and on-farm trials during 1999-2002 in Haryana and Western Uttar Pradesh with extra-short duration pigeonpea varieties (such as ICPL 88039, now released as VP Arhar 1) indicated that pigeonpea can be grown profitably in place of rice during the kharif season (sown in late-May and harvested in late October or early November), allowing timely sowing of wheat crop. Pigeonpea yields were 1.5 to 3 tha^{-1}, with an average of 2 t ha^{-1}. As pigeonpea adds nitrogen through BNF and leaf fall (contributing about 40-50 kg N to the system), the succeeding wheat crop needed less N fertilizers. The net economic returns under pigeonpea-wheat system were found greater compared with the rice–wheat system (Singh *et al,* 2005).

(iii) Pigeonpea at high altitudes

Extra-short duration pigeonpea was successfully cultivated up to the elevation of 2000 m above sea level in Uttarakhand. A pilot study in collaboration with Vivekananda Parvathiya Krishi Anusandhan Sansthan (VPKAS), Almora and the Department of Agriculture, Uttarakhand, with several on-farm trials across different elevations in the state during 2007-10 indicated that pigeonpea variety 'VL Arhar-1' (ICPL 88039) can be grown successfully in low and medium hill regions (Saxena *et al,* 2011). VL Arhar-1 showed high adaptability to high elevation regions and produced as high as 1,800 kg ha^{-1} of grains. Since the extended periods of cold and frost can severely damage the foliage and flowers of pigeonpea, its cultivation should be limited to only low and mid hill regions. Extra-short duration pigeonpea cultivar VL Arhar 1 is now extensively cultivated in Uttarkhand.

d. Seed systems

Despite a long list of improved pulses varieties released for cultivation, their impact has not yet been fully realized by the resource-poor farmers in many states in India. The accessibility of smallholder farmers to quality seed of improved pulses varieties is constrained by both inadequate demand creation and limited supply. This situation is also compounded by unfavorable and inadequate policy support and regulatory frameworks, inadequate institutional and organizational arrangements, and deficiencies in production and supply infrastructure and farmers' socio-economic situation (Rubyogo *et al*, 2007).

Numerous constraints limit the performance of seed systems in India including limited access of smallholder farmer to seed of improved varieties; limited supplies of quality (breeder, foundation and certified) seed of farmer and market-preferred varieties; lack of co-ordination among national seed production organizations and policy making institutions.

On the seed supply side, grain legume seed business generally does not attract large seed companies since profit margins are low. More than 95% of lentil seed in India (the leading global lentil producer) comes from the informal sector (Materne and Reddy, 2007). The situation with respect to other pulses in India is similar. The seed replacement rate in India varies from 14% in chickpea to 35% in soybean (www.seednet.gov.in), thus indicating that a majority of the farmers still use their own saved seed. This situation is due to several factors including: the low seed multiplication rate of legumes; the reuse of grains from previous harvest as seeds and; often demand for specific varieties adapted to more narrow agro-ecologies and consumers' needs. Furthermore, when seed production takes place, it is often in higher potential areas, with seed stores being concentrated in zones of higher population density or those with better infrastructure (i.e. not the remote, stress-prone areas).

As small and medium seed companies are emerging and gaining strength, they are also creating effective demand for pulses seed. However their capacities are still limited by the inadequate and discontinuous access to foundation seed, inadequate capital investment, and lack of appropriate marketing strategies including delivery systems targeting remote and small scale farmers (Rubyogo *et al*, 2011). Public and private partnership would be the best approach to increase the availability of foundation seed need for subsequent seed classes.

In the developing countries such as India, particularly for pulses, the formal seed sector is highly subsidized and evolving at different stages of development. The informal seed sector is and will remain the dominant player in legumes. In recent past, development partners and researchers have realized the importance and significance of quality seed in agriculture and several projects have been implemented or are in progress to improve seed availability of improved farmer-preferred varieties to farmers. The main issue in resolving access to quality seed would be a thorough understanding and critical assessment of the status of existing seed sector (both formal and informal), their bottlenecks and comparative advantages and complementarity.

e. Input supply (micro-nutrients and fertilizer application)

Legumes fix atmospheric nitrogen. However, availability of quality of Rhizobium inoculum is limiting. Phosphorous is becoming a limiting macro-nutrient which will affect the pulses production. A common difficulty in recovering P from the soil is that it is not readily available to plants because P reacts with aluminum, iron and calcium in the soil to form complexes. These nutrients are essentially insoluble resulting in very little movement of P in the soil solution, and none of the complexes can be taken up directly by roots (Sinclair and Vadez 2002). The use of phosphate solubilizing bacteria (strains from the genera of *Pseudomonas*, *Bacillus* and *Rhizobium* are among the most powerful P solubilizers) as inoculants simultaneously increases P uptake by the plant and thus crop yields (Khan *et al*, 2009).

A recent study by ICRISAT indicated that soils in many states in India are deficient in micro-nutrients such as boron, sulfur, zinc and magnesium (Wani *et al*. 2012). Application of small quantities (0.5 to 2 kg ha^{-1}) has resulted in 40-120% increase in grain yield. Hence, making these micro-nutrient fertilizers easily available to smallholder farmers in remote areas will go a long way in enhancing productivity and production of pulses. Under a mission to boost productivity of rainfed agriculture through science-led interventions in Karnataka (called the Bhoochetana project) the improved management practices (including application of micronutrients) have increased the yield by 31-57% in green gram, 26-38% in pigeonpea and 27-39% in chickpea during 2010-11. Similarly in 2011-12 black gram and green gram grain yields increased by 33-42% in response to improved management when compared to farmers management (Wani *et al*, 2012).

f. Response to irrigation

In many areas, grain legumes are grown under moisture stress conditions. Crops such as cowpea, pigeonpea, and chickpea are grown where soil water may be substantially limiting. Yields are necessarily limited by the amount of water available to support growth. Supplemental irrigation with a limited amount of water, if applied to rainfed crops during critical stages can result in substantial improvement in yield and water productivity. A recent review by Sinclair and Vadez (2012) has quantified this relationship. Results have shown that by doubling the available soil water from 150mm to 300mm will double yield to 3.52 t ha^{-1} (Sinclair and Vadez, 2012). This shows the great potential for enhancing the legume crop yields through providing irrigations. Studies have showed that in chickpea and lentil supplemental irrigation can significantly increase seed yields and water use efficiency (WUE) (Zhang *et al*, 2000; Oweis *et al*, 2004). In both chickpea and lentil, yields increased linearly with the amount of water applied. While supplemental irrigation is not always available, where it is available, it is a means of significantly increasing grain legume yields and WUE (Siddique *et al*, 2012).

g. Mechanization

Many pulses are harvested by hand in India because the available cultivars are not suited to mechanical harvesting. In developed countries, such as Australia, Canada and USA, pulses like chickpea, lentils etc. are harvested mechanically. With continuously increasing labor cost, manual harvesting has become an expensive field operation for many crops including pulses in India and farmers are increasingly opting for mechanical harvesting where it is feasible. The farmers, particularly in Andhra Pradesh, are demanding chickpea cultivars suited to mechanical harvesting. The current chickpea cultivars are not suited to mechanical harvesting because the plant height is not adequate and the branches are close to ground due to semi-spreading growth habit. Development of chickpea cultivars with 30 to 40% more height than the existing cultivars and semi-erect to erect growth habit will make the cultivars suited to mechanical harvesting (Gaur *et al*, 2012). Availability of cultivars suited to mechanical harvesting will reduce production cost and attract farmers towards increased pulses cultivation.

The other production practice where cost of cultivation can be reduced substantially is by promoting use of post-emergence herbicides in controlling weeds by developing herbicide tolerant cultivars. In general, pulses are sensitive to herbicides and manual weeding is currently the only option for weed control.

Management of weeds in pulses is becoming expensive and in some cases uneconomical due to high labor cost involve in manual weeding. Herbicide-tolerant cultivars offer opportunity of controlling weeds through need-based applications of herbicides. Weed management through herbicides is not only economical but also facilitate zero-tillage or minimum tillage methods.

Conclusion

India needs around 32 million tons of pulses by 2030, to feed the estimated population of about 1.68 billion. Global supply of pulses is limited, as India happens to be the largest producer and consumer of pulses. Hence, India needs to produce the required quantity, but also remain competitive to protect indigenous pulses production. Improved technologies (improved, high yielding varieties and appropriate crop management practices) are available. However, a concerted effort by farmers, researchers, development agencies, and government are needed to ensure that India becomes self-sufficient in pulses in the next 5-10 years. The recent efforts and programs initiated by the government are bearing fruits, and it is hoped that this momentum is sustained and strengthened to make India self-sufficient in pulses.

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Food and Environmental Safety and Productivity of Horticultural Crops

K. N. Krishna Kumar

Horticulture, comprising fruit, vegetable, flower, tuber, plantation, spice, medicinal and aromatic crops forms a vital component of Indian agricultural production. It not only plays an important role in Indian macro-economic issues, but also an essential element of the strategy to make growth more inclusive. Cultivation and processing of horticultural crops generate lot of employment opportunities for the rural and peri-urban population and their marketing channels create employment prospects for the urban poor, ensuring their livelihood security. Fruits and vegetables are rich sources of vitamins, minerals, proteins, carbohydrates and antioxidant principles that are essential in human nourishment. Flower and ornamental crops serve to enhance the aesthetic value of our environment while medicinal crops yield pharmaceutical constituents. New introductions like mushroom, bamboo and bee keeping (for improving the crop productivity) further expanded the scope of horticulture. Thus, horticulture assumes great importance in the food and nutritional prosperity and the general health and well-being of our population.

India is the second largest producer of fruits and vegetables in the world (221 million tonnes). At present, the horticulture sector has been the main stay of Indian agriculture with a contribution of about 30 per cent to the agricultural GDP from about 14 per cent of area and 40 per cent of total export earnings in agriculture. However, there is still a big gap between demand and supply due to rising demand and low productivity. With food security attained as a result of focused attention in the five year plans, nutritional security to the undernourished population

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is a priority. The per capita availability of vegetables and fruits is far below the recommended levels and the nutritional security can be achieved only by quantum jump in productivity. Hence, it is imperative that there is paradigm shift towards evolving technologies for enhancing productivity in horticultural crops through concerted efforts in research, development and extension.

Food, environmental safety and productivity

Use of chemicals in agricultural production and pollution in cities and other industrial pockets has a profound influence on arable lands, productivity of crops and consequential effect on the human and animal health. Several pollutants affect human and animal health. However, pesticide residues and non-degradable pollutants like heavy metals bother us much more than others. Rapid growth in horticultural production has been accompanied by heavy use of pesticides and chemicals and poor quality water. This has naturally resulted in increased awareness and concern about adverse health effects associated with pesticide use and abuse and heavy metal contamination. There is increasing awareness among consumers about the health hazards associated with high levels of pesticide residues in horticultural produce and they are ready to purchase safe, high quality produce at a premium price.

Intensive agriculture has not only increased crop productivity but also pose severe environmental problems because of heavy use of chemical inputs. The residues of the chemicals cause concern over the safety of food, soil health and sustainable production. To address these problems organic farming, GAP and safe produce farming practices are assuming importance all over the world in order to make the harvested produce free of pesticide residues and other harmful chemicals, to minimize pollution of soil, water and environment and sustain the soil productivity. These ecological production management systems promote and enhances biodiversity. The primary goal is to optimize the health and productivity of interdependent communities of soil life, plants, animals and people. The principal guideline for production are to use materials and practices that enhance the ecological balance of natural systems and integrate parts of the farming system. These farming methods are helpful to minimize pollution from air, soil, water etc. and provide healthy and chemical residue free agriculture products to the consumers.

Pesticide residues: Annually about 6000 tonnes of pesticides is roughly used for crop protection in vegetable crops in India. This accounts for 750 g/ha (considering the gross area under vegetable crops at 8 million hectare), which is 50% more than the world average of 500 grams per hectare. A lot of pesticides are applied on fruit crops too, as they are high value crops. Whenever a pesticide is applied at the beginning of the cropping season the residue level gets reduced due to various environmental factors like rain, wind and temperature etc. and also dilution factor due to increase in size of fruit. When a pesticide is applied during fruit growth stage its residue level per kg of fruits comes down due to dilution factor, but once the fruit is fully grown the residue level cannot come down due to dilution factor, but only due to environmental conditions. Thus, chances of having high residue level is higher, if pesticide application is given towards fruit maturity stage. To reduce pesticide load on fresh horticultural produce pre-harvest interval (PHI) or safe waiting periods have been recommended. During the year 2010-11, of the 5170 samples of vegetables (brinjal, okra, tomato, cabbage, cauliflower and capsicum, curry leaves) analysed, residues were detected in 593 (11.5%) samples and 120 (2.3%) samples only had pesticide residues above permissible levels prescribed by the Food Safety and Standards Authority of India (FSSAI). The most frequently detected pesticides in vegetables were chlorpyriphos, cypermethrin, endosulfan, profenophos and triazophos. The vegetables which were most likely to contain pesticide residues above permissible levels were cauliflower, okra, cabbage and curry leaves. Thus although, the number of vegetable samples which actually contained residues above permissible levels was only 2.3%, we cannot be complacent as a particular vegetable may always contain very high residues while others may be free of residues. Similarly out of the 2062 fruits analyzed residues were detected in 145 (7%) samples and residues above MRL were in only 20 (0.9%) samples.

Pesticide exposure through consumption of horticultural produce can cause a range of neurological health effects such as memory loss, loss of coordination, reduced speed of response to stimuli, reduced visual ability, altered or uncontrollable mood and general behavior, and reduced motor skills. These symptoms are often very subtle and may not be recognized by the medical community as a clinical effect. Other possible health effects include asthma, allergies, and hypersensitivity, and long term exposure may lead to cancer, hormone disruption and problems with reproduction and fetal development.Of the chemicals that have been identified as endocrine disruptors (EDCs), 105 are pesticides, of which 46% are insecticides, 21% herbicides and 31% fungicides. Some of these e.g. aldin, endrin, chlordane etc. have already been banned in India but most are still being used. Out of the EDC pesticides, acephate, propiconazole, carbendazim, chlorothalonil, carbofuran, captan, hexaconazole, methomyl, iprodione etc. are extensively used for horticultural crop production. EDCs act mainly by interfering with natural hormones because of their strong potential to bind to estrogen or androgen receptors. In all countries in the world, legislation has been laid down regulating the presence of pesticide residues in food products by setting maximum residue levels (MRL) of individual pesticides. As long as the individual residues do not exceed the MRLs, the presence of multiple residues in one sample as such is not a reason to be considered as not compliant with the MRL legislation. Although international regulations do not consider harmful health effects of pesticides interactions at their low (<MRL) concentrations, in the near future the combined toxicological effects of low dose pesticide mixtures will have to find regulatory forms for a more comprehensive protection of human health. A large amount of toxicological data need to be generated before this can be fully implemented.

Heavy metals: These are generally defined as "a group of toxic metals and metalloids associated with pollution and toxicity, having atomic weight more than that of iron. There are 35 metals that concern us because of occupational or residential exposure; 23 of these are "heavy metals. (Pb, Cd, Hg, Cr, Ni etc) Heavy metals become toxic when they are not metabolized by the body and accumulate in soft tissues. The danger lies in the fact that once heavy metals enter into the soil-plant-animal continuum, their removal is extremely difficult and expensive. In healthy and normal agricultural soils foods produced will not contain heavy metals in concentrations anyway harmful to human consumption. Under situations where heavy use of phosphatic fertilizers and pesticides containing heavy metals and those other amendments added to soils carrying heavy metals the foods may accumulate heavy metals in proportions considered toxic to human consumption. Most of the reported cases of heavy metal pollution in food samples are fruits and vegetables, fish, milk and meat produced from periurban and urban areas or industrial areas with water sources containing heavy metals or around industries throwing dust into the atmosphere containing heavy metals that gets deposited on crops growing in nearby areas. In periurban area, the general trend in selection of crops is in the following order: vegetables, fodder, cereals and millets, ornamental crops and fruits, of which, vegetables and fodders occupy a major area. Among vegetables, short-duration leafy and succulent vegetables, root vegetables occupy the first place followed by fruit vegetables. Unfortunately, food crops are least accumulators and vegetables and fodders are the highest accumulators of heavy metals. Another paradox is that a major part of nutrient absorption by crop plants is in the first half of their life cycle. Hence, leafy vegetables that are harvested in the first half of their life cycle pose a potential danger with respect to heavy metal circulation in the food chain.There is a wide variability in heavy metal content in vegetable and other crops grown on polluted soils in urban and periurban areas. The content of heavy metals in vegetables depends mainly upon concentration in soil and water, type of vegetable, season, soil type, etc. Several agencies prescribe permissible levels, but there are significant differences in permissible levels prescribed by various organizations. Reasons for such differences are not clear. However, this may be due to differences in tolerance levels of people of different origin, differences in threat perception of people, racial differences in tolerance levels, etc.Among the crops grown, vegetables and fodders accumulated more heavy metals than cereals, pulses and fruits. Among vegetables, leafy and root vegetables accumulated higher concentrations of metals than fruit vegetables. Several studies conducted in periurban areas in India suggest that most of the crops grown are unsafe for human consumption. We must hence look at alternatives to use these lands. There is a need to generate data on crops other than those eaten by humans like flowers, biofuel plants, mulberry, timbers etc. This would enable us to develop an entirely different land-use strategy for contaminated areas that is economically viable and socially acceptable so that entry of heavy metals into the food chain may be contained.

Increasing productivity in fruits and vegetable crops

The need for appropriate technologies for increasing productivity of fruit and vegetable crops need not be overemphasized.India produces 65% of world's mango, 11% of world's banana, ranking first in the production of both the crops. Compared to world average productivity, the productivity of grape, banana and sapotais highest in the world, while, in citrus, mango, apple, guava, pineapple, papaya, India has substantially low productivity. Among vegetable crops, India is the largest producer of okra and second largest producer of most of the other important vegetable crops (brinjal, cabbage, cauliflower, pea, onion and tomato) globally and third largest producer of potato in the world. However, it falls behind in productivity in majority of these crops except for tomato. In okra, it is at par with world productivity and in cauliflower it is quite close to the average world productivity and hence, there is enormous scope for accelerating productivity of fruits and vegetables.

Increase in the productivity can be achieved by the adoption of improved technologies, which include quality disease free planting material, high yielding / hybrid varieties, precision farming, protected cultivation, micro irrigation with fertigation, high density planting with suitable canopy management, rejuvenation of senile orchards, pollination support, balanced nutrients with emphasis on micro nutrients and timely protection against major insect-pests and diseases.

Innovation of new techniques and modernization of cultivation is vital for maximizing the yield of various horticultural crops to which these crops are highly responsive. Availability of certified disease free planting material is the basic foundation for horticulture. Micro-propagation, practice of pro-tray production of quality vegetable seedlings, modern immunodiagnostic techniques for quick detection of viral diseases is the need of the hour for increased productivity.

Protected cultivation with better benefit cost ratio is contributing to higher productiviy in vegetables, crops like pepper, tomato, cucumber, musk melon, baby corn and low poly-tunnel has been used to produce quality strawberries and high value vegetables. Lower volumes of water are needed if drip irrigation is practiced and the benefits of drip irrigation are further enhanced when used with plastic mulch. Integrated nutrient management (INM) practices for maintenance of soil fertility and plant nutrient supply to an optimum level without affecting the soil health for sustaining the desired crop productivity is indispensible in horticulture sector. Bad practices would increase secondary and micronutrient deficiencies it is evident in recent years as they are frequently emerging and the crop response to these nutrients is increasing. Integrated Pest Management (IPM) with judicious use of host plant resistance/tolerance, cultural, biological, chemical, physical /mechanical control and employing bio-pesticides, antagonists and bio-agents etc., backed by regulatory control methods increases the plant health and thereby increasing the productivity indirectly or the percentage of marketable produce directly.

The introduction of bee pollination through enhanced pollination definitely increases productivity in horticulture crops. In other countries, like USA, Canada and Australia, there is practice of renting / supply of hives during the peak flowering fruit crops, especially in crops like apple, citrus, cherries etc., and the hives are door delivered. According to an estimate, the productivity accompanied with quality of the crop can be increased to the tune of over 20 per cent in some crops with this simple intervention. There is need to introduce such practice in our country too, especially in protected cultivation environment.

In the years of dwindling agricultural labour supply, adoption of simple machineries for filling of bags/ pots, digging of soil, application of fertilizers, weeding, spray of chemicals, training and pruning and installation of automated micro-irrigation and fertigation goes a long way in increasing productivity.Machineries can also be devised and utilized for harvesting, washing, grading, sorting, packaging, processing, and value addition.

It is not sufficient to develop these technologies, to realize the potential of innovations, Intensive and focused extension activities have to be practiced to enable farmers to adopt these advanced technologies. Domestic corporate sector and transnational corporations are showing tremendous interest in horticulture because of lucrativeness. This is a good trend and involving such institutions, the technologies can be easily translated in to reality. The creation of Agri-Export Zones (AEZ) cover such traditional products such as grape, mango, pomegranate, acid lime, litchis, mangoes, apples and walnut further boost exports and hence interest in farmers / entrepreneurs to adopt modern production technologies.

National priorities in vegetable production research are

- Enhancing productivity and improving quality of vegetables.
- Sustaining soil health and minimizing the environmental pollution by good agricultural practices, organic farming and precision farming practices etc.
- Year round production of vegetables in cost-effective structures like net house and rain shelter etc.
- Reduction in cost of production by improving input use efficiency.

Safe vegetable production technology: Developing technology for organic production of vegetables and Good Agricultural Practices (GAP) with minimum use of chemicals.

Organic production of vegetables for export and domestic markets as there is an increasing demand for organic foods in metros and other urban markets. The vegetables like onion and gherkins that are largely exported have greater demand if organically produced. Field research trials are being carried out to standardize organic production package for these crops.

Health conscious consumers are demanding safe vegetables that are devoid of harmful pesticide residues and other contaminants. The vegetables like cabbage, cauliflower and tomato receive more pesticide sprays; therefore reduction in the use of theses harmful pesticides with integrated approach is the need of the day and trials on these crops are on.

Precision farming: Developing precision-farming practices for open field and protected cultivation of vegetables.

Precision farming practices are being developed for vegetables at this institute starting with tomato, the crop that has been widely grown with intensive practices, to refine the techniques of production and make it cost-effective.

Cost effective technologies: Developing cost-effective technology for micro-fertigation and protected cultivation.

The available designs for structures are costly and it is the main deterrent for spread of this time-tested technology to increase productivity two fold and more. Designing cost effective structures and production technology would make it attractive to more farmers to adopt the technology to produce superior quality vegetables round the year with less pesticide load in the produce. Paired planting to reduce the cost of drip laterals and also testing the feasibility of conventional water soluble fertizers as against specialty water soluble solid fertilizers will be standardized to develop need based delivery of water and nutrients in the active root zone.

Enhancing water productivity: Developing strategies for enhancing productivity of vegetables per unit of water

Irrigation with inline drip system and pulsed irrigation techniques and covering the beds with mulch are being standardized to improve the productivity per unit water used for production.

Enhancing productivity and reducing cost of production by delaying crop senescence and extending the crop bearing period: Developing techniques to delay senescence and prolonging the bearing period in vegetables.

Drip irrigation, fertigation, foliar nutrition, plant growth regulators, rain shelter and s, net houses will help to keep he crop yielding continuously and use of plant growth regulators are prolong the bearing period and keeps the crop live arresting early senesce of crop.

In brief the research protocols that would enhance competence to provide guidance in important areas to enhance factor productivity are:

- Pulsed irrigation with the use of appropriate drip system.
- Organic production protocols for selected vegetable crops.
- Cost-effective structures including rain shelters for protected cultivation of crops to ensure higher yield and quality, pest free environment, guarding against the abiotic stresses, rain shelter and to facilitate year round production
- Improving the water productivity
- Prolonging the bearing period and delaying senescence to cater to the needs of the market for an extended period and to reduce the cost of production by use of appropriate crop growth inputs such as growth promoting hormones and other natural extracts that arrest senescence and improve plant growth and yield.

Post Production Agriculture and their Role in making the Agriculture Sustainable

S. D. Kulkarni

Food grain production has touched the newer heights of 250 million tonnes thereby increasing the availability of food to the population. An economic growth led purchasing power enhancement of the population is claimed. However, fact remains that the global hunger index (GHI) of our country is 27 against that of the 34 for poorest country. At least 33 per cent of the population does not get two square meals a day. Population with low income group, spends about 60 per cent of their income to meet the food needs of family members and still remain under nourished. The situation is likely to worsen with increasing food demand and population. Our food grain production increased four times (from 51 mt in 1950-51 to 200 mt in 1998-99) and productivity increased from 522 to 1627 kg/ha. However, availability has gone down due to population growth. Agro processing activities in production catchment, at least to meet food requirements of local population, if multiplied countrywide can serve as a road map for real development of countrymen in general and farming community and rural population in particular. Another achievable target is minimization of Post Harvest Losses and thereby improvement in food security of 1210 million population through Agricultural sustainability.

Post production agriculture

India, with nearly sixty per cent population dependent on agriculture, contributes to over 16 per cent of the national income. The present level of post-production losses is 5-10% in durables, 20-30% in semi-perishables and 30-50% in perishables. A substantial amount of these losses could be prevented if appropriate agro-processing activities with backward linkage (farmers) to ensure constant supply of quality raw food materials are established and made operational. The utilization pattern of

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produce and their by-products governs the use of process and machinery e.g. the total out-turn of rice can be increased by 10% by using improved harvesting, parboiling, drying and milling technologies. Conventional post-harvest operations can be improved to take better advantage of raw materials and modern technology.

Agro produce processing

Primary processing of major food raw materials like pulses, oilseeds and cereals used to be a cottage scale rural activity providing employment opportunity locally and primarily processed food raw materials to local people. Cottage scale units have almost disappeared from production catchment and thereby less employment opportunities in the rural areas. The trend needs to be reversed for ensuring economic growth of rural India and checking migration to cities. The by- products generated shall be useful either for cattle feed or food purposes. The waste generated can find a place in the field thereby minimizing pollution load of the town / cities.

Foods can be classified into raw (fresh), primary processed, secondary processed and tertiary processed. Primary processing at farm level covers unit operations like drying, pre- cleaning, etc. Of late, farmers of Maharashtra State have started processing of fruits at farm level for value addition e.g. grape processing for resin (Kismish), fig drying, mango packaging, etc. Such trend if comes up with time then realization about potential of agro produce processing activities in supplementation of farm income may go up considerably in favour of farmers; rural women and rural youth.

The agro processing activities are ordinarily to be of cottage scale and initially restricted to primary processing of locally available raw materials. Value addition to agro produce through processing at farm / rural level is now gaining importance for income and employment opportunities to empower poor population with purchasing power. Primary processing of agro produce, preferably at rural / farmers level ensures realization of full potential in agriculture sector and can generate gainful employment to rural youth. The lowest and the highest monetary values of a food commodity are, respectively, when it is in raw and fresh form and when it is in processed and ready-to-eat form.

Farmer and agro-produce: Small and marginal farm land holding size has made farmers earn low income. At present, to meet the immediate financial needs, resource poor farmers sell almost entire agro produce sold to mandis and they purchase the processed food raw material from town / city at more than double the price of raw material and become poorer. On the other hand the rich farmers retain the produce and sell it at higher prices appropriately. In the peak season fruits are available at very low price in production catchment. Some times producer does not get enough return due to the glut. Under such circumstances it is a must to initiate processing activities in the production catchments, to take up activities of supplying primarily processed raw material to large industries.

The need to supplement farm income has been proved beyond doubt through either integrated farming covering dairy, poultry, goat / sheep rearing, etc. or agro processing activities to make the agriculture sustainable. Empowering the rural population with agro processing units for primary processing would ensure availability of good quality processed material at relatively low cost.

The Indian consumer: Earlier, the price sensitive Indian consumer stayed away from high priced packaged foodstuff. However, now the trend is different – the young population is in favour of packed food- at any cost whereas, the mid-age and above are inclined for primarily processed pure health promoting food options. Primary food grain processing sector thus is expected to have bright future. If the rural population develops the habit of retaining enough food raw materials to meet their annual requirements of primarily processed raw material, then they can have the advantage of considerable savings. Even this approach demands agro processing units in rural areas for getting the processing done on custom hire basis like the functioning of atta chakkies.

Agri business

Agriculture sector in India has largely been for subsistence and not market driven and hence not developed. In-efficiencies in food sector are seen due to 6-7 intermediaries as compared to 2-3 in other countries. Value addition of agro produce in India is expected to increase from current level of 8 per cent to 35 per cent by 2025. Processing activities such as flour making, production of potato chips, spice grinding, cleaning and grading of grains, etc. can be successfully performed in rural areas. The activity can be simple, low budget and to give product of conventional nature with innovative approach. It can also serve as a source of good nutrition at the affordable cost by the local population. Development of enterprises for proper drying, cleaning and grading of spices also, has good potential for value addition.

Cereal processing: Cereal products like flour, grits, pearled grains can be easily prepared and made available for different end uses.

Pulse processing: Pulses can be processed for clean whole pulses (green gram, pea, lentil, Bengal gram), dal, roasted pulses (Bengal gram, Pea), fried and salted pulses (whole or split pea, Bengal gram, lentil, green gram.), cereal-Legume based food mixes–Sattu (cereal-legume based), ready to eat extruded products (cereal-legume based) and ready to eat fried products(pulse flour based).

Fruit and vegetable processing: The raw materials of desired type and quality are not available in fresh form for either consumption or processing. The establishment of cool chain right from farmers' field covering sorting, washing, packaging, safe holding of vegetables in cool chamber. Basically the need is to establish a proper retention, movement and primary processing chain in production catchment for safe product preparation, handling and transportation. Secondary processing units for puree, chips, dehydrated vegetables, etc. can also be the choice.

Soybean processing – enterprise

How people use soybean?: The awareness of nutritional and health benefits of soybean is increasing among the population. It is seen that raw (unprocessed) soybean mixed with cereals is milled and used for food purpose. This approach is not recommended owing to antinutritional factors in soybean. A simple domestic method is suggested which consists of 30 min boiling of soy splits in boiling water, drying and using in proportion of 1: 9 with cereals for preparation of roti, chapatti, poori, etc..

Soybean processing centres: Soybean contains about 20 per cent oil and 40 per cent high quality protein. Supplementation of traditional foods / recipes with 10-20% properly processed soybean is recommended. Properly processed, soybean can be used as an ingredient in variety of food products like bakery, diary, meat, breakfast cereals, beverages, infant formula, and dairy and meat analog. Soy processing centres can serve as a base system for supply of properly processed soybean based nutritious products to population and such availability can be ensured by initiating processing activities in the rural areas, towns and production catchments. Around 400 cottage scale soy enterprises have been established in different parts of the country due to the initiative of Soybean Processing and Utilization Centre established in 1985 at CIAE Bhopal through training of upcoming entrepreneurs for soybean processing at cottage scale for food uses.

Table 1: Technical and Financial Aspects of Production of different Soy food products

Details	Soy paneer (tofu)	Fullfat Soy-flour	Soy fortified biscuits
Cost of Machinery and other non-recurring items with 10% installation charges	Rs. 322740	Rs. 143880	Rs. 85140
Cost of raw materials per month	Rs. 17040	Rs. 52500	Rs. 32813
Salaries/wages of 3 workers per month	Rs. 4750	Rs. 4750	Rs. 7125
Cost of utilities per month	Rs. 796	Rs. 18874	Rs. 3765
Other contingent expenses per month	Rs. 6660	Rs. 8809	Rs. 3980
Sale price of soy fortified biscuits /kg	Rs. 38	Rs. 43	Rs. 48
Fixed capital	Rs. 322740	Rs. 143880	Rs. 85140
Working Capital (15 days)	Rs. 17548	Rs. 50960	Rs. 28610
Total Investment	Rs. 340288	Rs. 194840	Rs. 113750
Total turnover per year	Rs. 570000	Rs. 1290000	Rs. 720000
Cost of production per year	Rs. 435883	Rs. 1063529	Rs. 598200
Net Profit per year	Rs. 134000	Rs. 226471	Rs. 121800

It is necessary to develop a network- of cottage to small-scale enterprises in rural areas for processing soybean, agricultural produce, etc, to extend financial benefits to local / rural population. A modest investment of Rs. 60,000 to 3 lakhs can fetch annual profit of Rs. 1 lakh to 3 lakh per year (Table 1).

Future potential and avenues

The present status and huge production of agro produce available in production catchment does depict the large potential for value addition of raw materials and their by-products.

Specific raw-material supply: In general Indian Agricultural could not serve as a source of quality raw material to the food industry. Indian Farmers can become authentic supplier of specific type of raw material, in a organized way, to the food industry and avail income generation opportunity. This scenario leaves enough scope for new enterprises in this sector.

Coarse grains in public funded nutrition programme: The production of coarse grains (nutra-cereals) is scattered in different states. The demand of the coarse grains is now increasing with time and the ensured availability of these is expected to be the problem in years to come. It is therefore imperative to encourage farmers for enhancing the production of coarse grains. The incorporation of millets and soybean in public funded nutrition programmes may help establish rural enterprises to supply processed raw material for use in the programmes like Mid day meal and ICDS (Integrated Child Development Scheme).

Snack food market: It is increasing rapidly @ 20 per cent per annum and reached a value of Rs 15030 core. This sector may provide good opportunities for enterprises in rural sector.

Organic foods – opportunities: Today, safety and utility value of foods is being given the consideration for manufacture, supply, selection and consumption of foods. If organically produced raw material is organically processed and supported with certification then it may fetch good returns. The farmer is supposed to be the backbone of the organic crop production. The interests of the farmer need to be protected in organized way. It is seen that different state governments encourage the organic production of food raw material but farmers do not get enough premium due to the absence of marketing network / linkages. The value addition expected in the production to consumption chain of organic food raw materials and product is supposed to be of very high order.

Value addition to minor forest produce: Primary processing of minor forest produce is almost untouched area. It has resulted in heavy economic exploitation of tribal people through purchase of raw material at throw away price like exchange of material with salt. Its importance is now being realized and if properly shaped can transform into a dynamic agri-business community.

Opportunities for disabled persons: According to 2001 Census of India 2.13 % of total population, including 9.3 million women (42 % of total disabled persons) were disabled persons and 75 per cent of them live in rural area (www.censusindia.gov.in). The population of disabled persons in India with 2.13 % of 1210 million, for 2011 census, is 25.78 million. India -the agricultural country, among other occupations, can extend very good economic support to the disabled population through selection of appropriate agro – processing activity. The policy initiative for scheme development at Govt. level, The Ministry of Social Justice and Empowerment (www.socialjustice.nic.in), Govt of India, may help realize the potential. The purpose is to extend economic benefit to disabled persons for earning livelihood with self-respect and its sustenance through self-employment in rural / urban area.

Involvement of women: Rural women are mostly involved in post production agriculture activities like processing of cereals, pulses and oil seeds to the extent of 20 to 80 per cent. This aspect further clarifies the scope for women entrepreneurs in agro processing on tiny scale for revenue and employment generation in rural areas and towns with technical and financial empowerment of women. Women with little access to resources can find income opportunities in handling, processing and trading products in cluster of villages or towns. In the form of self help groups (SHGs), women may get good opportunity for supply of primarily processed food raw materials to Mid-Day-Meal programme activity in rural / urban areas.

Other options: Large scale industry can also be established in the production catchment which can facilitate production and processing of specific agro produce to any specified quality product thereby benefitting large number of farmers associated with the activity as a member or contract farmer for any given raw material. Some commercially viable proven examples of small, medium to large scale processing in production catchment are:-

i. Sugar cane processing units for sugar and *Khandsari,*

ii. Tomato and other fruit processing units for puree and pulp manufacture and aseptic packaging,

iii. Wheat and maize processing mills for flour, grits, refined flour, etc.

iv. Rice milling, maize starch, etc.

Examples of Cottage to Small scale are:

i. On farm grape processing units (proven in the Maharashtra State),

ii. On-farm primary processing of fruits and vegetables (proven in the Maharashtra State), Pack-houses for fruits and vegetables to serve as a base unit for cold chain, and

iii. Food grains, oil seed processing units.

Important aspects

Raw-material selection: The selection of raw materials may also depend upon the production locally, nutrition status and requirement of local population and availability of different nutritious low cost alternatives to meet their requirements. This approach, shall certainly contribute in supplementation of income ultimately leading to food and nutrition security improvement.

Equipment selection: The globalization of trade may compel many agro processing industries to rely on imported technology at a high cost. Advantage of such technology may be availed by few who have investment capacity. Majority of agro-produce based enterprises will continue to depend upon indigenous technology and therefore, R & D through public support needs strengthening to serve cottage to small scale food processing sector of the country and of developing world. Variety of processing equipment suitable for cottage / small-scale processing are commercially available. The selection of processing equipment shall depend on the type of food raw material produced in the area and also on food habits of the local population (Table 2).

Table 2: Indicative list of cottage scale food processing equipment

Sl. No.	Equipment	Capacity, kg/h	Use	Cost, Rs.
1	Maize sheller	20-25	shell dry maize cob	60
2	Groundnut Decorticator (with seat)	30-35	Decortication	2400
3	Groundnut Decorticator (Standing operation)	60-70	Decortication of groundnut	2400
4	Grain cleaner cum grader	300-800	Grain cleaning	20000
5	Soybean dehuller	80	Dehusking and splitting of soybean for dal	18000
6	Soy paneer (tofu) plant	200 lit. soy milk or 50 kg Tofu / day	Soy milk preparation	180000
7	Dal mill	100	Dal making	30000
8	Multipurpose Grain Mill	10-20	Milling to flour	19000
9	Potato peeler	50-60	Remove potato peel	17000
10	Potato slicer	40-50	Slice potato	12000
11	Solar Cabinet Dryer	20-25 / batch	Drying	25000
12	Solar Tunnel Dryer	100	Drying	100000

Drudgery reduction and processing: Processing of food crops / grains entitles for value addition of the end product. Each step in processing, irrespective of equipment used or not, adds value to the raw material. The contribution of the equipment is visible only when the time and convenience is taken in to account (Table 3).

Table 3: Drudgery reduction in post harvest operations crops-wheat

Activity / unit operation	Out put, kg/day	
	Manual operation	Equipment
Ground nut decortications	7 – 10	140 – 160
Cleaning – grain	200	1600

The processing unit capacity: The capacity of about 100 - 200 kg per day to 100 kg/hour of which about 50 per cent capacity may be used on custom hire like done by flour mills (atta chakkies). A cottage scale unit for four to five products can be started at an initial investment of Rs. one lakh to earn up to 10 - 15 thousand Rupees per month. Apart from self-employment and income generation, one is empowered to provide employment to needy. Product type may include dry products like cereal flours, soy flour, soy nuts, dal, besan, sattu, wheat grits (dalia), noodles, vermicelli, protein enriched cereal flours, roasted products, etc. After establishment of product in the market products like soy milk, soy paneer may also be added. While deciding the potential activities in Agro processing – region based raw materials and end products should receive due attention.

Cottage scale processing – some aspects: Cottage scale activity is bound to give relatively low recovery of end product compared to large scale unit. However, proper approach can help minimize the losses.

Main disadvantages of cottage scale processing are:

- Low output due to non-availability of efficient machine
- Non availability of skilled workers
- Lack of repair facilities in rural areas
- High energy input needs

The advantages are:

- Employment generation locally
- Checking of migration to cities
- Local processing
- Farm income supplementation

- Low transportation costs
- Nil or minimum adulteration
- Ease of waste disposal
- Pollution control
- Proper by-products utilization

However, the targets are many fold:

i) Minimize losses through adoption of proper approaches for processing and storage,

ii) To provide more employment opportunities

iii) To meet nutritional requirements of population at low cost

iv) Making available good quality raw material to processing units in cities

v) To supplement the farm income to make agriculture sustainable.

Operational problems: In many rural areas, a problem of electricity may have to be faced by the entrepreneurs, however, reorienting their activities matching to the availability in the respective areas may be of help in regular execution of the activity.

Employment potential: It is estimated that Rs. 1000 Crore investment in large food industry provided the direct employment to 54000 persons as against four fold (225000) through cottage scale with same investment in food units.

The support: The following minimal support is required to establish the agro processing activity for self-employment.

i. Identification of proper activity.

ii. Specialised Training for technical know how and selection of processing equipment

iii. Financial support – soft loan

Institutional back-up: Input support of Agricultural Universities in the country, some ICAR Institutes like Central Institute of Post Harvest Engineering and Technology (CIPHET)

Ludhiana and Central Institute of Agricultural Engineering (CIAE) Bhopal may be of significance as nodal institutions for Agro – food processing and related activities.

Policy issues: It is essential to address few questions to arrive at a policy

- Are we to encourage cottage to small units and generate income and employment opportunities in rural areas or only large industry to grow?
- Are the financing institutes required to take interest in encouraging many small enterprises and look for increasing success rate of such enterprises or feel satisfied with financing to one large enterprise and reduce the burden of management ?
- Are we to encourage the financing of agro based cottage to small scale enterprises in rural areas through a dedicated agency like KVIC and or lead bank ?

Accordingly,

- Govt. Schemes (Central / State Govt.), development and promotion of policy for agro processing activity with ease of access may be of significance..
- Development of policies congenial for rural growth orientation to facilitate checking migration to urban areas through:
- Financial provisions – KVIC, lead banks, Ministry of Food Processing Industries (MoFPI), Department of Agricultural and Co-operation (GOI) should be made responsible for encouraging the rural agro processing units.
- Infrastructure support: Govt. Regulatory support of FSSAI, BIS, etc.

Recommendations

The following recommendations are made for realizing Agro produce processing in rural area for employment generation for contribution to sustainable agriculture:-

- The policies be developed to explore the huge employment generation potential of cottage scale food processing sector
- Involvement of women be given due importance in the activity of agro processing.
- Nodal Institutions be identified to extend technical support for agro processing activity establishment to cover aspects like - selection of equipment, assessment of availability of raw material and market potential, product profile, technical empowerment training, finance, Custom Hire of Facility , etc.
- Nutritious products like Extruded Snacks, Soy Suji, SATTU based enterprises be encouraged.
- Enterprises for preparation and supply of micronutrient fortified cereal based food raw materials be encouraged for nutritional improvement of our population.
- Coarse cereal based enterprises be encouraged for innovative products and nutritional advantages.
- Prototypes / equipment developed at research organisations like ICAR, CSIR, etc. be considered for commercial use.
- Specialised training programmes sponsorship to Institutes / Agricultural Universities who have agro processing technologies for empowerment of disabled persons.
- Agro – food processing enterprises be identified as a potential income generation activity for income and employment generation for needy countrymen.
- Encouragement for development and manufacture of small capacity specific agro processing equipment for safe operation.
- Policy development for soft loans through KVIC (Khadi and Village Industries Commission) and possible marketing support.

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Importance of Aquaculture in Alleviating Farmers Poverty and Improving their Economy

A. G. Ponniah and T. Ravisankar

India though has become the fourth largest economy in the world due to a strong economic growth but still has a low per capita income (*Economic Survey,* 2012). The per capita income of India stood at $1,527 in 2011. Between 1980 and 2010, India achieved a growth of 6.2 percent, while the world as a whole registered a growth rate of 3.3 percent. As a result, India's share in global GDP more than doubled from 2.5% in 1980 to 5.5% in 2010. Consequently, India's rank in per capita GDP showed an improvement from 117th position in 1990 to 101st position in 2000 and further to 94th rank in 2009. China, however, improved its rank from 127 to 74 during the same period from 1990 to 2009.

The total number of head count of poor in the country has been estimated at 34.47 crore in 2009-10, as against 40.72 crore in 2004-05. The all India poverty has declined by 7.3% points from 37.2% in 2004-05 to 29.8% in 2009-10. Poverty in rural areas, as per Planning Commission estimates, reportedly declined at a faster pace than in urban cities between 2004-05 and 2009-10 (Economic Times, 19-3-2012). Rural poverty declined by 8% points from 41.8 percent to 33.8 percent and urban poverty declined by 4.8 percentage point form 25.7% to 20.9%. Further, poverty has increased in North-eastern states of Assam, Meghalaya, Manipur, Mizoram and Nagaland and bigger states, such as Bihar, Chhattisgarh and Uttar Pradesh have shown only marginal decline in poverty ratio, particularly in rural areas. Though India is undoubtedly growing at a faster pace, rural poor among the poorest of India are the most vulnerable section with 162% higher level of poverty incidence compared to urban poor as their economic avocation options are limited. Remoteness of locations, poor infrastructure and maximum vulnerabilities to climatic extremities might have led to this.

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For nutritional security also, fish and fishery products are important as they are very valuable source of protein and essential micronutrients for balanced nutrition and good health. In 2009, fish accounted for 16.6% of the world population's intake of animal protein and 6.5% of all protein consumed. Globally, fish provides about 3.0 billion people with almost 20% of their intake of animal protein, and 4.3 billion people with about 15% of such protein. Differences among developed and developing countries are apparent in the contribution of fish to animal protein intake. Despite the relatively lower levels of fish consumption in developing countries, the share contributed by fish was significant at about 19.2%, and for Low Income Food Deficit Countries (LIFDC) it was 24.0%. Fish contributes substantially to the domestic food security of India which has a per capita availability of about 5 kg per capita and average consumption of 8 kg per head for fish eating population. India with enormous resources for aquaculture can effectively make use of developments in aquaculture science for alleviating farmers' poverty and improving their economy along with assurance of nutritional security. In this paper we attempt to review the sector's development status at present and identify the issues of resources, technologies, investments, production, marketing and policy aspects. We will also make a consolidated recommendations and institutional changes and policy needs as felt required for strengthening of the sector.

Importance of aquaculture

India is the third largest producer of fish and ranks second in inland fish production and fifth in shrimp aquaculture in the world. Freshwater aquaculture has a long history in this country and brackishwater aquaculture is of recent origin with less than 200 years of traditional farming and about 40 years of scientific farming systems. Though infantile, the sector has been significantly contributing to the economy and has played a vital role in employment generation, poverty alleviation and infrastructure development in remote coastal locations. The aquaculture sector has provided in situ employment to rural poor and has significantly contributed towards infrastructure development in remote localities inaccessible due to lack of road, electricity and other basic infrastructure facilities. Rural poor and Economically Weaker Sections (EWS) like Women Self Help Groups have benefited from many rural aquaculture techniques like mud crab fattening, farm made feed manufacture and value addition. Large land resources, multiple species resources, a café of culture systems are available and being underutilised which will be described in detail in coming sections.

Large land resources

Aquaculture resources in India include 2.36 million ha of ponds and tanks, 1.07 million ha of beels, jheels and derelict waters plus in addition 0.12 million km of canals, 3.15 million ha of reservoirs and 0.72 million ha of upland lakes that could be utilised for aquaculture purposes. For brackish water aquaculture, India has been blessed with a long coast line of 8129 km distributed in nine coastal states and four Union Territories and the biodiversity of the coastal ecosystem of the country is rich with a wide spectrum of fauna and flora. The country has 3.9 million ha estuaries, 1.2 million ha brackish water area, 2.54 million ha salt affected coastal soils and 8.0 million ha inland saline soils. India is bestowed with vast resources of brackish water areas with 3.5 million ha consists of low lying, barren, unproductive or marginally productive coastal saline lands, swamps etc., India has coastal mangrove areas of about 0.5 million ha. The potential brackish water area suitable for development of brackish water aquaculture is about more than 1.0 million ha. In addition to this, around 8.5 million ha salt affected areas are also available, out of which, about 2.6 million ha area are unsuitable or marginally suitable for agriculture can be utilized for brackish water aquaculture. It is clear evident that with the availability of plenty of physical resources, augmentation of fish production is quite easily possible. Many of these land areas to be developed are under State governments ownership and control and some State fisheries departments initiated the land leasing process which was abruptly stopped after Hon'ble Supreme Court's verdict in 1996. Now with an existence of strong regulatory body Coastal Aquaculture Authority (CAA) backed by a Central act, the potential resources need to be reconciled with applicable rules and norms and permissible areas to be developed. As on date, updated and exact potential area that can be brought under aquaculture is not known and this has restricted effective planning. Use of remote sensing and geographic information system tools will help in this task.

Multiple species resources

While carp forms the most important group of species farmed in freshwater in India and contributes the bulk of the production, it is the shrimp from the brackish water sector which contributes high export value. The three Indian major carps, namely, catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) contribute nearly 90 percent of the total Indian aquaculture production. The three exotic carps viz., silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) form the second important group of species. Although introduction of these exotic carps into the carp polyculture system during early sixties added new dimension owing to their high growth rates and compatibility with our Indian major carps, the low consumer preference in most part of the country has been the major problem for their large-scale adoption. Diversification the freshwater aquaculture systems off late have also introduced high valued catfish species like magur (*Clarias batrachus*) and scampi or freshwater prawns (*Macrobrachium rosenbergii* and *M. malcolmsonii*), of course with moderate success. Introduction of legalized large exotic catfish, *Pangasius sutchi* into the system in recent years, however, has proved to be an important aspect for increasing freshwater pond productivity. Concerted efforts has been made or are being made for development of technologies pertaining to mass-scale seed production of several potential medium carps viz., *Labeo calbasu, L. fimbriatus, L. gonius, L. bata, Cirrhinus cirrhosa, C. reba, Puntius sarana* and *P. jerdoni*; catfish species like *Pangasius pangasius, Mystus seenghala, M. aor, Horabagrus brachysoma* and *Ompok pabda,* and other important live fishes like *Anabas testudineus, Channa striatus* and *C. marulius*, and protocol for their farming (Ayyappan and Jena, 2003).

For Indian brackish water aquaculture, potential cultivable species identified are : 10 shrimps, 8 fin fishes and 2 crab species (Ponniah, *et al,* 2011). But the estimate of Biodiversity Utilisation index (BUI) was very small for India (0.13 on a scale of 0 to 1); it was 0.5 for Taiwan and 0.34 for Thailand (Kutty, 1999). Though the BUI estimate is a crude measure, it does reflect the insufficient efforts of farmers for diversification of fish culture. The low diversity in aquaculture production has reflected in product diversification in seafood exports which was estimated at a Simpson Index Value of 0.593 (Ravisankar *et al*, 2005). Though tiger shrimp (*Penaeus monodon*) has been dominating the sector till last year, recently introduced (in 2009) alien species White leg shrimp (*Litopenaeus vannamei*) has taken strong roots in the last couple of years. Indian white shrimp (*Fenneropenaeus indicus*) is the native shrimp species which is not popular among the farmers due to low gross returns the species offered. CIBA has done pioneering work in species diversification with development of technologies for Asian sea bass (*Lates calcarifer*) seed production and farming and banana shrimp (*Fenneropenaeus merguiensis*) winter culture technology for Gujarat and mud crab (*Scylla* spp) culture. The other fin fishes like mullets (*Mugil cephalus, Liza parsia, Liza macrolepis, Liza tade*) milkfish (*Chanos chanos*), cobia (*Rachycentron canadum)*, pearlspot (*Etroplus suratensis)*, marine ornamentals like spotted scat (*Scatophagus argus)* and saline tolerant *tilapia* spp are considered as prime candidate species suitable for farming in brackishwater systems.

With the increasing trade of ornamental fishes in recent years in the country, there has been increased interest on establishment of ornamental fish breeding and production units all across the country, especially areas adjacent to the metropolitan cities like Kolkata, Chennai and Mumbai due to ready urban market and availability of international airport for both import and export business. Recent years has further witnessed establishment of several breeding units in states like Kerala, Andhra Pradesh, Orissa and West Bengal. While the domestic production and trade of ornamental fishes is largely confined to breeding of live-bearers like guppies, mollies, platys and swordtails, and a few egg-layers like goldfish, angel fish and gouramis, recent years has observed increased efforts on breeding of indigenous species like *Puntius denisonii, P. conchonius, P. fillamentosus* and several others (Ponniah, *et al,* 2008)

In short, enormous potential is available for aquaculture development in India in freshwater, brackishwater and ornamental fish culture sectors.

A suite of culture systems

Diversities of Indian ecosystem provide multiple possibilities for culture systems. Ponds and tanks are the prime resources for freshwater aquaculture. Ponds in eastern India are typically homestead ponds of less than 1 ha in size, while the watersheds in western India are larger covering expanses of between 15–25 ha each. In northern India, open waters with in-flows are common, while southern India has watersheds, termed as tanks, largely used for crop irrigation. Freshwater aquaculture activity is prominent in the eastern part of the country, particularly the states of West Bengal, Orissa and Andhra Pradesh with new areas coming under culture in the states of Punjab, Haryana, Assam and Tripura.

Sewage-fed fish culture and rice paddy-cum-fish culture are two important culture systems practiced in certain areas of the country; sewage-fed fish culture in 'bheries' in West Bengal is an age-old practice.

Paddy-cum-fish culture is undertaken in medium to semi-deepwater rice paddy fields in lowland areas with fairly strong dykes to prevent the escape of cultivated fish during floods, trenches and pond refuges in the paddy fields provide shelter for the fish.

Traditional farming like bheri fish culture in West Bengal, the rice-fish / shrimp culture in pokkali paddy fields of Kerala, ghery fish farming in Chilka lagoon of Odisha and Kazan lands in Karnataka and Goa are the age old systems of aquaculture in India. These are usually polyculture systems with 'trap and hold/crop' mode of stocking the seed from the natural waters during high tide. No external inputs are used. The culture goes about for 6-8 months and productivity varied from 300 to 800 kg/ha in a season depending upon the seed entered in the pond as well as the pond health.

Semi intensive shrimp farming was spreading fast during 1993-95, carrying capacity considerations for responsible aquaculture development lead to 'improved-extensive' model of shrimp farming getting stable in the country.

Mariculture is still low key, involving only a few shellfish species such as green mussel (*Perna viridis*) and brown mussel (*P. indica*) using raft or longline culture methods; Indian backwater oyster (*Crassostrea madrasensis*) using the rack and tray method; and the farming of Japanese pearl oyster (*Pinctada fucata*) by raft culture.

Investments and employment

Agriculture and allied activities contributed for 14.6 percent of National Gross Domestic Product (GDP) in 2010-11 with Agriculture accounting for 12.3 percent, followed by forestry and logging at 1.5 percent and fishing at 0.7 percent. The fisheries sector contributed 0.7 percent of total GDP at factor cost and 5.0 percent of GDP at factor cost from agriculture, forestry, and fishing in the year 2010-11. Fish production increased from 3.8 million tonnes in 1990-91 to 8.29 million tonnes in 2010-11. Fishing, aquaculture, and allied activities are reported to have provided livelihood to over 14 million people in 2010-11, apart from being a major foreign exchange earner. More than 90 % of coastal aqua farms are small farms with less than 2 ha of farm area. Many Women Self Help Groups have successfully adopted aquaculture technologies under the guidance of CIBA. Though full scale shrimp farming may be capital intensive other aquaculture activities like rearing seabass seeds, crab fattening, farm made feed units, value addition of fish are beneficial to weaker economic groups also.

Freshwater aquaculture is a homestead activity in several parts of the country with very low investments, , and besides adding to the nutritional security it also helps in bringing additional income to rural households. Modern fish culture operations are estimated to benefit approximately 830 000 people (FAO, 2012). The rapid growth of the sector has generated huge employment opportunities for professional, skilled and semi-skilled workers for the different support activities such as construction and the management of farms, hatcheries, feed mills, processing units etc. It has been estimated that over 300 000 jobs have been generated in the brackishwater sector alone in the main and supporting areas for shrimp culture. Over the years the cost of aquaculture feed has been increasing which has also given an opportunity for use farm made feed. A farm made feed unit developed by CIBA is under trial with a couple of women self-help groups.

Credit and insurance

Though shrimp farming is capital intensive and offers attractive returns, the shrimp viral diseases make the returns from aquaculture uncertain. The credit agencies are not very positive towards aqua farming and insurance agencies are wary. Even farming related development subsidies from government agencies like National Fisheries Development Board (NFDB) are linked to institutional credit. During the period 2007-11, the Ground Level Credit (GLC) flow for agriculture and allied activities registered a Compound Annual Growth Rate (CAGR) of 20.01 percent. The growth rate in short term credit flow and term loans were 24.52 percent and 12.11 percent, respectively for the five-year period (2006-07 to 2010-11). Sub sector-wise, during 2010-11; High-tech agriculture witnessed the highest annual growth of 62.95 percent, followed by Farm Mechanisation (25.36%), Animal Husbandry (24.49%) in GLC flow over 2009-10. Unfortunately the fisheries recorded an annual growth rate of only 4.15% (NABARD Annual Report 2011-12). Ground Level Credit to aquaculture, to broaden the scope of production of fish to coastal aquaculture, the outlay in 2012-13 is being stepped up to Rs. 500 crore (Union Budget 2012-13). Currently, as most of the farmers fail to get institutional credit, they also become ineligible to get subsidies. Hence the mandatory link between institutional credit and subsidies needs to be broken.

In the insurance front, though aquaculture crop insurance is said as available by one public insurance company (Oriental Insurance Company, 2013) (http://www.orientalinsurance.org.in/ Aquaculture-Shrimp-Prawn-Insurance- Policy.html), the premium charged is high and access is limited. MPEDA has taken an initiative to provide Insurance to cluster farms under NaCSA supervision in 2010-11 with NFDB funding support. The pilot scheme is being proposed to be developed to a full fledged ‘aquaculture crop insurance ‘insurance’ by NFDB and a series of consultations are underway.

Market and trade

Freshwater carp and shrimp from brackishwater are the principal aquaculture species produced in India, almost the total quantity of finfish produced by aquaculture is consumed on the domestic market, while shrimps and freshwater prawns are mainly exported. Main areas of consumption for freshwater fish are in West Bengal, Bihar, Orissa and north-eastern India, cultured brackishwater shrimps are destined mainly for export. While people of eastern India prefer freshwater fish, people from southern Indian prefer marine fish and thus depend on the capture fisheries. As the second most important producer of freshwater fish after West Bengal, Andhra Pradesh markets the bulk of its produce in the eastern and north-eastern states of India through an organised and established marketing network. Insulated trucks carrying ice are the principal means of transport over longer distances which can be over two thousand kilometres. The post-harvest processing of aquaculture produce other than for shrimps and freshwater prawn is almost non-existent in the country. The government has no regulatory control over the domestic marketing system for aquaculture produce and the price is influenced by supply and demand, furthermore, no certification system is available for the sale of the fish on the domestic market. As fresh or chilled fish are mostly desired by domestic consumers, facilities for live fish marketing and mini cold storages near major consumption areas need to be created. NFDB has few schemes for modernising domestic markets which need to be utilized by State fisheries departments for creation of these facilities.

The institutional framework

The Ministry of Agriculture of the Government of India has a Department of Animal Husbandry and Dairy, with a Division of Fisheries as the nodal agency. This agency is responsible for planning, monitoring and the funding of several centrally sponsored development schemes related to fisheries and aquaculture in all of the Indian states. Most of the states have a separate Ministry for Fisheries or else it remains within the Ministry of Animal Husbandry. All states have well-organised fisheries departments, with fisheries executive officers at District level and fisheries extension officers at Block level, who are involved in the overall development of the sector, however, the administrative structure at state levels varies from state to state. Centrally sponsored schemes like the 422 FFDAs cover almost all districts in the country and the 39 BFDAs in the maritime districts have also contributed to aquaculture development.

The Indian Council of Agricultural Research placed within the Department of Agricultural Research and Education, under Ministry of Agriculture, has a Division of Fisheries, which undertakes the R&D on aquaculture and fisheries through eight fisheries research Institutes. There are about 400 Krishi Vigyan Kendras (Farm Science Centres) in the country, operated through

State Agricultural Universities, ICAR Research Institutes and NGOs, most of which also undertake aquaculture development within their scope of activities.

The MPEDA, functioning under the Ministry of Commerce besides its role in the export of aquatic products also contributes towards the promotion of coastal aquaculture. MPEDA has NaCSA (National Centre for Sustainable Aquaculture) and RGCA (Rajiv Gandhi Centre of Aquaculture) under its control. Many other organisations and agencies also support or conduct R&D in the subject and include the Department of Science and Technology; Department of Biotechnology, University Grant Commissions, NGOs like MSSRF, PREPARE and CARE and private industries have specific programmes on aquaculture related activities.

Regulations

The Indian Fisheries Act (1897) is the oldest legal instrument related to fisheries and aquaculture penalizes the killing of fish by poisoning water and by using explosives. This law, under which the states have been empowered to enact their Acts, is an umbrella Act providing for certain matters relating to Fisheries. Under this empowerment, the states have enacted Acts from time to time to regulate inland fisheries and marine fisheries as per their requirements. Many of these are related to fishing. All maritime states have formulated state wise land lease policies which are defunct as now, after Hon'ble Supreme Court's 1996 verdict for proper regulation of shrimp aquaculture development in the country. The traditional system of brackishwater aquaculture (bheries, pokkali fields, khazan lands etc.) is governed and regulated by the individual State's land use policies and customary rights of owners and tenants. Coastal Aquaculture Authority Act 2005 clearly bestows legal powers on authority for stringent regulations on aquaculture development and farming.

A Model Bill on Inland Fisheries and Aquaculture was finalized by Government of India in 2010. Under this bill, all inland fishery resources are have been considered . Regulation of craft & gears, conservation of stocks, leasing and licensing of open waters , incentives for aquaculture, fish seed certification, use of chemicals andantibiotics in aquaculture, health monitoring and disease reporting and environmental and human health hazards are also addressed to.

Though not comprehensive, large number of regulatory legal instruments is available covering many areas of aquaculture in India. However a national aquaculture policy with comprehensive legal frame work coverage for aquaculture inputs, production factors and produce sale, protecting farmers and consumers, is yet to take shape in the country.

Policy options for responsible aquaculture development

Multi-species and disease free seed production, development of appropriate live feeds, formulated fish diets would be useful for stronger aquaculture production growth. Disease diagnostics and management science need to be further improvised and diagnostic kits that could be used at farm level need to be developed. Development agencies like MPEDA, NFDB and State Fisheries Departments can initiate supportive policy options for shrimp/ fin fish farming in India. A few of the available policy options are listed below:

1. A policy document that would guide the states to follow a decentralised aquaculture plan that ensures equitable and environmentally sustainable development and which addresses the issues of farmers poverty and economic wellbeing to be developed.

2. In a predominate agriculture country like India with relatively less funding to fisheries in relation to its potential for addressing poverty alleviation and improving economic wellbeing, greater funding support needs to be given.

3. The state must take upon the task of maintaining the common water supply resources essential for aquaculture development and specific schemes under NAREGA to be developed for this.

4. The area available for aquaculture development in each state to be clearly delineated using Remote Sensing and Geographic Information System tools. This database to be combined with the multi sectoral demand for water, road and other infrastructure and socio economic conditions of aquafarmers so that a realistic aquaculture master plan for development can be developed. Based on this district level aquaculture

database and development plans to be developed with the involvement of local community and district officials.

5. The institutional framework of State Fish Farmer Development Agencies be strengthened and the aquaculture component of ICAR Krishi Vigyan Kendra be further developed.

6. Multi-locational trials of new aquaculture species and technologies to be taken up by fisheries colleges and ICAR fishery institutes with NFDB funding.

7. To promote adoption of new species and farming practices, hatcheries and feed mills under PPP mode with initial infrastructure subsidy backup needs to be established. For the most widely cultivated species quality brood banks with genetically improved and Specific Pathogen Free(SPF) stocks be established.

8. From the view of low production cost and environmental sustainability, culture of species low in the food chain and polyculture to be extensively promoted in traditional shrimp farming areas in states like Kerala, West Bengal and Orissa.

9. Special packages with focus on finfish farming to revive shrimp ponds in disuse which is estimated to be around 30000 ha (in 2012) in Andhra Pradesh, Orissa, West Bengal and Kerala states to be implemented.

10. Realising the importance of feed and to reduce its share in the productions cost the use of farm made feeds using locally available ingredients and minimum machinery be promoted.

11. Mini cold storage facilities 10 to 20 tonnes fish capacity may be established in farming areas under the control of farmers' associations for storing and releasing the fish to domestic markets in sequential manner.

12. Special schemes for with farmer societies to set up vertically integrated aquaculture production companies by themselves or in association with entrepreneurs be developed

13. The on-going efforts by NFDB to modernise fish markets to be strengthened and specific measures undertaken to develop the domestic markets
14. NFDB should delink subsidy from bank credit , alternatively NFDB should promote culture of various species under contract farming by private agencies or by State Fisheries Development corporations
15. MPEDA may facilitate live fish export to Southeast Asian countries for better market price through air/sea ports
16. MPEDA may explore export new markets in European union where large market exists for whole fish and fish fillets

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Role of Indigenous Livestock for Sustainable Food Production under Climate Change Scenario

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Climate change is any significant deviation in the measures of environmental parameters happening around over the extended period of time. The climate change includes sudden major changes in temperature, precipitation, or wind patterns vis a vis the normal conditions during the same period over the years. Under the present paradigm of climate change, global warming is the major issue that has arisen because of ongoing rise in global average temperature near Earth's surface. Increasing concentrations of greenhouse gases like Carbon dioxide, nitrous oxide, methane in the atmosphere that ultimately is causing climate patterns to change abruptly, thus affecting human and animal life both directly causing disease and heat stress as well as indirectly by increased incidences of natural disasters viz. hurricanes, cloud bursts, floods and other disasters. So far human societies have adapted to the relatively stable climate we have enjoyed since the last ice age which ended several thousand years ago but now are feeling the consequences of global warming. A warming climate would bring changes that can adversely affect our water supplies, agriculture including livestock productivity, power and transportation systems, the natural environment, and even our own health and safety.

Earth's average temperature has risen by 1.4°F over the past century, and is projected to rise another 2 to 11.5°F over the next hundred years. These small changes in the average temperature of the planet can translate to much larger and potentially dangerous shifts in climate and weather. Rising global temperatures have often been accompanied by changes in weather and climate. Some places have experienced intense

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rainfall, resulting in more floods while at other places no rainfall causing droughts, or, as well as more frequent and severe heat waves. The planet's oceans and glaciers have also experienced some big changes - oceans are warming and becoming more acidic, ice caps are melting, and sea levels are rising. As these and other changes become more pronounced in the coming decades, they are likely to present challenges to our society and our environment.

Indigenous livestock under climate change

Traditionally, India has been a mega bio-diversity centre and rearing of domesticated animals was practiced since time immemorial. Almost all the major livestock species including cattle, buffaloes, sheep, goats, pigs, camels, horses, donkeys, yak and mithuns are found in India. Apart from poultry, domesticated species of avian such as ducks, geese, quails, turkey, pheasants and partridges also exist in India. In domesticate species there are over 140 well documented and defined breeds, whereas per FAO watch list there are about 220 breeds. The existence of wild ancestral species of sheep like *Ovis musimon*, O. *vignis,* O *orientalis*, O.*amon*, wild goats like Himalayan Ibex, Himalayan Tahr, Nilgiri Tahr and Markhors, Wild Yaks(*Bos mutus*), Gaur (*Bos gaurus*), Red Jungle Fowl and Snow Partridges in natural habitat, further make this subcontinent a treasure of farm animal biodiversity.

Tharparkar, Sahiwal and Rathi breeds of cattle and camels are indigenous to hot arid deserts where they experience excessive heat during day time in summer when ambient temperature may be as high as 48-50 ^{o}C. While the same animal stay in open in night when the outside temperature may be as low as 15-18 ^{o}C. Like-wise yak (*Bos grunniens*) is found in cold arid desert in upper Himalayas where day temperature may be 35-38 ^{o}C and night temperature may be sub zero. These highly adapted germplasm have fixed genes and alleles that give them sustenance in world's most inhospitable climate and can serve as excellent experimental model for studies related to animal production under changing climate. It is imperative to identify such alleles and gene combinations in our indigenous livestock breeds and populations and the develop strategies for gene based introgression in other populations which are prone to susceptibility to impending climate change.

Impact of climate change on livestock

Climate change comes as an additional factor affecting a livestock sector that is already highly dynamic and facing many challenges. Important objectives of livestock genetic resource management include ensuring that animal genetic resources (AnGR) are effectively deployed to meet these challenges (i.e. are well matched to the production environments in which they are kept) and that the genetic diversity needed to adapt production systems to future changes is maintained. Climate change is likely to create a number of problems in many areas of animal husbandry (housing, feeding, health care, etc.) and threaten the sustainability of many livestock production systems and their associated AnGR. At the same time, many of the specific challenges associated with climate change (high temperatures, disruptions to feed supplies, disease outbreaks, etc,) as well as the general unpredictability it brings to the future of the livestock sector, highlight the importance of retaining diverse genetic options for the future.

Livestock sector is affected by climate change and also contribute in global warming to some extent. Climate change affects livestock both directly and indirectly. The direct effects are due variation in air temperature, humidity, wind speed and other climate factors that influence animal performance viz., growth, milk production, wool production and reproduction. The impact of climate change on animal production has been due to differential availability of feed grain, pasture and forage crop production and quality, health, growth and reproduction and, disease and their spread under abrupt climate change. Animal health may be affected by climate change in four ways: heat-related diseases and stress, extreme weather events, adaptation of animal production systems to new environments, and emergence and re-emergence of vector borne and other infectious diseases.

Thus, an increase in air temperature, such as that expected in different scenarios of climate change, would affect directly animal performance by altering the animal heat balance. There are four modes of energy transfer: radiation, convection, evaporation, conduction, which is governed by several physical parameters control heat transfer by different modes. Air temperature affects energy exchanges through convection and evaporation. When temperature increases, evaporation becomes the most important way of heat loss, since it does not depend on a temperature gradient. Therefore combination of temperature and humidity acquire more relevance, since humidity enhances temperature effects. Therefore, it is important to evaluate the environment, from the heat stress stand-point, through the temperature humidity index (THI). Dairy cattle show signs of heat stress when THI is higher than 72. The comfort limit depends on level of production, type of germplasm and its longevity under given conditions. Animals presenting higher level of production are more sensitive to heat stress. It is not only intensity of stress, but also the length of the daily recovery period is important in determining animal responses to climatic stresses. They fail to dissipate the extra heat load accumulated during days when there are several hours with THI well above the comfort limit, and little opportunity to recover.

Climate change is likely to lead to changes in disease epidemiology, severity of outbreaks and spread to other areas. Precise effects of climate change on disease profile are difficult to predict, but combined with problems in the sustainability of some conventional disease control programmes, climate change-related effects are likely to increase the importance of genetic resistance and tolerance to diseases. Changes in the distribution and incidence of diseases that kill large numbers of animal or induce culling measures for disease control may pose additional threats to animal genetic resources diversity.

Climate change may affect the availability of feed resources within land-based production systems. The loss in biomass production due to drought in some cases often threatens the sustainability of livestock. The poor farmers can adapt to the local scale effects of climate change to some extent but feed supply by commercial producer is also affected due to dependence on world feed markets and that is again vulnerable to the effects of climate change, especially on prices. Sustainability of livestock especially, the exotic breeds or their crossbreds depends on better feed and fodder resources in adequate quantity is influenced more critically than the indigenous ones. The indigenous breeds have lesser feed/fodder requirements, able to utilize coarser feed/ fodder resources and can graze on meagre grazing resources that too when the ambient temperature is high. Therefore, the types of germplasm, their adaptability under different climate regimen are keys for sustainability especially under impending climate change.

Studies on impact of climate change in Indian livestock

The vulnerability of livestock to climate change has hardly been documented in India. Isolated experimental studies have been conducted on effects of season and climate on production, performance and other physiological parameters of dairy animals. From these studies it has been revealed that milk yield of crossbred cows in India (e.g., Karan Fries, Karan Swiss and other Holstein and Jersey crosses) are negatively correlated with temperature-humidity index. The influence of climatic conditions on milk production has been also observed for local cows which are more adapted to the tropical climate of India. The estimated annual loss at present due to heat stress among cattle and buffaloes at the all-India level has been estimated to 1.8 million tonnes, that is nearly two per cent of the total milk production in the country.

Heat stress has been found to have detrimental effects on the reproduction of buffaloes, although buffaloes are well adapted morphologically and anatomically to hot and humid climate. The thermal stress on Indian livestock particularly cattle and buffaloes have been found to decrease estrus expression and conception rate. The length of service period and dry period of all dairy animals was found to be increased from normal during drought. The outbreak of the disease has often been correlated with the mass movement of animals which in turn is dependent on the climatic factors. The higher incidence of clinical mastitis in dairy animals during hot and humid weather may be due to increased heat stress and greater fly population associated with hot–humid conditions

The preliminary assessment of impact of climate change and temperature rise on milk production of dairy animals indicate that temperature rise due to global warming will negatively impact milk production to about 1 .6 million tonnes in 2020 and more than 15 million tonnes in 2050. The Northern India will experience greater impact of global warming on milk production of both cattle and buffaloes during 2040-2069 and 2070-2099. The annual loss in milk production of cattle and buffaloes due to thermal stress in 2020 will be about 3.2 million tones milk.

Mitigation strategies

Since climate change could result in an increase of heat stress, all methods by which animals can cope with heat stress or alleviate the impacts of heat stress to mitigate the impacts of global change on animal responses and performance need to be assessed. Three basic management schemes for reducing the effect of thermal stress have been suggested: (a) physical modification of the environment; (b) genetic development of less sensitive breeds and (c) improved nutritional management schemes.

Physical modification of the environment

The different methods of environmental modification include: shades, ventilation, combination of wetting and ventilation. Providing shades to livestock is the simplest method to reduce the impact of high solar radiation. Shades can be either natural or artificial. Tree shades have proved to be more efficient. In traditional livestock rearing, animals are herded under the shade of trees in pasture or in forests during peak summer hours. When enough natural shade is unavailable, artificial structures may be constructed. Different aspects concerning design and orientation of shades have been published. Shades are effective in reducing heat stress in the dairy cow. Animals presented lower afternoon rectal temperature and respiration rate, and yielded more milk and protein when provided adequate shade. The artificial shade structure using heat proof materials may not differ from tree shades, in terms of the effects on animal well-being.

Increase in air movement is an important factor in the relief of heat stress, since it helps heat loss due to air convection especially under high ambient humidity leading to evaporative cooling. Wherever possible, natural ventilation should be maximized by constructing open-sided constructions. Forced ventilation, provided by fans, is a very effective method, if properly designed. An effective way of cooling cattle is spray evaporative cooling. There are several methods available: mist, fog and sprinkler systems. However, the single use of a sprinkler and fan system, for 30 minutes before milking, has proved to be useful to relieve dairy cow's heat stress.

Under current climate, average milk losses for cows with no shade represent 3.3% of annual production. By the year 2030, milk loss for those same cows could increase to 4% of annual production. By 2070, the milk loss would be 6% of annual production. Hence, benefits of adopting shade and sprinklers; milk losses under current climate can be reduced to 0.8% of annual production and a further 2.5% improvement on having shelter. In 2030, adoption could restrict losses to 1% of annual production. Finally, in 2070, milk losses would be reduced to 3 to 4% of annual milk production, by installing environmental modifications.

Genetic development of less sensitive breeds

Now it is well documented that Indigenous livestock breeds are resistant to many tropical diseases. The greater heat and water scarcity tolerance make them ideal germplasm for their wider use for production in hot and resource poor agro climatic zones besides their rich gene pool for introgression in high producing breeds from developed countries. Genetic improvement of animals for feed use efficiency and reducing methane yield may also enable emission reduction without compromising productivity. The strategies should be to explore all the livestock breed populations keeping following points in to consideration.

- Documentation of indigenous breeds for heat tolerance, disease resistance, adaptation to poor diet, etc. and their comprehensive evaluation of performance and use of animals in specific production environments;
- Phenotypic characterization studies on Animal Genetic Resources (AnGR), the surveys should have data entry on all phenotypic traits specifically;
- Improving knowledge and awareness of, and respect for, local and indigenous knowledge relevant to climate-change adaptation and mitigation;
- Identifying potential climate change-related threats to specific AnGR, ensuring that long-term environmental threats are monitored and that urgent action is taken to address immediate threats from climatic disasters to save small populations at severe risk;
- Modelling the future distribution and characteristics of production environments, to support the assessment of threats and the identification of areas that may be suitable for particular breeds in the future;

- Improving knowledge of breeds for their current geographical distributions and to facilitate planning of climate-change adaptation measures and AnGR conservation strategies;
- Improving the availability of the above-described knowledge, including via DAD-IS and other AnGR information systems.

Improved nutritional management schemes

The effects of climate change on livestock production can be mediated through change in feed resources and feeding schedules. It is known that feed resources can have a significant impact on livestock productivity, the carrying capacity of rangelands, the buffering ability of ecosystems and their sustainability, prices of grains, trade in feeds, changes in feeding options, grazing management and ultimately the control on greenhouse gas emissions. It is now well documented that increased temperatures cause more lignifications of plant tissues and therefore reduce the digestibility. This would lead to reduced nutrient availability for animals and ultimately to a reduction in livestock production and also have impacts on methane emission from livestock. Micro-level adaptation options, including farm production adjustments such as diversification and intensification of crop and livestock production; changing land use and irrigation; and altering the timing of operations can have significant impact on ramification of release of greenhouse gases from livestock excreta.

There are considerable opportunities to reduce the methane emissions per animal by individual and herd management changes that reduce the proportion of energy spent in maintenance. Maximised fecundity, health and maximising daily product output by provision of ad libitum high digestibility feed or specific supplementation for enhancing digestibility of coarse feeds and fodders. Reducing total emissions (kg/d) rather than simply emission intensity (methane/product) from the herd or flock will require reduction in animal numbers or implementing mitigation strategies such as the inclusion of fats or oils in the diet. Potential exists to reduce emission without restricting animal performance by grazing pastures of lesser tannin levels or by supplementing with oils or white cottonseed and by some small supplementations of tannin and saponins.

Pasture quality, supplementation and selection for NFI are potential means of reducing the emissions intensity and total methane emissions from livestock. Efficiency of the whole herd or flock can also be improved by further increasing productivity of stock and minimising the proportion of consumed energy utilised in maintenance.

Conclusion

There is a serious threat of climatic change (in the form of severe droughts, floods, intense rainfall, and landslides) apart from global warming undermining development programmes when millennium development goals are aimed at reducing poverty. Climate induced disasters directly affect the livelihood of the farmers as the livelihood of farmers is based on agriculture and animal husbandry. Although, reducing number of heads of livestock can reduce the emission of greenhouse gases but this is hardly possible under the present livestock-agricultural production systems. Since livestock is and will continue to play a very important role in rural economy, it is necessary to find suitable alternate solutions to reduce the ill effects of climate change on livestock production.

The climate change could affect animal production and well-being, especially because of increases in air temperature. However, the knowledge of animal responses to heat stress during the hot months in several areas of the world, as well as during extreme heat events, may be used to evaluate the impacts of global change. Some current practices and adoptions to reduce heat stress in dairy cows, such as shades, sprinklers and ventilations will be suitable for mitigating climatic change effects if the economics of heat stress management do not change radically. However, farmers are not quite aware about the impacts global warming can produce in their operation. Therefore, good research work is needed to help them take strategic and tactical decisions. The research programmes needs to be developed to prioritize the issues in agriculture and livestock production that need to be tackled first, keeping their impact on climate changes.

National Initiative on Climate Resilient Agriculture (NICRA) launched during February 2011 by Indian Council of Agricultural Research (ICAR) with the funding from

Ministry of Agriculture, Government of India has three major objectives of strategic research, technology demonstrations and capacity building. Assessment of the impact of climate change simultaneous with formulation of adaptive strategies is the prime approach under strategic research across all sectors of agriculture, dairying and fisheries. Evolving climate resilient agricultural technologies that would increase farm production and productivity *vis-à-vis* continuous management of natural and manmade resources constitute an integral part of sustaining agriculture in the era of climate change.

Mixed Farming for Sustainable Livelihood of Small Farmers in India

Narayan G. Hegde

With about 35 to 40% of the population living in poverty, livelihood security for the rural poor continues to be a cause of concern in India. Indian economy is heavily dependent on agriculture even today because about 65% of the population is living in rural areas and over 80% of them are dependent on agriculture and allied activities for their livelihood. Out of the total 129.22 million land holders in the country, 64.8% are marginal holders who own less than 1 ha and 18.5% families are small farmers owning between 1 and 2 ha. More than 50% of these families are located in arid and semi-arid regions, where the rainfall is scanty and erratic. These farmers have been growing drought tolerant food crops, mostly millets and pulses with very low investment in improved seeds, fertilisers and plant protection measures, resulting in poor yields and low returns. Fragmented land holdings, heavy depletion of soil productivity, inefficient use of water resources, out-dated agricultural production technologies, unavailability of agricultural credit and lack of infrastructure for post harvest management and marketing of agricultural produce, are the other factors which further suppress their agricultural production. Unfortunately, these regions have also been neglected by the scientific and business communities in introducing new technologies, high yielding varieties which are resistant to drought and developing necessary infrastructure as well as support services to boost agricultural production and value addition. Due to low agricultural productivity, these small and marginal farmers as well as about 15 to 18% landless families living in rural areas, are unable to generate remunerative employment and about 40% families are forced to live in poverty.

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For these small holders and landless, livestock has been a source of supplementary income. However, over 75% of the animals are uneconomical due to severe genetic erosion, inadequate feeding and poor veterinary care. With lower crop and livestock productivity, the employment opportunities in the farming and other related sectors are reduced further, leading to reduction in farm wages, seasonal employment, malnutrition and migration.

With lack of food security, poor families are compelled to migrate to cities in distress, keeping their agricultural lands fallow. Such barren lands accelerate soil erosion, run off of rain water, resulting in floods, siltation of water bodies and loss of biodiversity and thereby contributing to global warming. In the absence of efficient soil and water conservation, there will be a severe reduction in the ground water table, accelerating the process of denudation of the eco-system and shortage of drinking water. Distress migration will also deprive the women and children of their basic needs such as shelter, safe drinking water and health care, which will affect their quality of life. The children will discontinue their education and end up as child labour and illiterate unemployed youth of the future. Thus, improving the agricultural productivity of small land holders can play a key role in ensuring food security and improving the quality of life in the country.

Indian Green Revolution for Food Security

Realising the urgency of enhancing food production, the Government of India had launched the Green Revolution programme in the sixties, through introduction of high yielding varieties and coordination among organisations engaged in agricultural development. Although Green Revolution was successful only in Punjab, Haryana and parts of Uttar Pradesh and Rajasthan, this small region could ensure food security for the entire nation. Their major focus was on development of infrastructure for backward and forward linkages for cultivating high yielding varieties of paddy, wheat, maize crops and oil seed crops to some extent. As a result of Green Revolution, the food grain production increased from 82 million tons in 1960 to 176.4 million tons in 1990 and to 241.56 million tons in 2010. The positive impacts of Green Revolution continued till the 1990's. Subsequently, there was a decline in the growth of agricultural production, from 10-12% during the peak of the Green Revolution to 2.3% during the Tenth Plan Period (Govt. of India, 2011). Cultivation of high yielding varieties demanded higher doses of chemical fertilisers, pesticides, more diesel and electrical power to pump water for irrigation. The cost of these three inputs contributed to 15% of the total cost of inputs in 1970, which increased to 55% in 1994 and to over 80% in 2005. Increasing use of these inputs was no more economical and in the absence of newer technologies, the growth in agricultural production reduced drastically to less than 2%, which had an adverse effect on the purchasing power of the poor, due to reduction in employment opportunities and drop in wage rates. Most of the other regions which have not benefitted from Green Revolution, continue to suffer from low crop yields, resulting in unemployment, insecure livelihood and poverty, even today.

Strategy for Development of Rainfed Areas

While the regions experiencing stagnation in agricultural production after 3 - 4 decades of Green Revolution, require a special package, which includes scientific crop rotation, efficient water use and increased use of organic nutrients, the problem of low productivity in other areas which are dependent on rainfall for agricultural production, needs to be addressed with an innovative approach to enable the marginal and small farmers to sustain their livelihood. Some of the important recommendations for rain-fed areas are effective soil and water conservation through watershed development, increased use of organic nutrients, introduction of drought tolerant and short duration crops, efficient use of available water resources through micro-irrigation and mulching, timely tillage operations to conserve moisture and control weeds, development of wastelands through tree-based farming and introduction of appropriate farm tools to improve the efficiency of labour. Inspite of the above measures, it will be extremely difficult for the marginal farmers to depend only on crop production for their livelihood and hence, livestock can make significant contribution to bring them out of poverty.

Small and marginal farmers as well as the landless have been traditionally maintaining different species of livestock as a reliable source of income and cash reserve in times of emergency. However, in the absence of superior quality germplasm and lack of technical support to improve the productivity of livestock, most of them have been generating meagre income from livestock. Unable to cope up with their needs, these farmers try to increase their herd size, while causing pressure on fodder and feed resources and contributing to green house gases.

Therefore, the challenge is to address the problems of marginal farmers by improving the productivity of rain-fed agriculture and livestock owned by them, to enable them to enhance their income, while conserving the denuding natural resources and the environment. Such a model of promoting livestock development with agriculture, known as mixed farming, has several advantages such as efficient use of byproducts like crop residues as animal feed and dung as manure, fodder trees grown on field bunds as wind breaks as well as source of fodder, bullocks for tillage operations and efficient use of spare time to manage both the activities, without any demand for labour from outside. To ensure the success of mixed farming, it is necessary to improve the productivity of the livestock and develop a sustainable land use plan depending on the soil productivity and domestic needs. As animal husbandry demands a large quantity of fodder, low productive land can be profitably used for fodder production with very remote chances of failure. The programme should also include the development of efficient value chains, which will include small farmers as the key stakeholders.

Livestock in Rural Economy

Animal Husbandry is the main source of livelihood for small farmers who are deprived of fertile land and assured source of irrigation. As per the census of 2007, out of 528 million heads of livestock in India, there were 199 million cattle, 105 million buffaloes, 141 million goats, 72 million sheep and 11 million pigs. Cattle represented over 37% of the livestock population. While farmers having access to fodder resources, prefer cattle and buffaloes, the landless prefer to maintain sheep, goat and poultry. India ranks first in cattle and buffalo population, second in goat, third in sheep and seventh in poultry (Table1). Although the population of livestock during the last 10 years has been stable in the range of 485 million, the buffalo population has increased by 8.91%, while the cattle population has reduced by 6.89%. There has been a significant increase in the population of goats during the last five decades, which is attributed to the decrease in the size of land holdings and persistent drought caused by erratic monsoon, forcing many small farmers to shift from large animals to small ruminants.

Table 1: Livestock Population in India

Sl. No.	Species	Livestock Census		Growth Rate (%)
		1997	2003	2003 over 1997
1.	Cattle	198.9	185.2	-6.89
2.	Buffalo	89.9	97.9	8.91
3.	Sheep	57.5	61.5	6.96
4.	Goat	122.7	124.4	1.38
5.	Other Animals	16.34	16.05	-1.77
	Total Livestock	**485.4**	**485.0**	**-0.08**

Source: Livestock Census, Department of Animal Husbandry & Dairying, Ministry of Agriculture.

Cattle and buffaloes are the major species maintained by all sections of the community and unlike other natural resources, they are well distributed among small and large land holders. They are ideal for mixed farming because of their valuable contribution to human nutrition (milk and butter fat), plant nutrition (farmyard manure) and energy (bullock power). The present breedable bovine population under organised breeding programme is 113.61 million, which includes 12.62 million crossbred, 51.13 million indigenous cattle and 50.28 million buffaloes. India also leads in milk production, with 110 million tons/year. The value of output contributed by livestock in 2003 - 04 was Rs. 164,509 crores, of which Rs. 110,085 crores (66.92%) was from milk. Livestock has also been providing gainful employment all-round the year, to over 16 million people, of which 70% are women. Milk production accounts for 5.86% of the GDP while the total contribution from Animal Husbandry is 9.33%.

India possesses a good number of recognised breeds of cattle, which represent less than 15% of the total cattle population. These are classified into milch breeds, draft and dual purpose breeds (Table 2). Our milch breeds such as Gir, Sahiwal, Red Sindhi and Tharparkar were popular even in other countries but their major drawbacks were productive and reproductive inefficiencies. The bullocks of these breeds were very heavy and slow. There are many draft breeds, but the cows of these breeds are low milk yielders, not adequate even to feed their calves. Except for 10 - 15% of cows of good milch breeds, the rest of the cattle yield about 200 - 350 kg milk per lactation. Hence, even these elite breeds are being neglected by farmers. There has been no scope for selection by culling due to sentimental and legal restrictions on cow slaughter. Generally, these animals have been surviving on crop residues and free grazing on village forests and community pastures, while only the working bullocks and high milking cows were temporarily fed with supplementary concentrate feed. Most of these animals maintained by both rich and poor farmers, have been receiving vaccinations and veterinary services, free of cost, from the Government. Thus, farmers had an incentive to expand their herd size without any financial burden, while posing a serious threat to the environment and eco-system. To improve this status, it is necessary to adopt a scientific approach to formulate the cattle management policy, covering the conservation of native breeds, improvement of non-descript cattle, health care services and management of community pastures and grazing. Sheep and goat husbandry, piggery and fishery also have good potential to generate gainful employment in selected areas, provided, the farmers engaged in these activities are supported for backward and forward integration.

Table 2: Important Indian breeds of cattle

Breeds	Names
Milch Breeds: Average milk production: above 1500 kg/lactation	Gir, Sahiwal, Red Sindhi, Tharparkar
Dual-purpose Breeds : i. Average productivity breeds : Average milk production between 1000-1500 kg/lactation ii. Low productivity breeds: Average milk production less than 1000 kg/lactation	Haryana, Kankrej, Rathi, Minari, Ongole and Dangi Mewati and Deoni
Draught-Purpose Breeds: Average milk production less than 500 kg/ lactation	Nagor, Bachaur, Malvi, Hallikar, Amritmahal, Khillar, Bargur, Panwar, Siri, Gaolao, Krishna Valley, Kankatha, Kherigarh and Khangayam

Source: Anonymous, 1997.

Performance of dairy cattle

In spite of achieving the highest milk production in the world, the performance of our cattle has been extremely poor. It can be observed from Table 3 that the average milk yield of cattle in India is far below the yield in other countries. No doubt, the average milk yield of cattle has increased by 100% over 25 years, between 1965 and 1993, but it is still less than 25% of the yield in Europe.

Table 3: Yield of milking cows in different countries

Country	Average Yield (Kg/Lactation)	
	1961-65	1993
Asia	512	1125
India	428	987
Japan	4193	6092
Israel	4625	9291
Europe	2682	4233
France	2552	5289
Denmark	3739	6273
U.K.	3477	5462
North America		
Canada	2852	5938
U.S.A.	3519	7038
Oceania	2364	3508
Australia	2112	4451

It can be observed from Table 4 that the average milk yield of indigenous breeds of cattle has been around 1.98 litres as compared to crossbreds (6.75 lit) and buffaloes (4.50 lit). The above yield of indigenous cattle does not include the yield of draft breeds and nondescript cows which are hardly milked due to low yields. However, they compete for fodder and feed, resulting in huge shortage of feed resources. The future challenge is to cope up with the growing demand for milk without increasing the livestock population, amidst the shortage of fodder and feed resources.

Table 4: Expected growth of livestock population and milk yield

Year	2006-07			2021-22		
Type of Animals	Population (mill.)	Production (mill. tons)	Wet Average (kg/day)	Population (mill.)	Production (mill. tons)	Wet Average (kg/day)
Indigenous	28.158	20.263	1.98	31.264	26.248	2.28
Crossbred	2.580	18.682	6.75	12.347	44.703	7.98
Buffalo	32.864	53.986	4.50	40.061	97.789	5.94
Goat	--	4.073	--	--	6.512	--

Conservation of vanishing Indian breeds

Among 30 major Indian breeds of cattle, as shown in Table 2, there are only four milch breeds, which are under severe neglect. There are a few dual-purpose breeds and the rest are draft breeds. With the modernisation in agriculture, bullock power is losing its importance. On the other hand, small farmers cannot make optimum use of bullocks and hence, prefer to hire tractor services, whenever necessary. Thus, with the diminishing demand for bullock power, the farmers are not adequately motivated to conserve these draft breeds. In the absence of a clear policy and programme for conservation, these breeds are subject to heavy genetic erosion.

Realising the growing population of low productive non-descript cattle population, the Government of India promoted the Intensive Cattle Development Programme way back in the 60's to upgrade them through crossbreeding with exotic milk breeds such as Jersey or Holstein Friesian. While a well planned cross breeding programme, along with upgrading of buffaloes could significantly enhance the milk production in the country, dairy farmers are encountered with several new challenges to sustain the growth and profitability. These problems need to be addressed to enhance the milk production while enabling small farmers to increase their profit margin. Fortunately, with the estimated demand for milk increasing from the present quantity of 110 million tons to 175 million tons by 2022, dairy farmers are assured of remunerative price for their produce.

Problems of the poor dairy farmers

For involvement of poor dairy farmers in successful dairy husbandry programme, it is necessary to address their problems, which are presented below:

- Poor quality animals requiring genetic upgradation;
- Poor access to breeding and health care services;
- Nutritional deficiency due to shortage of feed and fodder;
- Ignorance about zoonotic diseases such as Brucellosis, TB, etc.
- Lack of technical guidance to adopt good husbandry practices;
- Inefficient milk collection and marketing;
- Poor linkage with research institutions;
- Unavailability of credit facilities.

Present status of animal husbandry services

Delivery of animal husbandry and veterinary services free of cost to farmers, has been accepted as the responsibility of the State Governments, since independence. These services included breeding of cattle and buffaloes through AI, preventive vaccinations, treatment of sick animals and extension services to promote new technologies. However, in the absence of greater mobility, most of the services were confined to the periphery of the veterinary clinics established at the block level. With the shortage of qualified veterinary graduates, most of these technical services were gradually assigned to semi-skilled livestock supervisors. In the absence of efficient services, farmers in interior areas could not take advantage of the programmes, to improve the productivity of their livestock. Infrastructure for marketing of milk has been very weak, due to poor performance of the cooperatives. Thus, the progress of livestock development, particularly dairy husbandry, could benefit a small population in selected regions, where milk cooperatives were efficient, while a large section of small farmers could not take advantage. In case of dairy husbandry, linkage of the dairy farmers with the processing unit is very critical.

Availability of fodder and feed can play a very important role as about 70% of the cost of dairy husbandry is on feed. There are several hurdles for the small farmers to procure good quality feed at a competitive price. While there is a severe shortage of animal feeds, farmers in fodder surplus areas are even burning crop residues or selling for alternate uses at substantially lower prices. In the absence of organised supply, the local traders take undue advantage by supplying inferior quality feed at high cost. In such a situation, dairy farming can become uneconomical in spite of superior technical inputs. Hence, the above problems need to be addressed, for transforming dairy husbandry into an important source of livelihood for small farmers.

Strategy for development of cattle and buffaloes for dairy husbandry

Considering the requirements of small dairy farmers, the following activities need to be initiated to boost livestock production.

Genetic improvement

Production of superior quality bulls

- For genetic improvement, the first step is to produce superior quality bull mothers and bull calves.
- Farmers maintaining elite herds of cattle and buffalo can also be involved in bull calf production through planned breeding and buy-back guarantee.
- Application of Super Ovulation and Embryo Transfer technology for production of superior bull mothers and bull calves.
- Progeny testing of sires should be undertaken to select sires having ability to transmit superior genetic traits.

Production of superior quality semen

- Semen freezing laboratories should be certified for quality and disease free status;
- Minimum genetic and health standards should be prescribed for bulls to be used for semen collection.

Conservation of genetic resources

Important native breeds of cattle and buffaloes should be conserved through the following activities:

- Study on economics and utility of different breeds;
- Incentive for maintaining elite animals of native breeds;

- Establishment of bull mother farms by procuring elite females from field;
- Use of sexed embryos for multiplication of elite progeny;

Breeding services and management

Training and regulation of AI technicians:

- Skill oriented training for paravets to improve breeding efficiency:
- Regular monitoring of the services of Paravets and vets to maintain high technical standards, without exploiting farmers;
- Periodic training of Paravets and farmers on good animal husbandry practices.

Support services

- Timely supply of inputs such as liquid nitrogen, frozen semen, vaccines, first aid kit, feed concentrates, mineral mixture and forage seeds to the paravets for onward supply to dairy farmers, through local Dairy Federation or NGO engaged in livestock husbandry.

Health care

- Privatisation of health care services, through Farmers' Federations;
- Support for private veterinary practice in close association with paravets;
- Establishment of Disease Investigation laboratories by the Dairy Federation or private agencies for effective treatment of animals;
- Strengthening of Research and Development facilities for disease diagnosis, production of effective vaccines and control of critical diseases;
- Regulatory role of State Animal Husbandry Departments in disease surveillance and promotion of clean milk production.

Strategy for feed management

Efficient management of crop residues: Promote new food crop varieties having higher grain yield with stalks of superior fodder quality. Plant breeders and agronomists should be sensitised to breed and promote dual-purpose varieties of sorghum, maize, bajra, and a wide range of legumes.

Improvement of nutritional values: Presently, the major quantity of dry matter is contributed by paddy straws, wheat straw, maize stalk, sugarcane bagasse and trash, which are of poor nutritional value, due to high fibre content. With new techniques, the quality of such fodder should be improved. This will also help in augmenting the fodder shortage.

Development of community wastelands: Efforts should be made to develop pasture lands involving local communities through soil and water conservation, introduction of improved legumes and grasses, forage tree species and prevention of grazing.

Increase in forage yields: Presently, improved practices are not followed for cultivating forage crops. Hence, efforts are needed to breed superior fodder varieties, produce and supply good quality seeds, promote use of soil amendments, biofertilisers and forage harvesting equipment.

Complete feed rations: To overcome nutritional imbalance in the field and to facilitate small farmers and landless to maintain their livestock under balanced feeding, decentralised complete feed production units can be established.

Fodder banks: Establishment of fodder banks in fodder scarcity regions through Dairy Federations and People's Organisations can help small farmers to feed their livestock during scarcity. In paddy and wheat growing areas where the straw is wasted, facilities for compacting straw can be installed and arrangements can be made to collect and pack them. Fodder banks can play a critical role in timely supply of feed to livestock owners during the years of drought. The fodder banks can also take up the production of complete feed for local distribution.

Introduction of by-pass protein feed: Techniques have been developed to avoid wastage of nutrients by feeding by-pass protein and fat. Support should be provided to establish by-pass protein/fat production units particularly in milk sheds where high quality milch animals are maintained.

Reduction of herd size: It is necessary to create awareness among farmers to reduce herd size and ensure optimum feeding instead of maintaining a large number of underfed animals.

Support for small farmers: For calf rearing, feed subsidy, insurance coverage, venture capital, etc. may be given to ensure their active role in dairy development and in rearing of small ruminants.

Nodal agencies for backward and forward linkages

- The responsibility of providing back-up services to paravets and veterinarians can be assigned to milk processing units, dairy federations, voluntary organisations or private entrepreneurs in the region.
- These nodal agencies can also take up the production of critical inputs such as frozen semen, cattle feed, forage seeds, etc. required by the farmers.
- There is a need to develop a value chain, by establishing coordination among all the stakeholders to enable them to play an efficient and transparent role for improving the production and profit margins of the farmers.

Management of culled animals

- Presently, small farmers are not able to get rid of unproductive or sick animals suffering from contagious diseases. Such unwanted animals not only put pressure on feed resources, but also spread diseases. Therefore, suitable arrangements should be made for disposal of the culled animals by way of establishing *panjarpoles* through voluntary organisations or any other means.
- Export of animals to neighbouring countries desiring to procure, can be permitted and coordinated through the nodal agency / AHD.

Processing and marketing of produce

- Mini dairies should be established in small towns where large dairies are not viable. This will ensure transparency and efficiency.
- Milk processing units should assume a prominent role in Dairy Value Chain management by promoting breeding services, input supply and health care provision, apart from collection of milk. The farmers should be trained in clean milk production.

Development of other species of livestock

Sheep, goats, pigs and fishery also have the potential to provide gainful employment in selected areas. For instance, piggery is an excellent source of livelihood in the North-Eastern states. A family with 6-8 pigs can be assured of food security. Families maintaining 8 - 10 goats can come out of poverty, within a period of 18 - 24 months. Similarly, a flock of 40 - 60 birds of indigenous poultry breeds can contribute to the income substantially.

Innovative approach of BAIF

BAIF has been a leader in taking up dairy husbandry as a powerful tool for generating gainful employment in Rural India. BAIF's strategy has been to use the non-descript unproductive local cows and buffaloes with superior quality exotic germplasm to produce high yielding crossbred cows. BAIF adopted frozen semen technology to ensure the use of elite germplasm at the doorsteps of farmers. Engagement of school drop outs for providing breeding, each covering 1500 to 2000 families and other essential services, not only provided employment to the local youth but also helped them to closely interact with illiterate dairy farmers and assist them in adoption of good management practices. This innovative model was recognised by the Government of India in 1979, enabling BAIF to establish Cattle Development Centres across the country with the support of IRDP Infrastructural Fund of the Government of India and to expand the programme through 4000 centres across 16 states covering over 40 lakh families in 60,000 villages. The programme covers breeding of cattle and buffaloes, promotion of fodder cultivation, minor veterinary care such as deworming and vaccination and mobilisation of farmers to develop their organisations to collect milk and supply to the local dairies.

This programme turned out to be successful as farmers with low yielding nondescript animals, were able to produce high yielding cows and buffaloes without any capital investment. With the increasing demand for milk and higher price realisation, farmers maintaining 3 cows were able to earn Rs. 40,000 - 45,000 per year and come out of poverty. Such high yielding cows and buffaloes produced at the doorsteps of the farmers, today, fetch over Rs.40,000 to Rs.60,000 and truly serve as security to tide over financial crisis. There is no other programme wherein the poor have an opportunity to build such high value assets without any risk or capital investment. Presently, the milk produced by the farmers participating in BAIF programme, contributes to over Rs. 4000 crores to the national GDP every year.

BAIF has also initiated an eco-friendly Goat Development Programme wherein 6 - 8 goat keeping women form a group to maintain a superior quality breeding buck to ensure genetic improvement, while a trained local paravet mentors 6 – 8 such groups and provides critical services such as deworming, vaccination, castration, guidance on fodder production and feeding, periodic monitoring of growth and linkages with the market. As a result of these interventions, the goat keepers are now able to enhance their income by 250 - 300%, due to prolific kidding, high weight of kids at birth and at various stages of growth, low mortality and better price realisation. Rigorous culling to restrict the herd size depending on fodder availability and promotion of stall feeding to avoid biotic pressure on the eco-system, are helpful to keep this programme eco-friendly. The impact of this programme on livelihood and attitude of the goat keepers can be observed in 18 – 24 months. BAIF is presently operating this programme in the states of Rajasthan, Maharashtra, Jharkhand, West Bengal, Orissa and Tripura with good success.

Reduction in green house gas emission

Livestock has an adverse impact on environment. Firstly, livestock demands huge quantities of fodder and feed. As there is a severe shortage of cultivated fodder and feed resources, farmers let their livestock for free grazing on community lands and forests. Such stray livestock not only denude the vegetation but also accelerate soil erosion. Secondly, ruminants produce methane and carbon dioxide during digestion. The dung releases methane and nitrous oxide during anaerobic decomposition. It is estimated that livestock contributes 18% of the carbon dioxide equivalent green house gases in the atmosphere, which is a serious concern. However, livestock being a major source of livelihood and food security for small and marginal farmers in most of the developing countries, it is necessary to find solutions to reduce their ill-effects on global warming and ensure a sustainable future for poor farmers.

Emission of methane

The global methane production in 1988 was in the range of 400 - 600 million tons per annum of which livestock contributed about 28%, amounting to 80 million tons/annum. When the feed reaches the rumen, it is converted into short chain fatty acids, microbial biomass and fermentative gases, mainly carbon dioxide and methane, through microbial degradation, known as enteric fermentation. The proportion of these components produced in rumen varies to a great extent, with the type of feed and microbes (Blummel, *et al* 2001). The variation in digested outputs occurs due to the type of feed, level of intake, retention time in rumen and type of microbes present. On an average, each adult cow emits about 15 - 20 kg methane in a year. With about 100 million livestock, USA emits 5.5 million tons of methane/year. India has 485 million livestock and these are likely to release proportionately higher quantity of methane due to consumption of inferior quality fibrous fodder.

Scope for reducing methane production

Depending on different species of microbes, nutrients and other chemical substances present in the feed, the degree of fermentation will vary and the volume of gases released, will also change. Thus, there is scope for reducing the production of gases by proper manipulation of these factors.

Balanced feeding: Efficiency of microbe has a significant impact on production of various products, particularly gases. While the short chain fatty acids provide 70 - 85% of energy requirement, microbial biomass provide 70 - 100% amino acid requirements of ruminants. With proper feed selection, supplementation and balancing of various ingredients, it is possible to maximise the conversion of feed into microbial biomass and short chain amino acids, while reducing green house gases. With high protein diet, formation of gases can be reduced significantly, while high fibre content in diet can increase the production of gases. These gases are released in the atmosphere through digestive and respiratory systems.

Improving feed quality: A majority of the livestock in India is low productive. They are under-nourished and survive on open grazing or on poor quality, high fibre roughages. These animals release more methane than high yielding animals, who consume better quality feed. To reduce the ill-effects of poor quality feed, breaking of lignin in roughages before feeding to livestock through various methods should be explored. Steam treatment of sugarcane bagasse and paddy straw and urea - molasses treatment of paddy straw are some good examples. Conversion of high fibre grasses into silage may be easy and beneficial. Even simple chopping of fodder before feeding livestock, can reduce methane production by 8 - 10%.

Good health conditions: Animals suffering from diseases also release higher volume of methane compared to healthy animals. As most of the farmers are unaware of the threat posed by their livestock to the environment, no efforts are being made either to reduce the herd size or to control methane emission. These animals further demand fodder, feed and water, thereby creating pressure on the natural resources which are already scarce (Hegde, 2010).

Efficiency of microbes: It is presumed that there are a wide range of microbes involved in degeneration of biomass. The efficiency of different species and strains is likely to vary widely. Thus, there is scope to identify various species and their strains of micro-organisms present in rumen which are efficient convertors of feed into amino acids and microbial biomass. Such microbes found even outside the rumen, can be introduced into the rumen to improve digestion in ruminants.

Methane absorbing microbes: There are also microbes which have the capacity to absorb methane and convert it into other products. Such selected micro-organisms capable of feeding on methane, can also be incorporated in the rumen flora for reducing the emission of methane while improving the productivity and profitability of livestock husbandry.

Methane traps: Most of the low productive livestock generally go out for grazing during the day and return to the shed in the evening. They release significant volume of methane and carbon dioxide during the night when housed in a cattle shed. Trapping these gases inside the barn by fixing efficient filters, may be possible by using modern technologies.

Dung management: Animal dung and urine also release methane and nitrous oxide. Methane is generally released through anaerobic decomposition, when dung is heaped as manure for a longer period. In countries like India, farmers have been following the practice of dumping dung in manure pits for 3 - 6 months for better decomposition, thereby contributing substantially to emission of methane. Better management of farmyard manure and compost pits can also reduce emission of methane in the atmosphere to a great extent.

Use of dung for production of biogas is the best option to convert this threat into an opportunity. The old models of biogas plants were inconvenient to manage in congested residential areas. New compact models have now been developed which are ready for wider replication.

Control of livestock population: The aim should be to reduce livestock by improving the productivity of the animals, so that with small number of livestock, farmers can earn higher income. This can happen by producing genetically superior quality animals and maintaining them well with balanced feeding.

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Agroforestry for Sustainable Agriculture

A. K. Handa, S. K. Dhyani and Ajit

Agroforestry play an important role in ecosystem and provide a range of products and services to rural and urban people. Farmers have practiced agroforestry since ancient times. Agroforestry focuses on the wide range of trees grown on farms and other rural areas. Among these are fertilizer trees for land regeneration, soil health and food security; fruit trees for nutrition; fodder trees for livtestock; timber and energy trees for shelter and fuel wood; medicinal trees to cure diseases and trees for minor products *viz.* gums, resins or latex products. Many of these trees are multipurpose, providing a range of benefits.

The National Agriculture Policy (2000) emphasized the role of agroforestry for efficient nutrient cycling, nitrogen fixation, organic matter addition and for improving drainage and underlining the need for diversification by promoting integrated and holistic development of rainfed areas on watershed basis through involvement of community to augment biomass production through agroforestry and farm forestry. The Task Force on Greening India for Livelihood Security and Sustainable Development of Planning Commission (2001) has also recommended that for sustainable agriculture, agroforestry may he introduced over an area of 14 million ha out of 46 m ha irrigated areas that are degrading due to soil erosion, water-logging and salinization. For integrated and holistic development of rainfed areas, agroforestry is to be practiced over an area of 14 million ha out of 96 m ha. This all will, besides ensuring ecological and economic development provides livelihood support to about 350 million people. The practice of agroforestry can help in achieving these targets. Therefore in the quest of optimizing productivity, the multitier system came into existence. Gap of demand and supply of forest produce in India is widening

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and forests are unable to fulfill the demand. Agroforestry can play an important role in filling this gap and conservation of natural resources.

Traditional agroforestry systems

In about 700 BC, man changed from a system of hunting and food gathering to food production. Shifting cultivation in India is prehistoric and partly a response to agroecological conditions in the region. Horticulture as co-existent with agriculture is found to have been prevalent in India from early historic period when a certain amount of share in garden crops started to have been enjoyed by the king for providing irrigation. Some stray references occur in different texts of the Vedic literature. The cultivation of date-palm, banana pomegranate, coconut, jujube, aonla, bael, lemon and many varieties of other fruits and requirement of livestock in agriculture and mixed economy of agriculture and cattle-breeding may be traced in proto-history chalcolithic periods of civilization. But in India, the plant husbandry (intentional sowing or planting for production of desirable plants or plant domestication) happened to start under progressively arid climatic zone from about pre-Neolithic period. The role of many common trees such as khejri or sami (*Prosopis cineraria*), aswattha (*Ficus religiosa*), palasa (*Butea monosperma*) and varana (*Crataeva roxburghii*) in Indian folk-life has been mentioned in ancient literature of Rig Veda, Atharva Veda and other ancient scriptures. Traditional agroforestry systems manifest rural people's knowledge and methods to benefit from complimentary uses of annuals and woody perennials on the sustained basis. It also indicates that farmers have a closer association with trees than any other social group and promoters of forests.

In Central America it has been a traditional practice for a long time for farmers to plant about two dozen species on a small piece of land configuring them in different planes. In Europe, until middle ages, it was the general custom to clear fell, degraded forests, burn slash, cultivate food crops for varying periods on cleared area and plant trees before or along with, or after sowing agricultural crops. This farming system was widely practised in Finland up to the end of the last century and in a few areas in Germany as late as the 1920s. In certain far-east countries practice, people clear forest for agricultural use-they deliberately spared certain trees which by the end of the rice-growing season provided partial canopy of new foliage to prevent excessive exposure of soil to sun.

The farmers and land owners in different parts of the country integrate a variety of woody perennials in their crop and livestock production fields depending upon the agroclimates and local needs. Most of these practices are, however very location specific and information on these are mostly anecdotal. Therefore, their benefits have remained vastly under exploited to other potential sites. It has now been well-recognized that agroforestry can address some of the major land-use problems of rainfed and irrigated farming systems in India, and that a great deal can be accomplished by improving indigenous systems. With the current interests in agroforestry worldwide, attempts are being made in India to introduce agroforestry techniques using indigenous and exotic multipurpose and nitrogen-fixing woody perennials.

Agroforestry research in India

India is seventh largest country in the world encompassing geographical area of 328.7 million ha, which is about 2 per cent of the world, but has to provide food and fodder to about 1.2 billion human and almost half a billion livestock population. In order to meet the increasing demand of our fast growing population, we would require to boost the production of food grain and fuel wood for human consumption and green and dry fodder for livestock. Under these circumstances we have no alternative but to follow the integration of trees with agricultural crop, which is known as agroforestry. Agroforestry research is more than hundred years old in India beginning with introduction of shade trees in tea gardens, but organized research was initiated during fifties in few ICAR Institutes namely Central Arid Zone Research Institute, Jodhpur, Central Soil and Water Conservation Research and Training Institute, Dehradun, Indian Grassland and Fodder Research Institute, Jhansi, as fuel- fodder plantations on degraded lands or the silvipastoral system.

India has been at the forefront since organized research in agroforestry started worldwide. In 1979 at Imphal, when the first seminar on Agroforestry was organized by the Indian Council of Agricultural Research, New Delhi to accumulate and compile the data on the research and development of agroforestry in India. The All India Coordinated Research Project (AICRP) on Agroforestry with 20 centers all over country was launched in 1983 to implement the major recommendations of the aforesaid seminar. Further, National Research Centre for Agroforestry was established in 1988 at Jhansi to accelerate the basic, strategic and applied research in agroforestry. At the initial phase agroforestry research also got financial support from different international agencies primarily USAID, UNDP and others, which helped in strengthening infrastructure and human resource component. At present there are 37 centers under All India Coordinated Research Project on Agroforestry with project coordinating unit at National Research Center for Agroforestry, Jhansi. These centers represent almost all the agroclimates of the country. In addition to ICAR, Indian Council of Forestry Research and Education (ICFRE) and its Institutes, private institutions and NGOs such as WIMCO, ITC, BAIF, IFFDC, West Coast Paper Mills Ltd, Hindustan Paper Mills Ltd, National Tree Growers Cooperatives are also engaged in research and promotion of agroforestry in the country.

The major thrust of agroforestry research in the beginning was on the following areas

1. Diagnostic survey and appraisal of existing agroforestry practices.
2. Collection and evaluation of promising tree species/ cultivars of fuel, fodder and small timber.
3. Studies on management practices of agroforestry systems.
4. Environment, wasteland and community land development through agroforestry interventions, and
5. Integration of livestock, fishery, apiculture, lac etc. as component of agroforestry.

Agroforestry as a multiple land use systems is an obvious means of fulfilling these objectives. The advantages and implications of agroforestry are too many. The value of trees on farmland may considerably exceed that offered by woodlands and plantations (Singh, 1987). The research and developmental efforts undertaken during the last more than two decades have clearly demonstrated the potential of agroforestry for resource conservation, improvement of environmental quality, rehabilitation of degraded lands and providing multiple outputs to meet the day to day demand of the rural population.

The diagnostic survey and appraisal of existing agroforestry practices in the country revealed that there are enumerable number of agroforestry practices prevalent in different agroecological zones (Pathak *et al*, 2000). These reviews indicate that agroforestry systems or practices are widely based on nature and arrangement of the components and ecological or socio-economic criteria. In the documented agroforestry practices trees serve as wind breaks and shelterbelts, delineate boundaries, and provide shade, ornamentation and seclusion around homesteads. They supply not only poles, stakes, timber and fuel, but also cash crops, fodder, fruits and nuts, dyes, gums, resins, fiber and medicines. Fodder and food trees provide balanced diets during dry seasons, when other foods are scarce. Trees, with their deep rooting systems, consume moisture and nutrients from higher depth in the soil than arable and pastoral crops, and thus there is least competition among the different components.

The second major aspect of the research endevours under agroforestry was collection and evaluation of promising tree species/cultivars of fuel, fodder and small timber (Pathak *et al*., 2000). A lot of germplasm has been collected and evaluated in arboretum established by different centres of the project. About 184 promising tree species have been determined based on growth performance trials at these centers. The review of agroforestry practices indicate that the safest choice of agroforestry species have come from the native vegetation, which has a history of adaptation to local precipitation regimes. There are a number of tree crop combinations, which in turn reflect the differences in the climates and soil fertility of various regions in the country. The examples of major trees in agroforestry practices are (1) *Grewia optiva, Ulmus wallichiana*, *Morus alba*, *Robina pseudoacacia* and *Alnus nepalensis* in western Himalayan region; *Acacia auriculiformis, Alnus nepalensis, Bamboos, Parasanthes falcataria* and *Gmelina arborea* for eastern Himalayan region; (2) Populus, Eucalyptus, mangifera and *Dalbergia sisoo* in indogangetic region: (3) *Dalbergia sissoo,* *Acacia tortilis, A. nilotica, Ailanthus excelsa, Prosopis cineraria* and *Leucaena leucocephala* and *Azadiracta indica* for arid and semi arid regions; (4) *Acacia nilotica, Prosopis cineraria* and *Zizyphus* in western India: (5) *Tectona grandis*, *Tamarindus indica* para rubber (*Hevea brasilensis*) and cashew nuts: in southern region and (6) *Albizzia spp. Gmelina arborea, Gliricidia, Acacia auriculiformis* for humid and sub humid regions; (7) *Artocarpus*, *Azadiracta indica*, *Casuarina equisetifolia, Grevillea robusta* and bamboos in coastal and island region. This would correspond to the high rainfall levels and long rainy seasons in the south, with drought periods comperatively longer for the regions to the west, indo-gangetic and central (Dhyani *et al*., 2003). The efforts made so far has created voluminous database, which is strength. The information collected may be utilized for creating local and regional volume tables. The Planning Commission, GOI (2001) has also identified six species for major thrust in agroforestry and Joint Forest Management (JFM) programmes in the country. The species are *Acacia nilotica, Casuarina equisetifolia, Eucalyptus spp., Populus deltoides* and *Prosopis cineraria and Bamboo species.*

On the basis of identification and evaluation of promising trees and D&D survey of the existing systems, agroforestry interventions were initiated in different agroclimatic regions. Primarily these systems are catagorised into agrisilviculture, agri-horticulture, agri-horti-silviculture, hortipastoral, silvipastoral, and specialized systems. Among these systems, agrisilviculture followed by agrihorticlture, are the most prominent being practiced and advocates the maximum agroclimatic zones. Home gardens, block plantation, energy plantation, shelterbelts and shifting cultivation are some of the specialized agroforestry systems developed by the research institutions. However the agroforestry systems developed and recommended by the centres are location specific, besides in many situations these systems are not looked favorably by the farmers due to wide variations in the choice of species, crop preferences etc. also some of the systems developed have not completed a full rotation for the tree component, therefore biomass production and returns are only on the basis of extrapolation. The stakeholders also require full package of practices, choice of crops with trees in temporal sequence and information on insect pest disease and effect of aberrant weather conditions, which are now of common occurrence.

Agroforestry initiatives in the country has had its role in creating greater concern among the common man for the protection and preservation of trees, bushes and grasses. It has also been realized that destruction and degradation of forest resources may have detrimental effect on soil, water and hence on human and animal life. Unfortunately, most forest soils are not suitable for agriculture and quickly became unproductive. The felling of trees for commercial and domestic wood products is mostly unregulated and beyond the forests ability to replenish itself. Similarly the grazing of livestock in forested areas is often beyond their carrying capacity. Going by the potential for economic exploitation, it would appear that 90% of the forests are performing critical functions of protecting fragile watersheds and are not fit for commercial exploitation. As a shift in the National Forest Policy of India harvesting from forests has now practically been banned with social benefits mainly flowing from the protective and environmental functions of the forest apart from meeting the subsistence needs of the communities living close to the forests.

Agroforestry potential

Owing to increase in population of human and cattle, there is increasing demand of food as well as fodder, particularly in developing countries like India. In general, there is acute shortage of food and fodder in developing countries. However, the situation in India is more alarming than in other countries of the third world. Asia posses the smallest area of the potentially arable land compared to South America and Africa and has the highest population. Therefore there is little scope to increase food production by increasing the area under cultivation. Hence food production is to be increased from the land already under cultivation or from land not conventionally considered arable. A management system, therefore needs to be devised that is capable of producing food from marginal agricultural land and is also capable of maintaining and improving the quality of producing environment. The agroforestry has both productive and protective potential, and it can play an important role in enhancing the productivity of our lands to meet the demand of ever- growing human and livestock population.

Agroforestry for food and nutritional security

The country's food production has increased many folds since independence but recent improvements in food supply have been insufficient to fulfill the nutritional needs of the average person in an ever increasing population of the country. Wheat and rice have shown the greatest increase in yields, while production of coarse grains and pulses has changed only marginally. Increasing the production and consumption of protein-dense foods, pulses in particular, will be necessary if the country is to meet its protein needs. Agroforestry with appropriate tree-crop/ legume combination is one option in this regard. The different agroforestry systems provide the desired diversification options to increase the food security of the country and act as a shield against the poor production during drought and other stress conditions. The agroforestry also provides nutritional security because of diverse production systems which include fruit, vegetables, oilseed crops, medicinal and aromatic plants in addition to normal food crops grown by the farmers. Vegetables crops yield higher return on an average than the common field crops. Crops like peas and cowpeas can be grown successfully during winter and summer months, respectively under trees and these crops can also fix the atmospheric nitrogen and improve the fertility status of the soil along with providing additional income from the production of vegetable crops.

Agroforestry for fodder production

Trees and shrubs often contribute substantial amount of leaf fodder in arid and semi arid and hill regions during lean period through lopping/pruning of trees, popularly known as top feed. The leaf fodder yield depends on species, initial age, lopping intensity and interval as well as agroclimatic conditions. Fodder from trees is mainly available from two parts viz., leaf twigs and pods. This forage is usually rich in proteins, vitamins and minerals like calcium. They are however in general low in phosphorus and crude fibre (Singh, 1990). Such top feeds species play an important role in human food security through their function as animal feed resource. The importance of top feeds increases with the severity of drought and progression of drought season. Other uses such as for live fencing are complimentary, as they encourage cultivation of the species and increase the availability of feed. The top feeds are considered very important in vegetation stabilization and sustained productivity of rangelands. They also play an important role as windbreaks and by providing shade for the grazing animal. The important ones are *Prosopis cineraria, Albizzia lebbeck. Acacia spp,* *Leucaena leucocephala, Dalbergia sissoo, Ailanthus excelsa, Azadiracta indica, Acacia leucophoela etc.* for the arid and semi–arid region and *Grewia optiova, Morus alba, Celtis australis* etc for the hilly regions. Thus tree fodder provides enough nutrients and can serve very well as a green fodder supplement. Besides providing green fodder, such leaves are also conserved in the form of hay and silage to supplement feed during scarcity periods. Bamikole *et al*, (2003) reported that feed intake, weight gain, digestibility and nutrient utilization can be enhanced by feeding *Ficus religosa* in mixture with *Panicum maximum*, and it can be used in diet mixtures up to 75% of dry matter fed. Dagar *et al*. (2001) reported that for silvipastoral system on alkali soils *Prosopis juliflora, Acacia nilotica* and *Tamarix articulata* are the most promising trees and *Leptochloa fusca, Chloris gayana* and *Brachiaria mutica* most suitable grasses. *L. fusca* in association with *P. juliflora* produced 46.5 t ha^{-1} green fodder over a period of four years without applying any amendments and fertilizer.

Agroforestry for biofuel production and energy security

India ranks 6^{th} in the world in terms of energy demand accounting for 3.5% of worlds energy demand since the beginning of 21^{st} century. The energy demand is expected to grow at 4.8%. A large part of India's population mostly in rural areas, does not have access to the conventional source of energies. Further the Indian scenario of the increasing gap between demand and domestically produced petroleum is a matter of serious concern. In this connection, fuels of biological origin have drawn a great deal of attention during the last two decades. Biofuels are renewable liquid fuels coming from biological raw materials and has proven to be good substitute for oil in the transportation sector as such biofuels are gaining worldwide acceptance as a solution for problems of environmental degradation, energy security, restricting imports, rural employment and agricultural economy. The potential tree borne oilseeds holding promise for biofuel are *Jatropha curcas*, *Pongamia pinnata*, Simarouba, *Azadiracta indica*, *Madhuca spp.,* etc. These biofuel species can be grown successfully under different agroforestry systems. There is need to identify the genetically superior germplasm of these biofuel species for higher seed yield and oil content. At present the superior germplasm of Jatropha and Pongamia is under multilocation trials to identify the superior germplasm.

Agroforestry for energy plantation

The main biomass energy sources in rural areas which are being used in the households, include wood from forest, croplands and homesteads), cow dung and crop biomass. Bioenergy from tree biomass is one significant contribution from agroforestry. Ravindranathan *et al*, (1997) reported for a Karnataka village that 79% of all the energy used came mainly from trees and shrubs. *Prosopis juliflora* due to high calorific value of over 5000 Kcal is the major source of fuel for the boilers of the power generation plants in Andhra Pradesh (the other materials are rice husk, cotton stalks, other wood etc.). About Rs.700-1300/t is the price offered for *P.juliflora* wood at factory gate depending on the season and moisture. An estimated 0.51 million ha area is under *P. juliflora*. Even if 25 percent of the area is meant for power generation leaving the rest 75 percent for fuel and charcoal, the bioenergy potential works out to 1000 MW. Similarly other tree species can be used for running the biomass based power plants. Thus a total of 5000 MW power could be produced from the biomass sources from trees under moderate conditions, which meets almost one third of the ultimate potential of 16000 MW from biomass. Establishing power plants of such a capacity attract an investment of Rs. 90830 crores. R & D can help in enhancing productivity and assisting the power plants in captive plantation management on degraded lands. Promoting bioenergy through *P. juliflora* also encourages tremendous employment generation to the tune of 6.34 million mandays and 7.03 million woman days for fuel making Tamil Nadu alone.

The fuel wood potential of indigenous (*Acacia nilotica, Azadirachta indica, Casuarina equisetifolia, Dalbergia sissoo, Prosopis cineraria and Ziziphus mauritiana*) and exotic (*Acacia auriculiformis, A. tortilis, Eucalyptus camaldulensis* and *E. tereticornis*) trees was studied (Puri *et al*, 1994). The calorific values ranges from 18.7 to 20.8 MJ $kg^{-1}$for indigenous tree species and 17.3 to19.3 MJ kg^{-1} for exotics. Pathak (2002) opined that species such as *C. equisetifolia*, *Prosopis juliflora, Leuceana leucocephala* and *Calliandra calothyrsus* have become prominent due to there potential for providing wood energy at the highest efficiency, shorter rotation and also their high adaptability to diverse habitats and climates.

Agroforestry for employment opportunities

Agroforestry systems due to diverse options and products provide opportunities for employment generation in rural areas. Dhyani *et al.* (2003) have highlighted the role of agroforestry products and environmental services to meet the subsistence needs of low income households and providing a platform for greater and sustained livelihood of the society. Increased supply of wood in the market has triggered a substantial increase in the number of small-scale industries dealing with wood and wood based products in the near past. Such industries have promoted agroforestry and contributed significantly to increasing area under farm forestry. Recognizing agroforestry as a viable venture, many business corporations, limited companies such as ITC, WIMCO, West Coast Paper Mills Ltd, Hindustan paper Mills Ltd., financial institutes such as IFFCO have entered into the business and initiated agroforestry activities in collaboration with farmers on a large scale. One of the major contributions of agroforestry for the economy is the livelihood impact, both in terms of income and employment generation. Besides the existing agroforestry practices, there is a tremendous potential for employment generation with improved agroforestry systems to the tune of 943 million person days annually from the 25.4 million ha of agroforestry area. Dhyani *et al.* (2005) have indicated the potential of agroforestry for rural development and employment generation to the tune of 5.763 million human days yr^{-1} from Indian Himalayas alone.

Agroforestry for soil conservation and amelioration

Agroforestry plays a key role in keeping the soil resource productive which is one of the major sustainability issues. Closely spaced trees on slopes reduce soil erosion by water through two main processes: first as a physical barrier of stems, low branches, superficial roots and leaf litter against running water and secondly as sites where water infiltrates faster because of generally better soil structure under trees than on adjacent land. Agroforestry played a major role in the recent past in rehabilitation of wasteland such as desert and lands that have been degraded by salinization and ravines, gullies and other forms of water and wind erosion hazards. Trees in agroecosystems can enhance soil productivity through biological nitrogen fixation, efficient nutrient cycling, and deep capture of nutrients and water from soils. Even the trees that do not fix nitrogen can enhance physical, chemical and biological properties of soils by adding significant amount of above and belowground organic matter as well as releasing and recycling nutrients and thus altering the soil properties and texture and increasing the productivity.

Plantation of compatible and desirable species of woody perennials on farmland results in an improvement in soil fertility. There are several possible mechanisms of this, which include: Increase in organic matter content of the soil through the addition of leaf litter and other plant parts; More efficient nutrient cycling within the system and consequently more efficient utilization of nutrient that are either inherently present in the soil or externally applied; Biological nitrogen fixation and solubilization of relatively unavailable nutrients, e.g. phosphate through the activity of mycorrhiza and phosphate-solubililising bacteria; Increase in the plant-cycling fraction of nutrients, with their resultant reduction beyond the nutrient-absorbing zone of the soil; Complementary interaction between the component species of the system, resulting in a more efficient sharing of nutrient resources among the components; Enhanced nutrient economy, because of different nutrient-absorbing zones of the root system of the component species; Moderating effect of additional soil-organic matter on extreme soil reactions and consequently improved patterns of nutrient-release ability.

Improvement in the organic matter status of the soil can result in an increased activity of the favourable micro organisms in the root zone . In addition to the nutrient relations, such micro-organisms may also produce growth-promoting substances through desirable interaction and result in better growth of plant species. Inclusion of trees and woody perennials on farm lands can, in the long run, result in marked improvements in the physical conditions of the soil, e.g. its permeability, water-holding capacity, aggregate stability and soil-temperature regimes. Although these improvements may be slow, their net effect is a better soil medium for plant growth.

The influence of trees on hydrological characteristics can extend from the microsite to the farm and regional levels. Although the effect of water use by a tree component on water availability to crop plants in different climatic conditions is not yet fully understood, there is evidence that the hydrological characteristics of catchment areas are favourably influenced by the presence of trees.

Agroforestry may hold promise for regions where success of green revolution is yet to be realized due to lack of soil fertility. A useful path, complementary to chemical fertilizers, to enhance soil fertility is through agroforestry as it is more effective for soil organic matter restoration.

Carbon sequestration potential of agroforestry

Agroforestry for carbon sequestration is attractive because: (i) it sequesters carbon in vegetation and in soils depending on the pre-conversion soil C, (ii) the more intensive use of the land for agricultural production reduces the need for slash-and-burn or shifting cultivation, (iii) the wood products produced under agroforestry serve as substitute for similar products unsustainably harvested from the natural forest, (iv) to the extent that agroforestry increases the income of farmers, it reduces the incentive for further extraction from the natural forest for income augmentation, and finally, (v) agroforestry practices may have dual mitigation benefits as fodder species with high nutritive value can help to intensify diets of methane-producing ruminants while they can also sequester carbon.

Agroforestry has importance as a carbon sequestration strategy because of carbon storage potential in its multiple plant species and soil as well as its applicability in agricultural lands and in reforestation. The potential seems to be substantial; average carbon storage by agroforestry practices has been estimated as 9, 21, 50 and 63 Mg C ha^{-1} in semiarid, subhumid, humid and temperate regions. For smallholder agroforestry systems in the tropics, potential carbon sequestration rate ranges from 1.5 to 3.5 Mg C ha^{-1} yr^{-1} (Montagnini and Nair, 2004). Agroforestry can also have an indirect benefit on carbon sequestration when it helps to decrease pressure on natural forests, which are the largest sinks of terrestrial carbon. Another indirect avenue of carbon sequestration is through the use of agroforestry technologies for soil conservation, which could enhance carbon storage in trees and soils. Carbon compounds are sequestered or accumulated by plants to build their structure and maintain their physiological process. The energy captured in the molecular bonds of carbon compounds generally present between 2-4 % of the radiation absorbed by the tree canopy. Stem wood growth often accounts for less than 20 % of the dry matter produced in a year, the rest being used by foliage most of which is shed during leaf fall which is an important pathway for the flow of organic matter and energy from the canopy to the soil. Only green plant can assimilate carbon on the earth. The analysis of Carbon stocks from various parts of the world showed that significant quantities could be removed from the atmosphere over the next 50 years if agroforestry systems are implemented on a global scale. Carbon storage depends on several factors including climatic, edaphic, and socio-economic conditions. Perennial systems like home gardens and agroforestry can store and conserve considerable amounts of carbon in living biomass and also in wood products. For increasing the carbon sequestration potential of agroforestry systems practices such as conservation of biomass and soil carbon in existing sinks; Improved lopping and harvesting practices; Improved efficiency of wood processing; fire protection and more effective use of burning in both forest and agricultural systems; Increased use of biofuels; increased conversion of wood biomass into durable wood products needs to exploited to their maximum potential. Agroforestry practices such as: agrisilviculture or agrihorticulture systems for food and wood/ fruit production; boundary and contour planting for wind and soil protection; Silvipasture system for fodder production as well as soil and water conservation; complex agroforestry systems, viz. multistrata tree gardens, home gardens, agrisilvi-horticulture and hortisilvipasture systems for food, fruits and fodder especially in hill and mountain regions and coastal areas and biofuel plantations are suitable for sequestering atmospheric carbon and act as the potential sinks for sequestering surplus carbon from the atmosphere.

The potential of agroforestry systems as carbon sink varies depending upon the species composition, age trees and shrubs, geographic location, local climatic factors, and management regimes. The growing body of literature reviewed here indicates that agroforestry systems have the potential to sequester large amounts of above and belowground carbon compared to tree-less farming systems. In order to exploit the mostly unrealized potential of carbon sequestration through agroforestry in both subsistence and commercial enterprises innovative policies, based on rigorous research results, are however required.

Biodiversity conservation through agroforestry

It is established that India is having rich vegetation with good biodiversity. According to the Government of India report, biological diversity is estimated to be over 45,000 plant species and 810,000 animal species, representing 7 % of the word flora and 6.5 % of world fauna respectively. The UN Convention on Biological Diversity calls for conservation of the biological diversity, sustainable use of its components and fair and equitable sharing of benefits arising out of the utilization of genetic resources. Agroforestry innovations contribute to biodiversity conservation through integrated conservation-development approach. Forest degradation has caused immense losses to the biodiversity, which can be conserved through agro-forestry by adopting a strategy of conservation through use. The biodiversity shall help in the development or improvement of new varieties or populations. It will further help in enhancing the availability of improved planting material, which is a key to the increase the productivity and production at farm level.

Conclusion

The retrospective and critical perusal of the agroforestry research conducted during the last two decades exhibits its wide spectral potential in sustenance of agriculture as these systems provide food, fodder, fruit, vegetables, fuel wood, timber, medicines, fibre etc. from the same piece of land at a time which not only fulfils the demand of people but also elevate their socioeconomic status and standard of life. Agroforestry is the key path to prosperity for millions of farm families, leading to extra income, employment generation, greater food and nutritional security and meeting other basic human needs in a sustainable manner. As mitigation strategy to climate change as well as rehabilitation of degraded land, the conversion of unproductive grasslands and crop land to agroforestry is a major opportunity as it helps for carbon sequestration and makes land productive and reduces further soil degradation. By virtue of diversity of the components of the agroforestry systems like food grains, vegetables, fruits, nutritional security to the communities could be ensured. Induction of fodder cultivation under agroforestry land use will ensure production of milk, meat and animal products and also wide range of food crops, pulses and oil seeds can meet diverse needs of society. The analysis presented here gives a clear identification of the advances made in understanding and appreciation the potential of agroforestry. Owing to increased supply of wood in the market, there has been a significant increase in the number of factories /industries dealing with wood and wood based ventures. Such industries have promoted agroforestry (through poplar and eucalyptus) and contributed significantly in increasing area under agroforestry. On the whole, in addition to promoting indigenous agroforestry models, it appears that a great deal of research needs to be done to identify short rotation, high value species which suit the farmers requirements of planting on marginal lands. It would probably be more realistic to select trees that could provide more cash benefit to farmers through their products, and to accept that in the longer term they will provide indirect environmental benefits arising from a more complex agro ecosystem.

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Bioindustrial Watershed – Improving Small Farm Productivity in Semiarid Regions in an Era of Climate Change

R. S. Shanthakumar Hopper

Water Security is essential for human food and nutrition security as well as for industrial and ecosystem maintenance needs. Over 80% of water resources are used for agriculture. Seawater constitutes over 97% of the world water resources. According to the Economic Survey of the Government of India (2012), the farm sector provides nearly 75% of the jobs in the country. However, the share of agriculture in GDP has gone down to below 14%. This explains why poverty persists on such a wide scale in our country.

Of the 127 Agro-climatic Zones defined under the National Agricultural Research Project 73 are rain-fed. Rain-fed areas account for 60% of the Net Sown Area and 55% of the Gross Cropped Area. Almost half of our food crop area (77% for pulses, 66% for oilseeds and 45% for cereals), over two-thirds of the non-food crop area and over 50% of our horticulture is rain-fed. Rain-fed areas produce 40% cereals, 60% cotton, 75% oilseeds 85% pulses and support 40% human and 60% livestock population. Most of the Scheduled Tribes live in rainfed areas. Even in the best case scenario for irrigation, rain-fed areas would have to produce 40% of our food (12^{th} five year plan (2012-2017) planning commission, Government of India).

Rainfed agriculture is practiced under a wide variety of soil type, agro-climatic and rainfall conditions ranging from 400 mm to 1600 mm per annum. It is estimated that 15 M ha of rainfed cropped area lies in arid regions and receives less than 500 mm rainfall, another 15 M ha is in 500-700 mm rainfall zone, and bulk of 42 M ha is in the 750-1100 mm rainfall zone. The remaining 20 M ha lies in 'above 1150 mm/ annum' zone. As rainfed

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production is spread over different climatic regions, it offers great scope for raising a number of diversified crops *(IWMI.org)*

According to Agricultural Census 2000-01, there were an estimated 98 million small and marginal holdings out of around 120 million total land households in the country. The share of marginal and small farmers accounted for around 81% of operational holdings in 2002-03 as compared to about 62% in 1960-61.

Thus bridging the gap and increasing small farm productivity in rainfed areas is a complex livelihood and agriculture growth challenge which is diverse and risk prone and is characterized by low levels of productivity due to poor soil health, quality seeds and management practices, low integration of value chains, market volatility, access to credit and irrigation, high input use and affected by climate variations.

Watershed approach has been used to manage soil and water for improving the productivity. Conservation of soil, increasing the fertility, augmenting water resources, introduction of better yielding crops and crop diversification etc., are some of the measures adopted in a traditional watershed context. But, experiences show that despite addressing such pertinent issues, unless the livelihoods of the vulnerable communities are addressed in the context of climate change adaptations, mere watershed approach does not yield results. The integrated role of eco based technology which is market driven, pro poor policies and infrastructure would be important in realizing the potential of rainfed agriculture.

Bioindustrial Watershed (BIWS) Concept

M.S. Swaminathan Research Foundation's (MSSRF) strategy for ensuring sustainable water security in the areas of its operation consists of (a) command area management in irrigated areas, and (b) watershed management in rainfed areas. Scientific watershed management helps to increase crop yield and income per every drop of water. Since economic access to food is the major food security challenge today, MSSRF tries not only to increase the productivity and profitability of small farms, but also to enhance non-farm employment and income-earning opportunities.

Bioindustrial Watershed concept (originally proposed by JS.Bali) Initiated by the M.S.Swaminathan research Foundation is based on the principles of the Biovillage paradigm of creating market driven multiple and diversified On Farm , NoN Farm and Off farm employment initiatives in reducing the vulnerabilities of the community. The strategy is to augment the local agro-eco-system, adding value to the available resources and enhance livelihoods through suitable technological interventions by selecting microwatershed as the unit for action research and development. It is in this context that the project is visualized as a "bio-industrial" watershed development project.

The three main components of the biovillage framework are:

(i) **Conservation and enhancement of natural resources management**– Participatory management of common and private property resources – CPR / PPR (Land, Water and Biodiversity) through awareness, infrastructure development and facilitation of community based institutions to ensure equity and rights of the socially and economically marginalized; convergence with Panchayati Raj Institutions and Government Departments for bringing in synergy

(ii) **Improving small and marginal farmers on-farm productivity and profitability** including Livestock – Adopting a Participatory Technology Development (PTD) approach to improve farm productivity through Farmers Field Schools (FFS) and Training of Trainers (ToT), and promoting a holistic Integrated Farming Systems (IFS) blending traditional knowledge with frontier technology for sustainable resource management

(iii) **Generation of** non and off-farm **market driven enterprises –** Promoting diversified livelihood options through grassroots institutional process - Self-Help Group (SHGs) and aggregate them into federations for both men and women under the framework of Biovillages.

Gender equity is integral to the bio-industrial watershed model, where participation of women goes beyond livelihoods. Women are provided space in the watershed committee and other Community Based Organisations to express their concerns and actively take part in the planning and execution of the interventions.

New and innovative initiatives like establishment of village Agromet weather stations and village knowledge centers has bridged the digital divide in information development and access for predicting, decision making and developing adaptive strategies for climatic variability's.

Thus it builds on the conventional system of watershed management through scaling up with value addition and new markets with appropriate socio – economic institutional support system which is co-owned and managed by watershed communities. Participatory Value Chain Analysis has created new opportunities for value addition, storage and marketing. Three farmers/ producers promoted organisation are envisaged at three different project locations.The challenge is how to make watershed initiatives "climate resilient / smart".

Location

(Block, District & State)	Watershed	Panchayats	Soil type	Climate
Illupur, Pudukottai, Tamil Nadu	South Vellar (4A2B6a6b1h)	Ennai, Thalinji	Red	Semi-arid
Vanur, Villupuram, Tamil Nadu	Nallavur (4C1D4a12a)	Karasanur	Black clay loam	Tropical humid
Boipariguda, Koraput, Odisha	Kukkadanalla, Tolla micro watershed (0405010407060101)	Tolla	Red Laterite (Hill soil)	Moist Sub humid
Gharshankar, Hoshiarpur, Punjab	Bhadiar (C3D)	Bhadiar, Dangori, Pandori	Sub-montane alluvial	Semi-arid
Narsinghpur, Madhya Pradesh	Bandhnalla (5D5B6Q)	Devri, Kheri	Black	Sub-humid

Key achievements:

Physical capital building

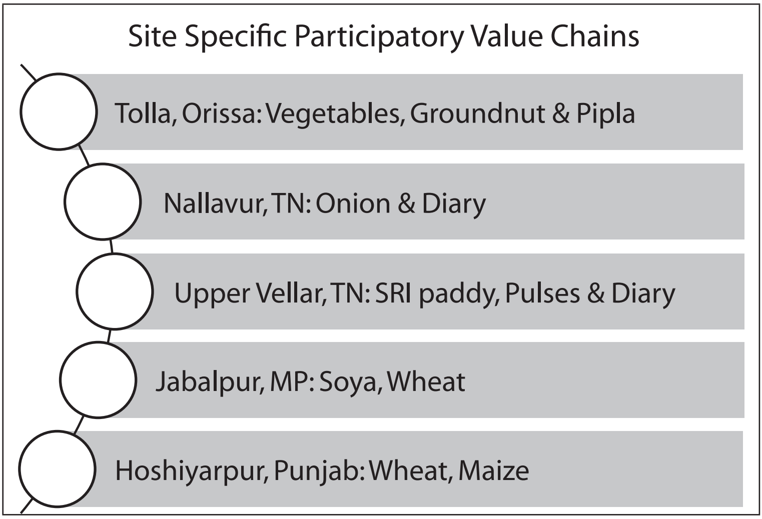
Based on the community needs, priorities and area features, a wide range of soil and water conservation works were identified with community participation and technical expert guidelines. During execution of the works not only the watershed committee members but also the technical expert and team members regularly visited, monitored and provided required inputs for increased efficiency and transparency - individual farm ponds, community farm ponds, percolation tanks, open wells, compartmental bunding have been constructed /rehabilitated. This has increase soil moisture, water conservation and augmentation. 108 Water harvesting and soil conservation structures, benefiting 6000 acres belonging to 4500 small and marginal farmers were reached. About 2 cores were leveraged from various sources for soil & water augmentation structures.

Social / financial capital building:

Two kinds of social institutions were facilitated – Farmer's business groups and their producer companies. Women SHG's and their federations

Social institutional building and microcredit: Established 10 grassroots institutions, two of them community banks, 600 self help groups, covering 8,500 households using bank credit of Rs.13 crores. The farmer's business groups are functioning as Farmers Producer Company with clear action plans. Each Farmers Producer company has identified and developed protocols for the crops to be grown and scaled up. Participatory Value chain analysis for these crops has also been worked out.

The social institutions have enabled the community to address their issues on access to credit, voicing for their entitlements, backstopping support for Microenterprises and marketing. CBO's around water harvesting structure has given them a sense of collective participation, ownership and equity. The active participation in their SHG's and gram Saba meetings has enabled some of the women to be elected as Panchayat ward members in the recent elections.



Natural capital ++ (on farm / off farm and non farm livelihoods)

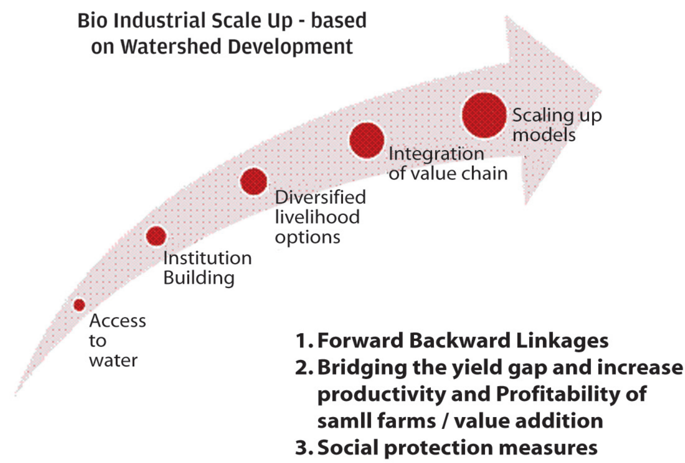
Productivity of more than 8000 acres of agriculture land over 6000 farmers have adopted integrated farming (Participatory Technology Development - PTD process).

More than 3 lakhs horticulture and forest trees planted in – rainfed, irrigated, hillocks and common lands with 50% supported with life irrigation. Dry Land Horticulture and open well irrigation models for small and marginal farmers developed and replicated. In Punjab small and marginal farmers have linked their horticulture gardens to Biogas production.

A large number of Off and Non Farm microenterprises has led in the creation of gainful environmentally sound employment opportunities for men and women; totally about 5000 HH (20,000 population) are involved in various Off and Non Farm enterprises. Forward and Backward linkages enabled them to market their produce and access credit and inputs.

Human capital building: knowledge management:

On an average, 30,000 trainee days are spent in a year on capacity building across various projects. To spread and scale up the project activities 120 Role models were identified specialized on various themes from different sites to facilitate horizontal transfer of knowledge during training programmes. The trainings are theme based and has enabled them to understand, internalize various issues and methodologies. The farmer's trainings are conducted through Farmers Field Schools and Trainers of Training. Exposure visits are conducted for enhanced knowledge and understanding and linkages.



Knowledge management: Through the Village Knowledge Centre on Sustainable Food Security, on-farm and off-farm technologies, market price intelligence, meteorological information and Entitlements are disseminated to the resource-poor, through use of ICT tools and technologies. Service facilities such as timely availability of quality seeds, custom hire of farm implements, input supply management, animal health care centre, bio-control agents, and poultry feed production; spawn and mushroom production and processing are provided.

Stakeholder's concerted action: The various project sites have established excellent networking with financial institutions, Universities, research institutes and government departments by dovetailing various schemes. Collaborations have also been established with OCP foundation on Pulse village programme, Morocco, CSR with HPCL. These linkages have enabled to dovetail funds, entitlements and access credit.

Conclusion

The "Bioindustrial watershed" has demonstrated that through the adoption of scientific methods of water harvesting, saving and sharing both employment and income security can be enhanced. Also Multidisciplinary opportunities for conservation of natural resources management and enhancing sustainable livelihoods arising from climate variability through building the local economic resilience and enhancing sustainability. Practical strategies have been initiated with the participation of vulnerable communities in addressing human, environmental and ecological needs, in order to reduce vulnerabilities and mitigate risks within the context of climate variability and change. Up-scaling of watershed activities is done by converging and leveraging with various stakeholders.

The Key challenge is to continuously research - What are the climate resilient Technologies (traditional & conventional) which would enhance NR and nurture Sustainable Livelihoods in different agro ecosystems? Can grassroots institutions and farming communities be empowered and involved to sustain and scale up initiatives that bring about gender equity, social inclusion and improve their quality of life?

The project has also built in the sustainability factor by empowering the respective user communities to manage and maintain the structures right from the implementation process, besides facilitating the user groups and the panchayats to contribute 10-20% of the total budget of a particular water harvesting structure as per the Common Watershed Guidelines. Regular participatory monitoring and management of the physical structures by the community and the other stakeholders has enhanced the ownership and contributed towards sustainability.

Capacity Building of Farmers through Education and Training

K. Narayana Gowda

India is a vast country with about 120 million farm holdings and agrarian based economy. Though the contribution from agriculture to GDP is around 14.1 per cent in the present scenario, agriculture sector provides employment to about 58 per cent of the workforce. India has made significant achievement in agriculture by increasing food production by five folds during last six and a half decades. Among many drivers to accomplish this task, the policy, research and extension support have played crucial role. Public extension played a major role in ushering green revolution in Indian agriculture. Studies have indicated that the public policies such as investments in research, extension education, and infrastructure and natural resource management have been the major sources of Total Factor Productivity (TFP) growth.

Studies conducted at IARI indicated that extension accounts for around 45 per cent of the growth in TFP, followed by research (36%), literacy (10.5%), infrastructure (8%) and urbanization (1.5%). There is need for intensive and extensive increase in investment in extension. In this context Agricultural knowledge has become one of the key drivers of accelerated agricultural growth. However, extension services have to be strengthened by scaling–up investment (Ramesh Chand *et al,* 2010). Hence there is a need for extensive and intensive increase in investment in extension. In view of this, agricultural extension has to be more vibrant to address the challenges and exploit potentialities by the concerned stakeholders especially the farmers.

Agriculture will continue to play an important role as more than 70 per cent of the population is dependent on agriculture either wholly or significantly for their livelihoods. Majority of the

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farmers in India are resource poor and possess low to medium management abilities. The contribution of small and marginal farmers to food production is enormous who constitute about 65 per cent of the farming population. The Situation Assessment of Farmers (SAS), survey conducted by National Sample Survey Organization, GOI during 2003, brought out rather depressing state of affairs regarding knowledge and awareness of farmer households in the country.

Need of the hour is to strengthen the abilities of farming community to make effective and efficient use of resources to realize increased income on sustained basis. Improving educational level of farming community being long term phenomenon, immediate need is to enhance the capacity of the farming community to efficiently address the challenges faced by the agricultural sector. This underlines urgent need to upgrade the knowledge base of farmers. In this context, the capacity building of the farming community plays an important role to meet the present day challenges.

Over the years country has made several experimentations to enhance its reach to the farmers by initiating number of projects and programmes. During post independence period, public sector extension system has played a dominant role in Indian agriculture. It is the state responsibility to undertake public extension. Extension system has under gone a paradigm shift during the last six and half decades in the country. While much emphasis was given to human and community development during earlier periods there has been steady progression towards technology transfer in recent years with organized manpower and technological inputs.

Despite the concerted efforts made by Public as well Private Extension systems to put in place an effective extension mechanism, the present extension systems appear to be inadequate to address the challenges faced by the farmers in the context of changing agricultural scenario. There is very little penetration of extension system below the taluka level unlike in the yester years. The major reason being, lack of grassroots level extension functionaries to work at panchayats or village level. The public extension system would continue to play an important role in technology dissemination to serve the large chunk of small and marginal farmers, besides the other extension service providers to supplement and compliment the public extension service.

In India, of the required 1.3 to 1.5 million extension personnel, there are only about 100,000 on the job (Working Group on Agricultural Extension 2007). The various line departments are working in isolation, with weak linkages and rare partnerships, which limits information flow. Additionally the research–extension link is weak in absorbing or using feedback from farmers and extension staff. The various components of the public-sector extension system suffer from duplication of programs, lack of convergence. Despite the pluralistic extension system in India—with the public, private, and third sector, all are playing some roles they tend to work in isolations.

Human capital

Human capital accumulation has long been stressed as prerequisite for economic growth. The growth of total factor productivity is a function of human capital. The presumption is that a trained labour force is better at implementing and adopting new technologies, thereby generating growth. Human capital levels influence the speed of technological catch-up and diffusion.

Effective utilization of natural resources for production of agricultural commodities mainly depends on the managerial abilities of farmers. In the words of Alfred Marshall "Knowledge is the most powerful engine of production; it enables us to subdue Nature and Satisfy our wants". Importance of quality of human agents in improving productivity of crops needs no emphasis especially when technologies are more knowledge intensive. Studies have shown that investment in improving quality of people can significantly enhance the economic prospects and welfare of rural community.

In the farm sector, human capital is the farmers. Building their capacity through education and training is essential for increasing the productivity in agriculture.

Education and training

Education in its general sense is a form of learning in which knowledge, skills and attitude of a group of people are transferred from one generation to the next through teaching, training, research or extension. Generally it occurs through any experience that has a formative effect on the way one thinks, feels or acts.

Agricultural education

Education in the context of agriculture is non-formal, out of school education, need based and learner centered leading to livelihood security.

Training is the acquisition of knowledge, skills and competencies as a result of the teaching of vocational or practical skills and knowledge that relate to specific useful competencies.

Difference between education and training

Education refers to all sorts of acquisitions with or without a pre-specified purpose or job to be performed. Thus, it is mainly concerned with personal development. Training is a process, which involves the creation and acquisition of knowledge and skills needed specifically for performing a particular job. It is not only knowing more but for behaving differently. Training is directed towards improving an individual's job proficiency. The main focus of education is on general training that has no immediate application, whereas, training aims at need-based, problem oriented and skill oriented learning with immediate practical applications.

Capacity building

Capacity building is upgrading or strengthening individuals or groups capabilities to perform or manage their work more efficiently. It is a prerequisite for any genuine practical empowerment. It is the process of equipping the individuals to improve the efficiency factors which enable them to perform effectively and independently.

The United Nations Development Programme (UNDP) defines capacity building as, *"the creation of an enabling environment with appropriate policy and legal frames, institutional development, including community participation (of women in particular), human resource development and strengthening managerial systems".*

Capacity building is closely related to empowerment. Empowerment is a process to gain strength, confidence and vision of work for positive changes in life. The institutions which mainly focus on farmers' capacity building are, State Agricultural Universities, Indian Council of Agricultural Research Institutes, Development Departments, Corporate bodies, Input Agencies and Civil Society Organisations (CSOs).

Need for training / capacity building of farmers

The agriculture has experienced a paradigm shift over a period of time. The agriculture was considered as way of life and mainly the farm produce were grown for self consumption. Gradually number of farmers who grow for markets have increased. This shift not only requires the knowledge about consumer preferences but also require scientific management of production to maintain the requisite quality. Increasing the skills of farmers to keep pace with current knowledge and diffusion trends is essential.

Through training one can improve the knowledge and skill levels of farmers and keep them up dated with the latest information required to carry out various farming operation more scientifically and to empower them to take appropriate decisions that enable them to realize better profits.

Capacity building past, present and future

Capacity building is an action plan to impart required skills through various extension education methods to upgrade their technical competency required for farmers. Among various methods / approaches trainings are more popular ones for farmers. Other methods used are Farmers Field School, participatory technology development, on farm demonstrations, etc.

Earlier, the emphasis in capacity building programs was on enhancing technical skills required by farmers on crop improvement and allied enterprises. The mode of delivery in capacity building programmes was mainly through lecture method.

In the present context, farmers also require sufficient exposure to consumer preferences and marketing of agricultural commodities to fetch better prices to their produce. In order to meet this requirement, technical, managerial, marketing and ICT related skills are necessary to acquire. The mode of delivery in capacity building programmes has been shifted from mere lecture to more of participatory and interactive approaches besides using appropriate audio visuals and ICT tools.

In future, group centered educational approaches are appropriate. The experience in some of the initiatives have shown that formation of commodity based organizations can empower farmers especially the resource poor in technology acquisition, production and marketing of produce at remunerative prices. It is a challenge to promote such groups and building their capacities to manage on their own.

Approaches in capacity building

With the penetration of ICT into rural areas, virtual training mode can be effectively used to reach the unreached.

Distance education can be an effective method for those farmers who have been deprived of formal education during their potential phase of learning. This method can overcome the geographical barrier.

Farmers Field School (FFS) is a non-formal learner centered education process, intended to empower farmers to address the field problems actively by fostering participation, interaction, dialogue, joint decision making and collective action. Farmers' field school believes in group activity as the productivity will be maximum within small groups.

Pluralistic extension education approaches involving public, private and CSOs for effective technology education on production, storage, grading, processing, value addition, marketing and trade.

Institutional efforts in capacity building

Krishi Vigyan Kendra (KVK)

Krishi Vigyan Kendra (Farm Science Centre) is an innovative institution of ICAR established at district level. The first KVK was established during 1974 and has grown as a largest network in the country with 631 KVKs during 2012. KVKs are funded by ICAR and administered by ICAR institutes / SAUs /

Deemed Universities / Non-government Organizations or State Department of Agriculture. KVKs play a supportive role in the larger agricultural extension system.

KVKs play a vital role in conducting on farm testing's to identify location specific agricultural technologies and demonstrating the production potential of crops at farmers' fields through frontline demonstrations. They also conduct need based training programmes for the benefit of farmers and farm women, rural youths and extension personnel to update their knowledge and skills and to orient them in the frontier areas of technology development. KVKs are providing both on campus and off campus programmes along with other educational programmes to cater the needs of the farming community. Critical and quality inputs like seeds, planting materials, organic products, bio-fertilizers and livestock, piglet and poultry strains are produced by the KVKs and made available to the farmers. Agricultural Knowledge and Resource Centers are set up at KVK to support the initiatives of public, private and voluntary sectors at district level.

The Krishi Vignana Kendra once started with an objective of imparting vocational training, now becoming a platform of learning at district level with enhanced backward and forward linkages. Of late, the roles of KVKs have become more challenging. The era of linkages, partnerships and convergence, demands a new sense of visioning, approach and commitment of KVKs to respond to the changing environment. Different models of linkages and convergence with ATMA, RKVY, NFSM, NHM, MGNREGA etc., have emerged over time. The contribution of KVKs in supporting ATMA initiatives have been quite significant in the areas of formulating SREP, CDAP and imparting HRD programmes for farmers and extension functionaries. The role of KVKs in horticulture mission has been tremendous for production of quality planting material.

Distance education

Distant education programmes are helpful in educating farmers located at distant to upgrade their knowledge and skills using different modes other than formal education. These educational programmes are organized for the benefit of various segments of the farming community, entrepreneurs, self help groups and other learners who are interested in establishing agro-based industries in rural areas. Distance education helps farming community by

- Promoting entrepreneurial skills among learners for creating self employment opportunities.
- Offering continuing professional education.
- Offering developmental extension education for the rural people.
- Offering agricultural education to special groups of rural people in general, and school dropouts, small and marginal farmers and women in particular.
- Providing innovative education by using distance learning and teaching methods supported by modern Information Communication Technology (ICT) including e-learning mode.
- Orienting the courses that would provide for developmental needs of the individuals, institutions/ organizations and the state.

UAS Bangalore has started offering Correspondence course in organic farming, certificate courses in collaboration with Karnataka State Open University study center activities for agriculture related courses under School of Agriculture, IGNOU, New Delhi and diploma courses through distance education center on food processing and value addition, integrated farming systems, etc.

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Diploma courses for rural youth

Decreasing trend in number of field level extension functionaries has necessitated development of field level extension workers to address the complex agricultural issues through technology education. In this regard, Government of Karnataka supported the SAUs to start two years duration diploma courses for the SSLC passed youth. This would also help diploma holders to settle down in farming to become successful agripreneurs. .

Attracting and retaining rural youth in agriculture

Youth is an important segment with one-fourth of population in developing countries. They are having spirit, enthusiasm, dynamics and receptive to new ideas. But in recent years, the youth are migrating to urban areas leaving agriculture which is a major concern for sustain agricultural growth. This demands new strategies in educating them in area like educating youth in establishing profitable enterprises in rural areas, creating directory of enterprises to guide them in establishing profitable ventures, capacity building of rural youth to serve as input managers, networking of rural youth, creation of youth hubs in selected locations, establishing rural incubation centres, etc.

Linking small producers with markets

Small and marginal farmers now constitute over 80 percent of farming households in India. They have only very small quantities of marketable surplus. Moreover, their staying power is low because of their extreme poverty. As a result, these farmers sell off most of their produce in the local markets at very low prices immediately after the harvest. Thus, farmers' suffer even in years of a good harvest, since they are not able to get food price realization. The obvious solution is for these farmers to aggregate their produce and reach bigger markets where they can get a better price for their produce. The University of Agricultural Science, Bangalore has experimented the concept of linking the farmers with markets through the Rural Bio-Resource complex project implemented in Bangalore district of Karnataka.

Rural Bio-Resource Complex Project

The Rural Bio-Resource Complex (RBRC) Project was conceptualized during 2004 in the UAS Bangalore by the team of 32 interdisciplinary scientists with a view to revisit the unsustainable agricultural system. The project was implemented on a pilot scale with financial assistance from DBT-GOI in Tubagere Hobli of Bangalore Rural District covering 8340 farming and non-farming families spread over in 75 villages from April 2005 to March 2010. The project has formulated and executed strategy consisting of six factors to enhance income and standard of living of farmers, which include, i) Promotion of capsule of integrated technologies, ii) Ensuring effective information support system, iii) Access to quality inputs and custom hire services of agricultural machineries, iv) Effective functional linkage with various institutions working in rural area, v) Market empowerment and vi) Establishment of producers/ commodity based associations. The RBRC project implemented series of capacity building programs to various stakeholders especially farmers through education and training. The results are highly encouraging.

Empowerment of farmers - A critical need

Enhancing farm production efficiently ultimately depends on management efficiency. Improvement in managerial efficiency can only be brought through empowering farmers by upgrading their knowledge and skill. Empowerment on various facets of agricultural activities right from choice of crops to consumer preference is essential to farmers to enable them to reap the benefit for their toil. While some of the farm activities need individual empowerment, like technology adoption, carrying out timely farm operations, etc., the other activities like information on markets, transportation of farm produce need group approach to strengthen especially small and marginal farmers with bargaining power to realize remunerative prices to their produce.

Challenges

- Farmers themselves are loosing confidence in farming particularly as individual.
- Ratio between extension personnel and farm family is continuously declining (0.1m against 1.3m required)
- Youth are migrating to urban areas leaving agriculture
- Wide margin between farmer share to that of what the consumer pays
- Per capita land holding and natural resources are declining
- Lesser aptitude of extension functionaries to work in villages
- The proportion of women farm graduates is increasing
- Decline in Commitment of extension functionaries

Opportunities

- Enough technologies are available to double the income in less than three years

- Forming farmer based / Commodity Based Associations (CBAs)
- Every district has a KVK and many NGOs have training institutes, expert centers to VRCs/VKCs
- Recognition of creative and innovative farmers as a local resource person at appropriate time & place
- Use of mobile / other ICT tools
- Possible to reduce the overhead charges
- Identify and encourage successful farmers / representatives of CBAs to serve as local resource persons
- Utilizing services of awardees for technology education to fellow farmers.

Constraints in capacity building

Following are some of the important constraints in organizing capacity building programs in agriculture:

Human resource

- Inadequate number of grassroot level institutions
- Wider extension worker –farmer ratio
- Lack of homogeneity among participants
- Socio-economic constraints among participants
- Lack of motivation
- Lack of convergence of stakeholders.
- Divergent skill sets required by the participants
- Lack of trained resource persons

Infrastructure facilities

- Inadequate infrastructural facilities
- Inadequate funds

Managerial

- Inadequate follow up
- Technology backup

Strategies to enhance the efficiency of training programmes

Human resource

- Conduct of trainers training programmes
- To address gender issues
- Training farmers as technology agents to provide guidance to fellow farmers

Infrastructural facilities

- Provision of adequate funds for capacity building programs.
- Adequate manpower and infrastructure support
- Creating virtual learning facilities

Managerial

- Proper linkage among the institutions associated with capacity building programs,
- Recognizing and rewarding farmers / extension personnel
- Use of trained participants as resources persons.
- Proper usage of modern ICT in capacity building
- Follow up programs to the impact of training program
- Providing economically viable, socially acceptable profitable technologies by increasing quality of resources
- Provision for handholding to trainees to establish own enterprises
- Policy framework for better convergence

Technical

- Evaluation of capacity building programs
- Wide coverage of successful entrepreneurs in mass media

- Impact assessment
- Yield gap analysis
- Different extension approaches for innovators, early adopters, late adopters and laggards.
- Introducing participatory technology development
- Blending of research and extension effort for up-scaling technologies
- Focus on knowledge management concept
- Focus on IFS model
- Focus on farmers innovations
- Youths should be encouraged
- Enhance Farmers-Scientists-Extension workers interaction programmes.

Conclusion

Capacity building is a continuous process for imparting knowledge, skill and required competencies to the farming community. Important approaches in capacity building of farmers are farmers field schools, participatory technology development, on farm demonstrations, use of ICT, working through groups, distance education, empowering youth, etc. The available institutional arrangements like KVKs, SAUs, ICAR institutions and CSOs need to be strengthened and involved in capacity building approaches.

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Agriculture: An Ecological and Economic Pursuit for Youth

Anil P. Joshi

Agriculture is one of the first sign of human civilization and will remain most important in future too. In past, growth in Agriculture has adjusted and absorbed all stresses that it had to go through. Today's agriculture is a product of several hundred years untired human efforts. Some steady change in demography and environment brought pressing demand of change in agriculture in recent past. The major challenge of agriculture has all time been to cater large population of the world. The productivity syndrome brought major shift from culture to commerce in farming system. The agriculture was defined to produce eatables from a given piece of land within available resources to cater food need. It was totally pro-environment where resource uptake and release were strikingly balanced. It was called Agriculture. The philosophy changed with the time. It became more as to meet not hunger only but to commercialize the same. This also changed the course of agri-culture to commerce. In order to gain more and more from piece of land, the other unnatural practices were adopted. The justification given was to meet large hungry population, such practices can only do the wonder.

Where is toady's agriculture is not debatable but where it is ultimately leading us is more important. There is urgent need of review of our agricultural policy specially its ecological sustainability. The increasing inputs in agriculture are making this community victim of market forces. The recent price hike in food items is an alarm to all of us. The whole economy was jeopardized mainly because of the rising cost of farm inputs.

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Indiscriminate use of environmental supplements especially water have paralyzed the water budget of the globe. Chemicals as major replacement of soil have spoiled genuinely of the same. More and more production have brought phenomenal change in agriculture, intact with it were all environmental hazards. The current agriculture is cultureless agri-commerce. There is no reason it to be any more honoured with culture.

The growing population food need is a reasonable issue and is moral responsibility of any state to cater food needs of its community. The issue infact requires to be looked from many other points of view. Way back in past, the land under agriculture was essentially used for production of grains only. In course of time for other development activities agriculture land was transformed for commercial purposes, reducing area under production. The growing population size should entail more and more area under agriculture which ironically is reducing. It is therefore necessary to reserve a fixed percentage (%) of land under agriculture to cater likely population of 2050.

There has been another unfortunate development in this sector. Wheat and paddy were promoted as major cereals as these crops were honored as food for elite class. Local cereals, pseudo cereals and millets were totally neglected from our plan of action. By doing so we just ignored a natural process of soil, seed and needs. Every climatic zone has an ecological relation with local soil and human physiology and nature governed this process. What we produce locally in a particular set of condition is important for human physiological needs. The crop inputs are also limited and pro-environment. The commercializations of this sector brought many local changes in choice of crops and accordingly change in inputs.

What is currently needed is to redefine regional strength and needs, which of course may vary from community choice. This largely depend upon what has been offered them in past. Pizza, chowmin and other foreign recipes have made very strong place in Indian food table. Such experiences teach us a lesson to bring attractive value addition in local produce so that their acceptance values gain hike. Such a wide community approval will bring respect to neglected crops. The evidences are many now. Many nutritionally rich crops are gaining popularity now. These crops once become regular part of daily appetite, their production demand will conditionally take place and will significantly contribute in food requirement of the state. This would ultimately encourage local crops too and will open avenues for true agriculture. This is high time to restore and rejuvenate pro-environment agriculture with new knowledge inputs.

There are few sectors where replacive knowledge can damage vary systems and besides water, air and soil, agriculture is one. We must ensure that high productivity must be inclusive to local eco-physiological condition. Such efforts can check the ever growing chaos on soil, water and varietal conflicts.

It is currently difficult to involve youth in agriculture or back to village. They are ready to become agricultural graduates to get job in agricultural outfits but never tend to come back in villages as farmer or producers. They don't find primary productivity remunerative and paying against the labour. Their interest as current state of farming is not possible. The ready and handsome return is the only way the youth can be attracted towards.

There are starking observation of one survey undertaken in 2008 by a group of social workers on farm and farming. Many farmers wanted their children/ youth to stay in farming provided they get minimum agri-education. This education was difficult for them as they did not either have access or was in affordable. It should be free especially for youth who intend to come back in villages. The other observation was pity. Farmers were selling their land to earn education for their children. They wanted their children to take some professional degree to get some job other than agriculture.

There were some observations with rays of hope. Many farmers with their children used "Combo" approach in farming. They were not only producing the crops but were marketing the same by adding the values. This brought them better return and also encouraged them to explore diverse possibilities.

We have to review our current approach in farming. It must be inclusive, where product and market becomes more farmers share. This would bring attractive return and will also draw youth. There are example today and have been in past too. Where farmers became the owner of value added products of their farm produce. Take an example of sugarcane farming. Many farmers themselves process sugarcane to Jaggary and fetch better prices. In Uttar Pradesh, many farmers have mentha oil extraction units for their mentha produce. Mustard oil and cotton are some other example where youth get true return of their produce.

Agriculture in India and youth's involvement in same is a challenge today. It has to be in a combo approach; agri-education, production technologies, value addition and marketing have to be offered in a package form. This can only bring them to rethink on their stand towards agriculture.

Institutional Framework for Supporting Horticulture

Shailendra Kumar

Horticulture production base is distributed over an area of 22.25 million hectares across the length and breadth of the country, producing about 249 million tonnes of produce. This includes different commodities as indicated in Table 1.

Table 1: Area and Production of Horticulture Crops (2011-12)

Commodity	Area (M ha)	Production (MMT)	Productivity (MT/ha)
Fruits	6.6	75.3	11.4
Vegetable	8.8	150.6	17.1
Spices	3.0	5.7	1.9
Flowers (loose)	0.3	1.7	5.7
Plantation Crops	3.3	15.4	4.7
Other	0.5	0.7	NA
Total	**22.5**	**249.4**	**11.1**

During last couple of decades there has been a distinct shift in focus of development towards horticultural crops as compared to traditional food (cereal) crops. Horticultural crops, in view of their ability to generate higher profitability for farmers through higher economic returns per unit area and being a good source of nutrition have emerged as a viable agri-business diversification option. The focus has been combined with substantial increase in financial support by Government of India during Plan periods since VIII Plan. Channelization of financial resources through effective delivery mechanism called for development of appropriate institutional frame work at different levels. Such an Institutional framework for supporting horticulture programmes at National level

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has been initiated by the Ministry of Agriculture (MoA), Government of India.

The Indian Council of Agricultural Research (ICAR) under Department of Agricultural Research & Education (DARE) in the MoA addresses the research and education related aspects of horticulture through its Directorates / National Research Centres (NRCs). Presently there are 10 Central Institutes, six directorates, seven NRCs, 13 All India Coordinated Projects under the agies of Horticulture Division of ICAR.

The Horticulture Division in the Department of Agriculture & Cooperation (DAC), through various schemes / programmes cater to the developmental issues in the sector. At State level, Departments of Agriculture/Horticulture provide the required institutional support.

Various organizations / Institutions engaged in development of horticultural crops by DAC are detailed here under.

Horticulture division

The Horticulture Division was created in September, 1980. Policy planning for horticulture development is being done by the Horticulture Division in the DAC headed by Additional Secretary, who is supported by Joint Secretary & Mission Director (NHM) and Horticulture Commissioner. The Division has the following mandate:

- Support and formulate policies aimed for accelerated growth of horticulture.
- Provide leadership and co-ordinate activities for the promotion of horticulture.
- Implement programmes for improving production, productivity and utilisation of horticultural crops.
- Facilitate the availability of disease free planting material and seeds of horticultural crops.
- Work as facilitator for the transfer of technology to farmers and promote the use of information technology.
- Promote better utilisation and increased consumption

of horticultural produce to ensure higher returns to farmers and nutritional security to people.

- Develop strong base for the supply of inputs, transfer of technology and human resource developmental activities.
- Promote efficient irrigation systems.
- Promote horticulture in NE region, hills, tribal & backward areas for improving economic status of people.
- Promote cold chain logistics and management.

Schemes and related institutional framework

The Horticulture Division is implementing four Mission Mode schemes, viz, Horticulture Mission for North East & Himalayan States, National Horticulture Mission, National Mission on Micro Irrigation and National Bamboo Mission for the development of horticulture sector in the country. All these schemes have institutional mechanism for administering the programmes.

Horticulture Mission for North East & Himalayan States

The HMNEH, which was launched during the year 2001-02, comprises of four Mini Missions for addressing all the aspects of Horticulture development with an end-to-end approach. Mini Mission-I, involving research, is coordinated and implemented by the Indian Council of Agricultural Research (ICAR). Mini Mission-II, covering production and productivity improvement activities, is coordinated by the Department of Agriculture & Cooperation and is implemented by the Agriculture/Horticulture Departments of the States. Mini Mission-III involving post harvest management, marketing and export is coordinated by National Horticulture Board (NHB) and Mini Mission-IV involving processing is coordinated and implemented by the Ministry of Food Processing Industries (MFPI). A Central Steering Committee under the Chairmanship of Secretary (A&C) is responsible for overseeing the overall implementation of the scheme. State level Small Farmers Agri Business Consortiums (SFACs) have been constituted in most of the States for monitoring and implementing the programme at the grass root level. State Level Steering Committee under the

Chairmanship of Chief Secretary of the concerned state monitor the scheme at the State level.

National Horticulture Mission

The National Horticulture Mission (NHM) was launched during 2005-06 with the objective to promote holistic growth of the horticulture sector in all the mainland States & UTs by adopting an end to end approach, duly ensuring backward and forward linkages.

For overseeing the implementation of the Mission a three tier structure has been set up. At the National level, there is a General Council (GC) and an Executive Committee (EC). While the GC under the Chairmanship of Agriculture Minister provides overall direction to the Mission, the Executive Committee (EC) headed by the Secretary (Agriculture & Cooperation) oversees the activities of the Mission and approves the Annual Action Plans (AAPs) of the States and National level Agencies. At the State level, an Executive Committee under the Chairmanship of the Agricultural Production Commissioner, or Secretary Horticulture/Agriculture oversees the implementation of the programmes. At the District level, the District Mission Committee (DMC) under the Chairmanship of Chief Executive Officer (CEO) of zila parishad / CEO of District Rural Development Agency (DRDA) is responsible for project formulation and monitoring.

National Mission on Micro Irrigation

The National Mission on Micro Irrigation (NMMI) was launched during 2010-11 after restructuring the Scheme on Micro Irrigation with the objective of promoting improved systems of irrigation such as the drip and sprinkler irrigation. The Executive Committee of NMMI oversees the implementation of the scheme besides approving Action plans of different states.

National Bamboo Mission

The National Bamboo Mission (NBM) was launched during year. 2005-06 for the holistic development of bamboo sector. The Scheme has a National Apex Committee under the Chairmanship of Agriculture Minister and a National Steering Committee under the Chairmanship of Secretary (A&C) to oversee the implementation of the programmes. The NBM also has three Working Groups covering the area of (i) Research & Development, (ii) Plantation Development and (iii) Handicrafts, Marketing & Exports.

Commodity Boards & Directorates

There are two Boards namely, National Horticulture Board (NHB) & Coconut Development Board (CDB) and two Directorates namely Directorate of Arecanut & Spices Development (DASD) and Directorate Calicut of Cashew and Cocoa Development (DCCD), Kochi supporting horticultural development activities in the Ministry of Agriculture with a focus on selected crops except for NHB.

National Horticulture Board (NHB)

The National Horticulture Board (NHB) was set **up** by the Government of India in 1984 as an autonomous society under the Societies Registration Act, 1860 with a mandate to promote integrated development of horticulture, to help in coordinating, stimulating and sustaining the production and processing of fruits and vegetables and to establish a sound infrastructure in the field of production, processing and marketing with a focus on post-harvest management to reduce losses.

The Board's programmes include :-

- Capital investment subsidy scheme for construction/ expansion/modernisation of cold storages and storages for horticulture produce.
- Development of commercial horticulture through production and postharvest management.
- Technology development and transfer for promotion of horticulture.
- Market information service for horticultural crops.
- Establishment of nutritional gardens in rural areas.
- Horticulture promotion service.
- Strengthening capabilities of the NHB.

NHB has a network of 33 regional offices located in different states to promote horticulture in the country.

Coconut Development Board (CDB)

The Coconut Development Board was established on 12th January, 1981 under the Coconut Development Board Act, 1979 enacted by the Parliament. It has a mandate for integrated development of coconut industry in the country through promoting production, processing, marketing and product diversification of coconut. The functions of the Board are:

- Adopt measures for the development of coconut industry.
- Recommend measures for improving marketing of coconut and its products.
- Impart technical advice to those engaged in coconut cultivation and its industry.
- Provide financial and other assistance for expansion of area, improving productivity and product diversification.
- Compile statistics on coconut.
- Undertake publicity and publication activities.
- Encourage adoption of modern technologies for processing of coconut and its product.
- Recommend measures for regulating imports and exports for coconut and its products.
- Fix grades, specifications and standards for coconut and its products.

The Board has its headquarters at Kochi, Kerala, with three Regional offices at Bangalore (Karnataka), Patna (Bihar) and Chennai (Tamilnadu) and six State Centres at Hyderabad (Andhra Pradesh), Kolkatta (West Bengal), Guwahati (Assam), Agartala (Tripura), Bhubaneshwar (Odisha) and Port Blair (Andaman & Nicobar Islands).

National Centre for Cold Chain Development (NCCD), New Delhi

NCCD has been constituted during the year 2011-12 in a Public Private Partnership mode for addressing the issues relating to cold chain management including standards, protocols and HRD. The Governing Council of NCCD under the Chairmanship of Secretary (A&C) is responsible for overseeing the activities of NCCD.

Directorate of Cashewnut & Cocoa Development (DCCD), Kochi DCCD

Came into existence with effect from 01.04.1966, with its headquarters at Kochi (Kerala), as a subordinate office of the Ministry of Agriculture which is devoted to the development of cashew and cocoa. DCCD is responsible for formulation and coordination of schemes / programmes for development of cashew and cocoa in the country. It maintains close liaison with the State Governments and other state level agencies in implementation of its programmes. DCCD is also an NLA under NHM.

Directorate of Arecanut & Spices Development (DASD), Calicut

This Directorate was established at Calicut, Kerala with effect from 01.04.1966 as a subordinate office of the Ministry of Agriculture. It has the mandate to monitor and implement schemes on development spices, medicinal & aromatic plants and arecanut at the national level. These schemes are implemented through State Governments, Agricultural Universities, ICAR Institutes as well as through Regional Research Laboratories under Council of Scientific & Industrial Research (CSIR) and monitored by the Directorate.

National Committee on Plasticulture Application in Horticulture (NCPAH), New Delhi

A National Committee on Use of Plastics in Agriculture was initially constituted in the Department of Chemicals & Petro-chemicals to promote use of plasticulture in agriculture. In November, 1993, it was transferred to the Ministry of Agriculture. Subsequently, in 1996 it was reconstituted as National Committee on Plasticulture Applications in Horticulture. The Committee is Chaired by Agriculture Minister. The NCPAH has the mandate to monitor the activities relating to plasticulture under various schemes involving micro irrigation green houses, shade net house, plastic mulching etc.

There are 22 Precision Farming Development Centres (PFDC) working in the country at major Agriculture Universities situated in different agro-climatic conditions. PFDC's had been given broad mandate to develop and valide precision farming technologies besides carrying out adaptive research in areas of drip irrigation, green houses, mulching, online field channels, sprinkler irrigation, etc.

Bee-keeping development board, New Delhi

This is a co-ordinating Board to integrate the programme on honey bee. The Board is headed by Secretary (A & C). The Board decides the various programmes to be taken up for the development of honey bee & bee products.

State departments

Many State Governments have created separate Departments of Horticulture along with Directorates of Horticulture for implementing the horticultural development programmes with Central / State funding. The Directorates are also responsible for transfer of technology to the farmers for cultivation of horticulture crops.

List of states along with the Departments looking after various horticulture commodities is given in Table 2.

Table 2: Departments responsible for development of horticulture in different States

Sl. No.	Name of States/ UTs	Department	Crop Responsibility
1.	A&N Islands	Agriculture	All horticulture crops
2.	Andhra Pradesh	Horticulture	All horticulture crops
3.	Arunachal Pradesh	Horticulture Agriculture	Fruits Vegetable & Spices
4.	Assam	Forestry Agriculture	Floriculture All horticulture crops
5.	Bihar	Horticulture.	All horticulture crops
6.	Chhatisgardh	Agriculture	All horticulture crops
7.	Goa	Agriculture	All horticulture crops
8.	Gujarat	Horticulture.	All horticulture crops
9.	Haryana	Horticulture	All horticulture crops
10.	Himachal Pradesh	Horticulture Agri-culture	Fruits/floriculture and me-dicinal & aromatic plants Vegetables, potato and spices

Sl. No.	Name of States/ UTs	Department	Crop Responsibility
11.	Jammu & Kashmir		All horticulture crops Vegetables & spices floriculture All horticulture crops
12.	Jharkhand	Agriculture Forestry Horticulture.	
13.	Karnataka		
14.	Kerala	Agriculture	All horticulture crops
15.	Lakshadweep	Agriculture	All horticulture crops
16.	Madhya Pradesh	Horticulture	All horticulture crops
17.	Maharashtra	Horticulture	All horticulture crops
18.	Manipur	Horticulture & Soil conservation	All horticulture crops
19.	Meghalaya	Horticulture	All horticulture crops
20.	Mizoram	Horticulture	All horticulture crops
21.	Nagaland	Horticulture	All horticulture crops
22.	Odisha	Horticulture	All horticulture crops except cashew
23.	Puducherry	Agriculture	All horticulture crops
24.	Punjab	Horticulture	All horticulture crops
25.	Rajasthan	Horticulture	All horticulture crops
26.	Sikkim	Horticulture	All horticulture crops
27.	Tamil Nadu	Horticulture & Plantation crops Agriculture	All horticulture crops coconut, oil palm
28.	Tripura	Horticulture & Soil conservation	All horticulture crops
29.	Uttar Pradesh	Horticulture & Food rocessing	All horticulture crops
30.	Uttrakhand	Horticulture	All horticulture crops
31.	West Bengal	Horticulture Agriculture	All horticulture crops Potato

Institutional issues

The implementation of mission mode schemes like NHM, HMNEH, NBM and NMMI have reached a stage where there is possibility of integration and merger.

NHB has been playing an active role in promoting entrepreneur driven commercial horticulture in the country. The regional offices located in the States serve as a close link between the farmer / entrepreneur, State Government and NHB

HQ. There is scope to strengthen these centres with dedicated manpower and infrastructure facilities.

CDB's interventions are crucial for sustaining the coconut sector in the country. Of late there has been marked fluctuation in price of coconut, which calls for product diversification. CDB's efforts in this regard has helped in enabling farmers to get remunerative price for coconut through its diversification into products like desiccated coconut, coconut water, coconut vinigar etc. Close coordination between COB and the State Governments of coconut growing states is necessary for effective implementation of CDB schemes.

While in States like Karnataka, Jammu & Kashmir and Uttar Pradesh, the Departments of Horticulture are quite old, in most others these departments have been set up only during the last 2-3 decades. These departments have been carved out of Directorates of Agriculture without adequate infrastructure and technical support for horticulture.

Most of the States are in the process of strengthening the Horticulture Department looking into contribution of horticulture sector in state Gross Domestic Product (GDP).

With the launching of NHM, Mission Directors in the respective states are assigned with the task of monitoring the NHM activities. Post of separate Mission Director been created in the States of Kerala and Maharastra where as in other States, the Director of Horticulture continue to function as Mission Director of State Horticulture Mission (SHM).

Provisions have been made under NHM scheme to engage Technical support Group (TSG) by drawing experienced resource personnel / scientists on contractual basis for providing technical support under different disciplines of horticulture.

Under the Mission Management component, the SHMs have been allowed to engage Field Consultants for providing support at Block level in the NHM districts. Most of the states have availed this facility to strengthen the manpower requirement of grass root level. However, it is a fact that in most of the states there is lack of suitable manpower at the block level and below.

Looking into the role of horticulture sector in accelerating growth rate in agriculture, the horticulture sector is expected to play a key role in the coming years. It is imperative that a strong institutional back up with deployment of trained manpower is need of the hour for sustaining the growth in horticulture sector.

Research and Policy Framework for Conservation and Utilization of Edible Bamboo

A. Arunachalam, J. M. S. Tomar and O. P. Chaturvedi

India ranks third next to China (300) and Japan (237) in bamboo diversity (Tewari, 1992) and ranks second only to China in bamboo production with 3.23 million tons per year. From a total area of 10.03 million hectares (Sharma, 1980; Biswas, 1988), this constitutes around 12.8% of the total area of forest cover in the Country. Out of 125 plant species (represents 23 genera) recorded so far in India, nearly 78 are available in the north-eastern region. Amongst six states of the north-eastern hill (NEH) region, Mizoram occupies largest forest area (30.8%) under different bamboo species (Table 1), followed by Meghalaya with 26.0% (Trivedi and Tripathi, 1984). Environmentally, bamboos have been found to be the best for restoration and short-rotation forestry (Arunachalam and Arunachalam, 2002). On an average, living and litter biomass of bamboo has significantly higher concentration of potassium than dicot trees (Rao and Ramakrishnan, 1989). Owing to their gregariousness and fast growing nature, bamboo form complete colony within 4-5 years of plantation with production of young shoots after 3 year of plantation (Pynskhem *et al.*, 2010). Mature culms are used to make house, flooring, roofing, fencing, carrying the water from long distances and various other day-to-day requirements. Most importantly, the bamboo shoots being an intercontinental edible delicacy are typical secondary products exported to Japan, USA, Germany, Saudi Arabia and Denmark by China and Taiwan. In the north-eastern hill (NEH) region, an array of fresh and fragmented bamboo products are prepared for internal consumption. But the biochemistry of edible bamboos has not been given due attention (Bhatt *et al.*, 2001). Nevertheless, the edible species are quite frequently cultivated in home gardens, besides their occurrence in the natural forests. If scientifically explored and validated, the

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NEH region can share the global export of steamed and canned bamboo shoot to European countries. As this region is the largest reservoir of bamboo resource in India (Table 2), screening is required to find most delicate bamboo species and develop package of practices for their mass multiplication. This paper discusses on a research and policy framework for conservation and utilization of edible bamboo in the country and NEH region in particular.

In order to evolve a research and policy framework for edible bamboo utilization and conservation, relevant information from published information with special reference to northeast India were analyzed, based on which, important research and policy issues attributing to management and marketing have been appraised thereof. For critical analysis of the framework, a SWOT analysis was carried out and institutional arrangements have been suggested in this paper.

Management of bamboo resources

Being a versatile and renewable resource, bamboo has been over-exploited to the extent that concern is being expressed over erosion of this gene-pool (Renuka, 1996). Over-exploitation affects regeneration of bamboo in their wilderness, apart from mundane flowering. As far as edible species of bamboo are concerned, there are seven genera (Table 2) whose tender shoots are consumed over a prolonged period (Hore, 1998). Such continued extractions could also be limiting to the natural regeneration potential, perhaps threatening their survival. This region has witnessed mass flowering of *Melocanna baccifera* during 2005-2007 (Pynskhem *et al*., 2010). Absence of quality planting material and continued supply of bamboo to paper and pulp industry has significantly affected the livelihood of the humans. Therefore, conservation of this valuable gene pool is warranted for sustainable utilization and profitability. Furthermore, given the climate change scenario, bamboo could contribute tremendously to the carbon sequestration process. Evidently, the recent report on State of Forests in India (FSI, 2011) indicates the role of bamboos and trees outside forest (TOF) in carbon budgeting.

Appreciable research has been carried out on bamboo germplasm collection and resource conservation by various prominent agencies like Forest Departments, Kerala Forest

Research Institute (KFRI), State Forest Research Institute (Itanagar), Indian Grassland and Fodder Research Institute (IGFRI), Indian Council of Forestry Research and Education (ICFRE), National Bureau of Plant Genetic Resources (NBPGR) and Forest Research Institute (FRI) etc. several amongst others. Nonetheless, independent research highlighted the importance of bamboo-based agroforestry systems in increasing soil moisture and, nutrients, while reducing water run-off and soil erosion (Sharma *et al*., 1992; Ramakrishnan and Toky, 1981). Due to the shrinking bamboo resources, careful determined and consistently chalked out programme for plantation in farm and forest sector is very much essential.

Table 1: Area-distribution of major edible bamboo species in hilly states of the North Eastern region

State	Geographical area (km^2)	Total forest cover (km^2)	Actual area under bamboo (km^2)	Potential availability (lakh tons)
Arunachal Pradesh	87,743	51500	7770 (9.50)	2.23
Manipur	22,327	6020	3263 (14.62)	14.48
Meghalaya	22,429	9490	5863 (26.00)	8.25
Mizoram	21,081	13030	6047 (30.81)	6.34
Nagaland	16,579	8620	2405 (22.19)	4.90
Tripura	10,486	6060	2849 (27.13)	5.50

(Source: Anonymous 1999); Percentage of area under bamboo species are given in parentheses

Being a cross-pollinated species, bamboo exhibits greater variation in wild, which can be utilized in genetic improvement of this species, although bamboo could be successfully grown by sowing of seeds. Nonetheless, most bamboo improvement programmes is based on phenotypic selection, followed by clonal multiplication of superior clumps. Since all the characters of mother clumps are inherited in the progenies, their performance is very well predictable. This is the only method of crop improvement in case of *Bambusa balcooa*, *B. vulgaris* and *Dendrocalamus strictus* which however do not set seed after flowering. Moreover, the seeds of other bamboo species are short-lived (viability of 1-2 months). Nevertheless, no efficient storing techniques have so far been standardized

Table 2: Bamboo species in north-eastern states of India

	Species	Arunachal Pradesh	Assam	Manipur	Meghalaya	Mizoram	Nagaland	Tripura
	Edible Bamboo							
1	*B. balcooa* Roxb.	+	+	-	+	-	+	+
2	*B. bambos* (L.) Voss	+	-	+	-	-	-	-
3	*B. khasiana* Munro	-	-	+	+	-	-	-
4	*B. longispiculata* Gamble ex Brandis	-	-	-	-	+	-	-
5	*B. nutans* Wall. ex Munro	+	+	-	-	-	-	-
6	*B. pallida* Munro	+	+	-	+	+	+	+
7	*B. polymorpha* Munro	+	-	+	+	-	-	+
8	*B. teres Buch*.- Ham. ex Munro	+	+	-	+	-	+	+
9	*B. tulda* Roxb	-	+	-	+	+	+	+
10	*B. vulgaris Schrad*. ex Wendl	-	-	+	-	-	-	-
11	*Chimonobambusa hookeriana* (Munro) Nakai. Synonym *Himalayacalamus hookerianus* (Munro) Stapleton	-	-	-	+	+	-	-
12	*Dendrocalamus brandisii* (Munro) Kurz	-	-	+	-	-	-	-
13	*D. giganteus* Munro	+	+	+	-	-	+	-
14	*D. hamiltonii* Nees et Arn. ex Munro	+	+	+	+	+	+	+

15	*D. hookeri* Munro	+	-	+	+	+	+	-
16	*D. longisphathus* Kurz	-	-	-	-	+	-	+
17	*D. sikkimensis* Gamble	+	-	-	+	-	+	-
18	*D. strictus* (Roxb.) Nees	-	-	-	-	-	-	+
19	*Gigantochloa albociliata* (Munro) Kurz	+	+	-	+	-	-	-
20	*G. apus* (Bl. ex schult. f.) Kurz	-	-	-	+	-	-	-
21	*G. macrostachya* Kurz	-	+	-	+	+	-	-
22	*Himalayacalamus falconeri* (Hook. f. ex. Munro) Keng	+	-	-	-	-	-	-
23	*Melocanna baccifera* (Roxb.) Kurz	-	+	+	+	+	-	+
24	*P. bambusoides* Sieb. & Zucc.	+	-	-	-	-	-	-
	Others							
25	*Arundinaria gracilis* Blanch	+	-	-	-	-	-	-
26	*A. hirsute* munro	+	-	-	-	-	-	-
27	*A. microphylla* Munro	-	-	-	+	-	-	-
28	*A. racemosa* Munro	+	-	-	-	-	-	-
29	*A. rolloana* Gamble	-	-	-	-	-	+	-
30	*Bambusa affinis* Munro	-	-	-	-	-	-	+
31	*B. auriculata* Kurz	-	+	-	-	-	-	-
32	*B. cacharensis* R. Majum	-	+	-	-	-	-	-
33	*B. griffithiana* Munro	-	-	+	-	-	-	-
34	*B. jainthiana* R. Majum	+	+	-	-	-	-	-

35	*B. kingiana* Gamble	-	-	+	-	-	-	-
36	*B. masiersii* Munro	-	+	-	-	-	-	-
37	*B. multiplex* (Lour) Raeusch	+	-	-	-	-	-	-
38	*B. oliveriana* Gamble	-	-	-	-	+	-	-
39	*B. pseudopallida* R. Majum	-	+	-	+	-	-	-
40	*Butania pantlingii* (Gamble) Keng	+	-	-	-	-	-	-
41	*Chimonobambusa callosa* (Munro) Nakai	+	-	+	+	+	+	-
42	*C. griffithiana* (Munro) Nakai	+	-	-	+	+	+	-
43	*D. catastachyus* (Kurz) Kurz	-	-	-	+	-	+	-
44	*D. patellaris* Gamble	+	+	-	-	-	+	-
45	*D. sachni*i Naithani and Bahadur	+	-	-	-	-	-	-
46	*Dinochloa maclellandii* (Munro) Kurz	-	+	-	-	-	-	-
47	*D. indica* (Majumdar) Bennet	-	+	+	-	-	-	-
48	D. gracilis (Majumdar) Bennet & Jain	-	+	-	-	-	-	-
49	*D. compactiflora* (Kurz) McClure	-	+	-	-	+	-	-
50	*Drepanostachyum hookerearianum* (Munro) Keng	+	-	-	+	+	-	-
51	*D. intermedium* (Munro) Keng	+	-	-	-	-	-	-
52	*D. khasiananum* (Munro) Keng	-	+	+	+	-	-	-
53	*D. kurzii* (Gamble) Pandey	-	-	+	+	-	-	-

54	*D. polystachyum* (King ex Gamble) Pandey	-	-	-	+	-	-	-
55	*D. suberectum* (Munro) Majumdar	+	-	-	+	-	-	-
56	*G. rostrata* Wong	-	+	-	+	-	-	+
57	*Neomicrocalamus clarkei* (Gamble ex Brandis) Pandey	-	-	+	-	-	-	-
58	*N. manii* (Gamble) Pandey	-	-	-	+	-	-	-
59	*N. prainii* (Gmble) Keng	-	-	-	+	-	+	-
60	*Oxytenanthera parvifolia* Brandis ex Gamble	-	+	-	-	+	-	-
61	*Phyllostachys assamica* Gamble ex Brandis	+	+	-	-	-	-	-
62	*P. mannii* Gamble	+	-	-	+	-	-	-
63	*Pleioblastus simonii* (Carr.) Nakai	+	-	-	-	-	-	-
64	*Schizostachyum arunachalensis* Naithani	+	-	-	-	-	-	-
65	*S. capitatum* (Munro) Majumdar	+	-	-	+	+	+	-
66	*S. capitatum* (Munro) Majumdar var. *decompositum* (Gamble) Majumdar	-	-	-	+	-	-	-
67	*S. dullooa* (Gamble) Majumdar	-	+	-	+	+	-	-
68	*S. fuchsianum* (Gamble) Majumdar	+	-	+	-	-	+	-
69	*S. griffithii* (Munro) Majumdar	-	+	-	+	-	-	-

70	*S. helferi* (Munro) Majumdar	-	-	-	+	-	-	-
71	*S. mannii* Majumdar	+	+	+	+	+	+	+
72	*S. pergracile* (Munro) Majumdar	-	+	+	-	-	+	-
73	*S. pallidum* (Munro) Majumdar	+	-	+	+	-	-	-
74	*S. polymorphum* (Munro) Majumdar	+	+	+	+	+	+	-
75	*S. seshagirianum* Majumdar	+	-	-	-	-	-	-
76	*Sinarundinaria longispiculata* Chao & Renvoize	-	-	-	-	+	-	-
77	*Sinobambusa elegans* (Kurz) Nakai	+	-	-	-	-	+	-
78	*Thamnocalamus aristatus* (Gamble) Ca.	+	-	-	-	-	-	-
79	*Yushania maling* (Gamble) R. Majum.	+	-	-	-	-	-	-
	Total	**39**	**29**	**21**	**36**	**20**	**20**	**12**

For sustainability, harvesting is prescribed every year for culms older than three years under farm sector, and alternate year in the wilderness. Harvesting is not encouraged during active growth period (April-October) and clear felling should be barred in order prevent degeneration of clumps. Intensive cultural practices to mitigate congestion of clumps in order to facilitate growth of new clumps. Trees providing light sheds should not be removed in the habitat, as the bamboo grow better under shady environment.

In all, bamboo being a multipurpose eco-friendly crop abundantly available, yet an underutilized natural resource, needs to be managed and exploited for sustainable use. Bamboo is conceived as a thrust area in Industrial Development of NEH Region for the economic and ecological security of the people. This precious resource needs to be fully tapped as an industrial raw material, as substitute for wood in rural/urban housing, engineering works, handicrafts, furniture and value addition through export. Potentially, bamboo can revolutionize the economy of the States ensuring employment opportunities to a large number of people.

Research and policy framework on bamboo

Having the socio-biological principles of the local livelihoods, the research and development approach should follow the following framework in order to have backward and forward linkages integrated in to bamboo resources management and marketing *per se.*

i. Inventory of bamboo and short-listing the edible bamboo through extensive survey.
ii. Market survey to understand the bamboo consumption and preparation of detailed inventory of bamboo species.
iii. Development of agro-techniques for identified bamboo species for higher yields.
iv. Establishment of planting stock for edible bamboos to farmers/growers.
v. Nutritive value analysis of young edible bamboo shoots.
vi. Restoration of degraded lands and watershed through potential bamboo germplasm.

vii. Evaluation and conservation of economically important bamboo germplasm.

Strategically, the strengths and weaknesses, opportunities and threats of edible bamboo scenario in the NEH region are given in Table 3. Overall, planning and management of bamboo resources could be effective by strengthening inventories, of creation of holistic database on important products and allied information, and economic analysis related to domestic market and export. In NEH region, a critical issue of land/resource tenure has to be resolved by appropriate legislation and policy framework for sustainable management of bamboo resources, as reportedly most land is under private ownership in the region.

Perhaps, we may need to strategically regulate bamboo-exploitation in jhum regrowth and jhum areas by involving Village Councils/Village Forest Development Committees (VFDCs) and eventually facilitating a gradual change over to systematic agroforestry management and practices. Sustainable management and use of dedicated bamboo forests and/ or regrowth areas for providing essential bamboo materials for traditional use and commercial use in bamboo-based industries, enterprises, handicraft sector and also for bamboo trade and commerce. In spite of this fact, shortage of raw material for industry is anticipated in near future. Therefore, appropriate policy instruments to encourage community and/or private bamboo plantations need to consider subsidy and incentives, apart from the mundane forward and backward linkages.

Simultaneously, expanding market for bamboo in various sector like biochemical, edible shoot, fodder, ornamental, hedge, geotechnical structures for earth reinforcement, low-cost housing and water supply systems for rural masses and handicraft and many other industrial application will be a boost to this sector in the country as a whole, and NEH region in particular. Improving access to appropriate market informations and reducing restriction for domestic market and export as well as reducing fiscal disincentives could help accelerate growth of bamboo sector in India. Capacity building to stakeholders in management of micro-enterprise or a cooperative, availability of mirco-credit for people operating at very subsistence level, value added bamboo processing and design technologies will be beneficial, if adopted under a logical framework in a phased and systematic manner.

Table 3: SWOT analysis of edible bamboo scenario in the North Eastern Hill region.

Strengths	Weaknesses
- High diversity of edible bamboo in NEH region - Amicable climatic conditions and diverge harvesting seasons - Easy to grow - Low production costs - Processing possibilities: drying, semi fresh packaging - Strong indigenous knowledge systems associated with growing bamboo	- Limited supply - Low productivity due to poor socio-economic condition of the farmers and faulty land tenure system - Non-conventional taste and odour - Lack of storage and processing facilities - Lack of policy frame work for channelization of production, processing and marketing.
Opportunities	**Threats**
- Diverse range of products and markets - Growing demand of (semi) fresh shoots in the neighboring countries such as Myanmar and Thailand. - High export potential - Development of agro-ecological zone specific farming and production systems using bamboo - Industrial approach to bamboo sector.	- Illegal to trade of bamboo shoots - Poor market linkage - Low cost-benefit ratio at times - Loss of traditional knowledge systems - Diversification into high value case crops

Institutional arrangements

Funding support to implement the various policy initiatives enunciated shall be provided from the programme funds of the various development departments (Fig. 1). While bamboo resource development within the notified forest area shall be supported by bamboo development projects under centrally sponsored schemes, development of bamboo plantation in agroforestry sector shall be supported from respective programme funds of Agriculture/ Horticulture/ Rural Development departments. Special programmes to finance bamboo plantation in farmer sector shall also be supported by Developmental Banks. Establishment of cottage and small and medium sector industries can be supported by government subsidies with due institutional finance from industrial financing agencies and industrial investors/ exporters.

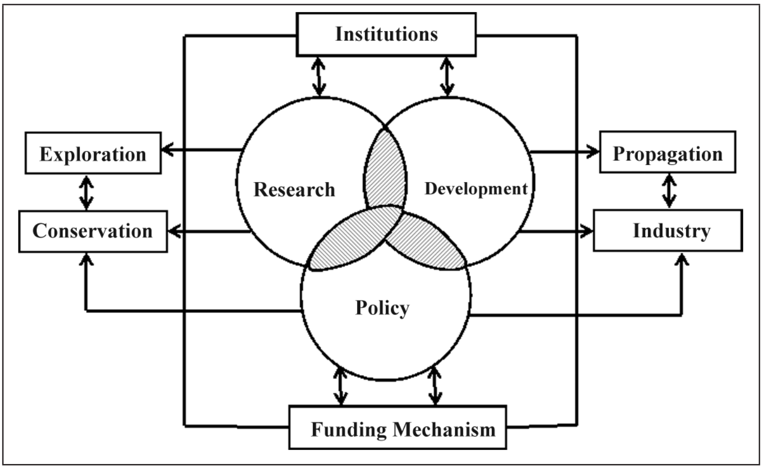

Figure 1: Framework for Bamboo utilization and conservation

States such as Tripura and Mizoram have adopted bamboo policy in the NEH region. In the Valley, the Assam state has bamboo and cane policy, realizing its potential both ecologically and also in economics terms. Nevertheless, a biodiversity rich state like that of Arunachal Pradesh is yet to develop inclusive bamboo policy. Thus, sensitization and thorough awareness of the potential edible bamboo species would only set in remarkable returns that could manifest sustainably in bamboo-based livelihood system in the northeastern hill region in particular.

Conclusion

Despite food self-sufficiency at the national level, the country has not attained food security at a household level particularly in the tribal states of the NEH region. Eventually, a considerable proportion of rural population is still under-nourished and they meet their nutritional requirement through non-conventional means, i.e., by consuming various wild plants and animal resources and bamboo shoots. Being at par with various edible fruits leaves, twigs roots and tubers in nutritive value, bamboo resource plays a significant role in the food and nutritional security of the tribal population of the NEH region. Recent break-through in induction of bamboo flowering through appreciation of tissue culture technology (Nadgauda *et al*., 1990) provides greater opportunities for genetic improvement of bamboo. Further research is needed to study the microelements in various edible species besides studies on homogentisic acid (HGA), which is reported to be responsible for the disagreeable pungent taste of bamboo shoots (Etsuko and Susumu, 1989).

Since there is no systematic documentation on edible bamboo and its utilization pattern tin NEH region, planning priorities should be fixed for exploration, validation, mass multiplication and production of edible bamboo species. Natural death of some of the potential edible bamboo species due to flowering is a serious threat in the region however. Hence planning priorities are needed to conserve the germplasm of major edible species of the region. Meanwhile, a few potential species have already been identified along with production potential and cost-benefit analysis (Bhatt and Bujarbaruah 2003), and hence an inclusive policy framework (Figure 1) shall yield better market prospects that could help improve the quality of bamboo products and also the socio-economic development of indigenous communities that practice bamboo-based livelihoods, considering its potential in the region.

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Policy Framework to Support Farmer Producer Organisations (FPOs) for Inclusive Growth in the 12th Plan

Pravesh Sharma

Globalization is changing the way agriculture marketing is organized, even within relatively sheltered produce markets such as India. National, regional and local marketing systems are increasingly adopting global best practices in procurement, storage, transport, packing and processing of food products. Food supermarkets are a reality and even if their present market share is tiny, they are likely to become major players in the coming decades to cater to the growing urban demand for quality farm produce delivered in modern formats. This in turn will create pressure for higher food quality standards and usher in new procurement systems. Efforts to loosen the tight hold of the APMC inspired mandi system over agriculture marketing will intensify in the near future, leading to the entry of new players bringing cutting edge technology and modern supply chain processes. Indian companies are also increasingly likely to attempt to capture larger market shares of the expanding international trade in primary commodities and processed foods and hence seek quality produce in large volumes from domestic producers.

At the same time the production base of Indian agriculture is characterized by millions of small producers, who are finding it increasingly difficult to manage the high risk of farming, evidenced by growing weather uncertainties, unreliable input supplies, stressed infrastructure in the power and irrigation sectors and antiquated marketing arrangements. The trends outlined in the preceding paragraph will further weaken the bargaining power of the vast majority of these producers and it is unlikely, given present conditions that they will benefit from emerging opportunities at the national or international

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level in any meaningful way. If anything, their situation is likely to worsen without the urgent adoption of new and innovative institutional solutions.

The largely macro level, cereal production oriented official agricultural growth strategies are unable to target vast sections of the peasantry, and rainfed regions in particular continue to witness both the volatility and distress associated with the vagaries of nature, as well as imperfections in factor and commodity markets. Producers in these regions already suffer from a serious technological and productivity gap compared to better endowed areas. Their condition is likely to deteriorate further and their isolation from the new emerging markets is almost a foregone conclusion. Hence the urgent need for solutions that mark a break from the past and significantly improve the terms of smallholder access to the market.

Present situation of smallholders in the market context: an overview

The constraints faced by small producers in the current scenario may be summed up as follows:

1. Shrinking land asset, rising per unit investment costs and shrinking profit margins
2. Difficulties in accessing critical inputs for agriculture, especially credit, water, power as well as quality seeds, fertilizers and pesticides and appropriate and timely technical assistance
3. Episodic, expensive and unreliable access to technology, especially mechanization
4. Fragmented value chain in agriculture marketing, monopoly and/or monopsony conditions; few opportunities for value addition at the bottom of the chain.
5. Weak bargaining with market agents and low returns on investment

Even as the above are stark realities, there is a market context in which smallholders survive and seek to leverage their labour and produce. Despite their weak bargaining power, smallholders continue to seek better purchase in the market.

The major features of the present market scenario may be summarized as follows:

1. Globalization, an expanding domestic middle class and diversification of the food basket are driving growing corporate interest in agriculture as a source for raw material for agri value chains. The globalization of the economy in general and particularly the agriculture sector is working in two directions – ever increasing importance of exports of agricultural products and the growing competition of food imports on the domestic market. There are numerous examples of backward linkages between the corporate sector and farmers which suggest that direct producer-retailer relationships have developed in almost all parts of the country. The market has finally arrived at the farmgate; the question is: whose farmgate?
2. The majority of existing examples of tie-ups between farmers and processors/retailers involve medium and large farmers, with very few instances of small and marginal farmers successfully linking up with corporate players.
3. The highly fragmented nature of production and low per capita surplus of small and marginal farmers limits their ability to access the market to leverage better returns for their produce.
4. Corporate and other bulk buyers of agri commodities find the transaction costs of dealing with a large number of small producers prohibitively high and prefer dealing with bigger farmers and *mandi* aggregators.
5. Contract farming has not benefitted small producers in a meaningful way, as information asymmetry, weak bargaining power and legal ambiguities create insurmountable hurdles to producer-buyer relationships. However, there is growing evidence that contract farming arrangements are expanding across the country and will ultimately seek out small producers.
6. Access to timely and affordable credit, effective extension services and availability of adequate inputs remain out of

the reach of the majority of small producers, restricting the exploitation of the full potential of their natural resource base, even where these endowments are satisfactory.

7. Current examples of institutional aggregation of small producers, whether informal collectives or formal cooperatives and producer companies, are scattered and few in number. They face a variety of constraints, including an unfriendly regulatory and legal environment, lack of opportunity to access capital and credit and are unable to scale up to a size significant enough to deal with market forces on favourable terms.

8. Unrecorded tenancies are mostly held by small and marginal farmers and tribals, with attendant disadvantages, such as lack of access to institutional credit and subsidized inputs, inability to benefit from new market instruments like warehouse receipts and insecure tenurial conditions. All these drawbacks are doubly magnified in the case of women holding informal tenancies. At the same time, it is observed that absentee landlordism is an acute problem in some regions (especially the hill states and rainfed areas), resulting in huge tracts of cultivable fallows lying idle.

9. Present arrangements for risk mitigation, especially crop insurance instruments, are highly unsatisfactory and do not adequately cover the risks faced by small producers. The marketing and assessment mechanisms for crop insurance are skewed in favour of the insurance companies, leaving small producers especially vulnerable to the vagaries of weather and market alike. This holds back small and marginal farmers from shifting to higher risk commercial crops, which would otherwise bring better returns.

10. Finally, it is noteworthy that there is no special targeting or earmarking of resources for small and marginal farmers in centrally sponsored agriculture development programmes during the XI Plan. This raises unanswered questions about the equity impact of such interventions.

Proposed interventions to support smallholder agriculture in the 12th Plan

It is clear from the available data and market behaviour that small producers, especially if they happen to be women, dalits and tribals, are among the most disadvantaged in the current economic scenario. The challenge in the next Plan is to devise interventions that enable these disadvantaged producers to benefit from the growing market opportunities and enter the value chain on more favourable terms. We must, however, distinguish carefully between completely marginal producers (cutting across all the categories listed above and with holdings of less than 1 hectare) who are focused primarily on subsistence farming versus smallholders (typically with land parcels between 1-2 hectares) who are more likely to be following a diversified cropping pattern and producing small surpluses for the market. The development strategies for these two distinct categories must be completely separate, as grouping them together under the larger label of "smallholder agriculture" is fraught with negative consequences for marginal producers. Pushing marginal farmers towards commercial agriculture without adequate risk protection would actually worsen their already precarious situation. Hence at this stage we do not feel that marginal farmers can enter into the agri value chain via agribusiness enterprises with any assurance of success, given their extreme vulnerability and tiny resource endowment.

The approach to the problems of marginal farmers must essentially have a "poverty alleviation" focus, with a suite consisting of wage employment through MNREGA, assured access to public services such as the PDS, ICDS, MDM and basic health. Since these initiatives are already in place and are likely to be expanded in the 12th Plan, this paper will not go into further details and return to its main theme of addressing the challenge of building agribusiness enterprises for small farmers and ensuring greater market access for their produce.

It is in the context of small farmers that the present trends offer a significant opportunity to leverage market opportunities to enhance incomes and return on labour and investments. Evidence suggests that this category is already more integrated with the market and is exploiting opportunities wherever feasible. At the same time they suffer from various hurdles and constraints which limit the returns that they are justly entitled to. A recent paper has noted the competitiveness of small farms on virtually all parameters of resource and input use but concludes that this is in itself not sufficient to pull smallholders out of the grip of poverty. The missing elements of support, information asymmetry and the most critical issue of finance are among the key factors that seem to determine the terms on which small producers relate to the market.

The broad strategy that the 12th Plan should follow in respect of extending help to smallholder agriculture must expressly address these gaps and rest on the following principles:

(i) It must aim to improve the terms of trade of small producers with the market

(ii) It must address risks faced by small producers and help to reduce them

(iii) It must recognize the importance of small producers in the value chain and facilitate their inclusion in the wider economy

(iv) It must target moving small producers further up the value chain to increase their returns on investment and their economic security.

(v) It must actively support the principle of aggregating producers in suitable institutional arrangements to leverage the benefits of collective production and marketing power.

In the following paragraphs some specific strategies are suggested to be adopted in the 12th Plan period that could help to achieve the above goals.

Institution building for small producers: supporting the formation of Farmer Producer Organisations (FPOs)

The first and foremost need is to aggregate smallholders into members based farmer producer organisations. This is an urgent task which should be undertaken in a mission mode during the 12th Plan to support thousands of FPOs across the country. Member based FPOs offer a proven pathway to successfully deal with a range of challenges that confront small producers, empowering their members in a variety of ways. Overcoming the constraints imposed by the small size of their individual farms, FPO members are able to leverage collective strength and bargaining power to access financial and non-financial inputs and services and appropriate technologies, reduce transaction costs, tap high value markets and enter into partnerships with private entities on more equitable terms. With fragmentation of holdings a continuing phenomenon, FPOs offer a form of aggregation which leaves land titles with individual producers and uses the strength of collective planning for production, procurement and marketing to add value to members' produce. International and limited national experience in the performance of FPOs makes a strong case for supporting member based farmer bodies to significantly increase their power in the market place, reduce risks and move up the agri value chain.

FPOs can provide essential goods and services to the rural poor, besides their own members, and contribute significantly to the process of rural poverty alleviation. They are seen as an important risk mitigation device to overcome the constraints faced by farmers, especially small producers seeking to benefit from growing market opportunities in developing nations. One FAO (2007) estimate placed the value of agriculture produce generated by existing FPOs (largely cooperatives) in India and China in 1994 at US $ 9 billion each. They have been found to positively impact research priorities through participation and closer feedback to scientists, besides providing valuable inputs to policy formulation by channelling the opinions of the farming community. The role of FPOs in reducing costs of financial intermediation for formal financial institutions and more effective targeting of small producers for financial services has also been favourably noted.

However, it is an established fact that small producers require an external catalyst to bring them together in a FPO and to build their capacities to govern the institutions in a self-sustaining manner. This would require committing grant funds for such capacity development. Such support has traditionally come only from two sources: donor agencies and government budgets.

The 12th Plan should mandate an institutional development component in all Centrally Sponsored Schemes, specifically targeting FPO formation among small producers, especially tribals, dalits and women. Ideally, this component should be at least 10% of the total outlay of the scheme. Assistance for this component should be spread over at least 3 years, which is the ideal period for an FPO to mature. Costing norms can be adopted from NABARD's farmer club scheme (which provides Rs. 3000.00 per member per year for a period of three years). Civil society and private sector organisations, besides other resource institutions like agriculture universities, Krishi Vigyan Kendras, ATMA, banks, cooperatives and other similar bodies with a proven track record of success participatory performance' can be identified for promoting and hand-holding FPOs. This window could also be used to provide support to existing FPOs for capacity building, managerial inputs, marketing etc.

The support to FPOs should be structured in a manner that only genuine; producer member owned institutions are able to benefit from this window. For this reason, only producer companies registered under the special provisions of the Companies Act and cooperatives formed under a state cooperative act or the multi-state cooperative legislation should be recognised as FPOs. Safeguards will have to be built into the detailed guidelines to prevent the misuse of this facility.

The majority of FPOs that are likely to emerge as a result of this intervention will remain focused on addressing issues of crop planning, technology infusion, input supply and primary marketing. However, at least one fourth to a third could seek to leverage their presence further up the value chain, entering into post-harvest management, direct retailing, value addition, storage and processing and engage in contract production of primary and processed agriculture produce. There will be a need to support the business development needs, both financial and non-financial, of such FPOs, mostly at the lower end of the value chain (e.g. setting up pack houses, grading centres, milk chilling plants, small cold stores, drying or quick freezing plants).

Business Development Fund (BDF) for FPOs – investing in FPO equity

A window should be created at the national level to access a Business Development Fund (BDF) by FPOs, should they decide to enter the value chain. The BDF can be conveniently created in the Small Farmers' Agribusiness Consortium (SFAC) alongside its existing Venture Capital Fund. This should be available as a one-time grant to any FPO which is entering the agriculture value chain to undertake a list of activities identified under the agribusiness head. The one-time support should be in the form of equity investment to enable the FPO to raise capital from financial institutions. The one-time equity support should be a matching amount to the equity raised by the FPO members (e.g. if the FPO members raise an equity of Rs. 5.00 lakh, the BDF should invest an equal amount). There could be a cap of Rs. 10.00 lakhs on the equity support which a single FPO can seek from the BDF.

Venture capital, governance support and loan guarantee to FPOs

A Venture Capital Assistance Scheme was launched through SFAC late in the 10th Plan and continued in the 11th Plan. The main lessons from the scheme's performance in respect of small producers in general and FPOs in particular are as follows:

(i) The minimum investment size of VCA projects was pegged at Rs. 50.00 lakh, putting it beyond the capacity of individual small producers or even their collectives to qualify for assistance.

(ii) Almost the entire list of beneficiaries of the VCA during the 11th Plan consists of private entrepreneurs and companies.

(iii) Benefits to small producers are mostly indirect, primarily as a source of raw material

supply, with little or no sharing further up the value chain. There is not a single case of private entrepreneurs tying up with FPOs.

(iv) Most recipients of the VCA have noted the importance of organizing FPOs to making their enterprises more competitive and cite the high transaction costs of dealing with hundreds of individual producers.

(v) Since the scheme was implemented only through nationalised banks, it failed to leverage potential investment opportunities offered by cooperative and regional rural banks, besides private scheduled banks and specialized finance institutions, such as the National

Cooperative Development Corporation (NCDC), Northeastern Development Finance Corporation (NEDFi) as well State Finance Corporations.

(vi) The condition of clubbing the VCA investment with a bank loan was another insurmountable hurdle which FPOs could not cross, as financial institutions have generally held back from financing FPOs, citing lack of collateral and security issues.

These lessons should be incorporated in a reformed and expanded version of the VCA scheme during the XII Plan, especially with a view to support FPO-led enterprises.
Key among the changes should be:

1. The minimum threshold size for individual projects should be reduced to Rs. 10.00 lakh (Rs. 5.00 lakh in north eastern and hill states), to encourage projects promoted by FPOs.
2. The list of partner financial institutions should be widened as far as possible to include all bodies that are notified by RBI as financial institutions (this would include all the FIs listed in [v] above and even attract NBFCs licensed by RBI).
3. Venture capital support to FPOs should be clubbed with a one year grant to help them access managerial support, training and other governance related inputs. This one year grant should ideally be 5% of the sanctioned VCA.
4. While current VCA rules provide for a return of the investment without interest at the end of a 5 year period, it is proposed that the VCA should convert into a grant in case of FPOs, provided it has successfully repaid the bank loan. This will strengthen the FPO and allow it to continue to access institutional finance. Returning the VCA amount at the end of 5 years will weaken the borrowing capacity of the FPO and leave it vulnerable to business shocks.
5. Finally, it is proposed to create a First Level Default Guarantee Fund (FLDGF) in SFAC to incentivise lending by to FPOs by financial institutions. FIs can be encouraged to purchase the cover of the FLDG at

a nominal fee (which can be as low as 0.50% of the amount advanced to FPOs) and receive a first-level-default-guarantee of 10%. This is to say that the FLDG will cover upto 10% of default in the FPO loan portfolio of the FI. If a corpus of only Rs. 10.00 crores per annum is created in SFAC for the FLDG, annual lending of at least Rs. 100.00 crores can be guaranteed to FPOs. Assuming that the drawdown on the FLDG will not be 10% every year, the carryover amount can leverage even higher lending in subsequent years. This is one policy instrument which can trigger lending to FPOs by banks and other financial institutions. In particular, it would be a great incentive to advance loans to FPOs by MFIs, which are currently totally limited to lending to self-help groups. Banks will also be able to use the Business Correspondent model to reach out to FPOs using the cover the FLDG.

It may be pointed out in conclusion that SFAC is currently running a nation-wide pilot to promote 250 FPOs (targeting 2.50 lakh farmers, under a mandate given by Dept. of Agriculture and Cooperation, Ministry of Agriculture). This FPO pilot is being implemented in all States as a demonstration of the benefits of farmer aggregation, leverage collective production strength to improve access to investments, technology and markets.

SFAC has successfully mobilized over 2.50 lakh farmers over the past 14 months and registered over 50 FPOs so far. Another 100 FPOs are in the process of being registered (either as cooperatives under the relevant State laws or as producer companies under Chapter IXA of the Companies Act). By March 2013 all 250 FPOs are expected to be registered and fully functional. Continuous training, hand-holding and linking these emerging FPOs to input suppliers, financial institutions, market aggregators and technology sources is in progress. Detailed process guidelines to guide the resource institutions in FPO formation have been developed by SFAC, together with numerous training modules, guides, specialised studies on value chains, innovations etc. All this resource material has been placed on the SFAC website (www.sfacindia.com) in the public domain.

Important lessons have already emerged from this pilot, in particular a better understanding of the regulatory, training, managerial support, technical, input related, financial and marketing needs of producer organisations. The suggestions made above incorporate this learning and are absolutely essential elements of an ecosystem to encourage producer organisations to flourish. SFAC is also working on the modalities of a national level structure for federating FPOs, so that issues of concern to FPOs, especially related to access to finance, inputs and marketing opportunities, can be raised at appropriate fora for just resolution. Given adequate resources, SFAC is confident of supporting the development of FPOs on a large scale across the country, leading to a significant shift in the leverage of small producers in the market, boosting productivity and incomes.

Based on the learning of the past two years, SFAC proposes to spearhead a national campaign to develop at least 1000 FPOs during the 12th Plan period. This is very much in line with the strategy suggested in the chapter on Agriculture in the 12th Plan document, which recognizes the centrality of smallholder agriculture in India and accepts that FPOs present a viable pathway to reach out to large numbers of small and marginal farmers for their equitable integration into agri value chains.

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50 Years after Silent Spring: Looking Backward and Forward

T. P. Rajendran

Rachel Carson's 'Silent Spring' has the intonation of reminding mankind about the risks and hazards of agricultural chemicals that are used in intensive agriculture that has engineered sustained crop commodity production for feeding the teeming millions. Growth of human and animal population has been constantly rising in comparison to the decline in quality of cultivable land area. The pressure to produce more from less resource for more demand is the call of today. This tumultuous situation has been furthered due to the world trade order of the millennium that demands commodity production for the trade demands of nations. It has been severe commercial and trade driven agriculture that is making nations to compete for due space in the global hierarchy for competitive well-being of communities.

Scientific innovations and discoveries have enabled intensive agriculture to be a practice today. Communities are however, divided on the risks that are perceived from the various true and imaginary science-based perceptions of threats. Knowledge and information form the complex that dictate the perception of human communities on the hazards of commercial products and their utility. In commercial agriculture, the adequacy of resource management is now understood as the important input for sustaining long-term stability of production.

Risks and hazards, being the way of modern life of the globe, scientific innovations of times have been the wheels of changes in human enterprises. From the oldest to the current innovations and their applications in various spheres of agriculture and in life, one would imagine that global food production has to be guided with weather patterns and quality of natural resources

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upon which commodities could be farmed to meet the adequacy of the human needs. Commercial agriculture is today driven with supply-chain management of inputs for farms to those for consumers. Consumerism has been the landing point of commercial outlook. The slippage into 'need-to-greed' transition in the agricultural land resource use pattern is the present issue on challenge to world peace and order.

Global influence in Indian food production

The millennium development goals that were designed and ordained did support certain ecological principles that governs the sustained crop productivity of farm lands. The ecological chain that sustains natural food webs did enmesh human aspirations for better quality of food and nutrition. Food chains and webs in farm lands, being transient unlike in forest and such other natural niches, due to the annual nature of crop flora environment of seasonal sowing and harvesting, are more vulnerable to both natural calamities including pestilence. Specific road-map to achieve near-perfection of unhindered crop production cycles, hence, has to be a balancing act. Generalized crop production-principles cannot become any more the practice to attain large-scale servicing of food production towards food security and nutritional security. These two guide national security too. Nations have to define these two security systems to keep the communities of animals and humans healthy and satiated, The dimension of biosecurity has, in recent times been introduced to offer nations the exclusion from new and invasive crop pests.

Evolution of intensive agriculture prompted the use of agro-chemicals such as fertilisers, growth hormones and pesticides. While the first two classes of agricultural inputs are to enhance the quantity and quality of commodities, pesticides are aimed to save such commodities from overwhelming loss due to pestilence in crops. Discovery of pesticides since 1942 such as dichloro-diphenyl-tricholoro ethane (DDT) and a series of chlorinated hydrocarbon insecticides, followed by organo-phosphate one, carbamate ones, synthetic pyrethroid pesticides etc. and many modern chemistries have been keeping man in the solace that we could win over the noxious pests in their lives, be it in farms, livestock, or domestic situations. Selection pressure on pests due to incitement of the target site by continuous use of similar pesticide chemistries, outbreak of resisting pest strains and increased use of higher quantity of pesticides were the result of continuous use of conventional pesticide molecules / chemistries in crops. Modern pesticide chemistries could win over the noxious pests in their lives be it in farms, livestock, or domestic situations. Selection pressure on pests due to some target site incitement by a number of pesticides, outbreak of resisting pest strains and increased use of higher quantity of pesticides were the result of continuous use of conventional molecules /chemistry in crops. Modern pesticide chemistries with varying target sites brought down the chances of pests being selected to resist pesticide toxicity.

Pestilence in Indian agriculture has been on the increase, after the 'Green revolution' era, mainly due to intensification of agriculture deploying high fertilizer application to crops fields. The Standing Committee on Petroleum & Chemicals recently estimated Indian crop losses to an extent of over Rs.90,000 crore per annum in 2009. According to ASSOCHAM, 2009, since farmers have not resorted to scientific methods for spray of pesticides, insects, pests and weeds surface and destroy commodities in standing crops causing huge national loss of agriculture produce. According to ASSOCHAM, annual crop loss should be well within the range of ₹ 1 lakh crore, up by ₹ 10,000 crore as already estimated by Standing Committee on Petroleum and Chemicals.

Silent spring and beyond

The stimulated discussion on the aftermath of extensive application of pesticides in agriculture has been dealt by Rachel Carson in 1962 in her famous work 'Silent Spring'. This classic work drew attention to the world on the environmental issues that were resultant to wild use of synthetic pesticides. Rachel Carson did promote the concept of judicious use of pesticides and never condemned their utility through desirable judiciousness. Fifty years after Silent Spring, the need of the hour is to look at the gains and drastic ill-effects that befell the farming environment. Herbivory in crop fields got defined to the basic aspect of food chains / webs that are established by opportunistic organisms that rely on k-selection pressures. Insects, mites, disease causing organisms, as pests, took to of resource exploitation in crops that flourished under chemical-based agriculture. Recent research has proved that managing soil organic carbon shall be the best strategy to keep crop health optimally.

The analysis and understanding generated in the last century, through research on the agro-ecosystems created the basic principles of integrated pest management (IPM) from David Pimentel (1957) to now. Rachel Carson did analyse this process to bring in judiciousness of pest control to their management. Succinct research in development of IPM methods and prescriptions for various crop ecologies and pestilence levels could be brought out through creating definitions of economic threshold levels, economic damage levels and action thresholds of pestilence. Realizing that the component of pesticides in IPM is to stay in intensive agriculture, certain episodes of injudicious pesticides application in crops such as cotton and rice along with certain vegetables challenged the farmers' profitability in addition to bringing about issues on pest resistance to pesticides and outbreak of non-target pests as well as the degradation of agro-ecosystems.

Thus evolved non-chemical farming that emphasized the judiciousness of the use of agro-chemicals from 'no-use' to meaningful-use patterns. The off-shoot of this is the much discussed organic farming. Rachel Carson used to be debated and experimented by farmers and research systems alike. Consumer-driven, risk fee commodities market became WTO system. Rigid definition of risks as well as freedom from their hazards became the immense resultant of such debates.

Influence of climate change and altered biotic stresses in crops

Much of the empirical surmises on influence of climate change in crops could become potential possibility due to evidences that are currently available in Indian farming. The anticipated increase of temperature by the debatable range of 1.4^{o}-5.6^{o} C, has been perceived. Land use, ozone depletion, agriculture, and deforestation would add to these problems. Sap-sucking insects such as mealy bugs, whitefly, jassids and tissue raspers such as thrips, nematodes etc. have enhanced their presence in crop environment, be it in open fields or in protected agriculture with precision farming protocols. Viral and mycoplasma diseases enhanced in crops due to increased vector activity. Altered pestilence patterns due to changed physiology of flora including of crop plants has signaled the threats to the current IPM principles and practice. Insect pests have been globally estimated to cause $90.5 billion in damages to eight principal food and cash crops (rice, wheat, barley, maize, potato, soybean, cotton, and coffee) versus $76.9 billion in damage by disease pathogens and 76.3 billion by weeds. It shall be noted that the reduction in food supplies through damage by pests and weeds will be in the range of 30 and 70% of the harvestable crop commodity. Securing these commodities after harvest has been driven by adoption of modified environment storage systems. On-farm and off-farm crop commodity loss has been consciously minimized to take advantage of the agricultural intensification process.

Natural enemies of pests such as parasites and predators in crop environment provide 5-10 times insect control provided by insecticides and secure the enhanced crop production due to higher activity of the highly valued crop pollinators in cross-pollinated and often cross-pollinated crop flora. The understanding provided by plant protection scientists in the past few decades when the pest management did not attain perfection in spite of several tools being sharpened for IPM, the attentions of farmers and their advisory system.

Plant protection needs of the country have progressed through research and development activities under the defined agencies. Recent efforts of Indian Council of Agricultural Research to bring changes in its research support to the country such as establishment of National Bureau of Agriculturally Important Insects at Bengaluru or recently established National Institute for Biotic Stress Management at Raipur (Chhattisgarh) are directed towards sharpening research focus and enhancing the human resource to face new challenges in crop health care and crop health biology.

The Indian Council of Agricultural Research, has, through its network of research institutes as well as All India Coordinated Research Projects, undertaken basic, strategic and applied research in plant protection of crops since 1980s. Similar efforts through the support of University Grants Commission, Department of Science and Technology and

Department of Biotechnology, Department of Environment and Forest, State Councils of Science & Technology, Civil society organisations etc. have paid rich dividends in elucidating certain basic and strategic areas of plant protection research. Collated efforts are needed to be organised and the various professional scientific societies could take up such aspects to dove-tail the inferences with the concerned state governments for imparting suitable knowledge-centric plant protection inputs for farmers.

The government of India and state governments are seized with the issues through previous schemes to implement the research results. These have been translated in great measure to the developmental system and has offered much of the plant protection knowledge into cost-effective crop production paradigms. The National Food Security Mission (NFSM) as well as National Agricultural Development Project (NADP) – *Rashtriya Krishi Vikas Yojana* (*RKVY*) are the current vehicles to take up these programmes into enhanced crop production and sustainable farm-profitability. The District plans under NADP (RKVY) in each state could fortify the implementation process if only such plans are spearheaded by national agricultural research system (NARS) so as to support the states to take on knowledge-enriched technology backstopping.

There are several components to take up plant protection such as pest surveillance, assessment of crop loss, organising various pest suppression measures under the frame work of integrated pest management with its components such as cultural, legal mechanical and biological control strategies to suppress pestilence in any given cropping system and in any agro-climate. Examining the components, viz., systems of national pest surveillance, crop loss assessment, disaster management system, registration and mobilisation of pesticides and securing national biodiversity, the Ministry of agriculture established the Coordination Committee of Plant Protection (CCPP) in Plant Protection division of Department of Agriculture and Cooperation. The CCPP established Task Forces that recommended mechanism for standard national pest surveillance system, crop loss assessment system, e-governance and e-registration process for pesticides and also various measures to study the frame-work of integrate pest management in crops.

The new Pesticide Bill, 2004, now under the consideration of the Parliament, is also being piloted to see that existing gaps in the Insecticide Act, 1976 is appropriately plugged; it provide better definition of the pesticide quality management and attendant responsibilities on that. Due to the expanding World Trade Order (WTO) involvement for India in recent times, the policy framework to offer safe food to those nations that seek trade of such commodities would seek their production under good agricultural practice (GAP). The Bureau of Indian Standards (BIS) of the Department of Consumer affairs has brought out the first draft document of BIS standard for GAP. Definition of risks in terms of freedom from pesticide and other harmful contaminant residues to permissible limits, becomes issues in trade discussions between nations. Quality assurance of agricultural inputs is the need of the farmers who are lured to competitively cheaper products that end up as non-efficacious due to dubious quality in terms of purity, concentration as well as shelf life. Integrated pest management ordains the use of biological control agents that have been connoted as both microbial and botanical pesticides too. These demand registration with Registration Committee of the Central Insecticide Board, in accordance with the prevailing Insecticide Act, 1968 and rules there on, 1971. Registration of such products would enable all state governments to monitor the quality of these products in each state. Hazard free-commodities can be produced only if assured quality of pesticides (both synthetic chemicals and biological ones) reach the farm-gates.

Silent Spring of Rachel Carson remains alive at the back of each citizen in the country, as elsewhere, whether he is a food producer or food consumer. Those redeemable principles have been incarnated in the quest for safer food / environment (including food chains / webs) and risk-avoiding life-style of modern man. Information and communication technology is a master-piece innovation that drove this into the minds of all stakeholders.

Conclusion

Challenged stakes of life did push up the thrust to seek better alternatives, if not the best ones. Food security is assuming increasing dimensions and it is estimated that 800 million people of the globe will be undernourished. By the year 2025, it is thought that 97% of the global population will compete for food supplies. It is in these regions that that the effects of climate change will be more afflicting. Despite climate change-induced upsurge in the biotic potential of pests, the ongoing challenge is for reducing crop losses due to them. Harnessing the survivorship pattern of herbivores would aid for deploying that knowledge for on-farm and off-farm IPM of crop commodities. While war for food / water are prophesied in this century, the pressure on natural resources would always redeem the Silent Spring principles and foundations (as standard operating protocols-SOPs) of modern agriculture in crop production and in trade of agricultural commodities.

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Dr. P.K. SHETTY

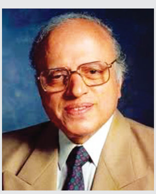
Dr. P.K. Shetty is a Professor and Former Dean of the National Institute of Advanced Studies, Indian Institute of Science Campus, Bangalore. Earlier, he was Head of the Environmental Studies Unit, the Dean (Administration) and the Dean (School of Natural Sciences & Engineering) at the National Institute of Advanced Studies, Bangalore and also an Independent Director, Power Grid Corporation of India Limited, Government of India. Dr Shetty received his Ph.D from Indian Agricultural Research Institute, New Delhi.

He carried out research and in-depth analysis in the multidisciplinary areas such as Agriculture, Ecology, Crop Protection/Environmental Stewardship, Plant Biosecurity, Science and Technology Policy Studies etc. Dr Shetty has successfully completed many externally aided research projects of societal significance and policy implications. He has reported several original works and published numerous highly cited peer-reviewed research papers in internationally reputed journals, also published many books, book chapters and popular articles. Dr Shetty has served on many Boards and Committees of the Government of India and the Government of Karnataka mainly in the areas of Agriculture, Forest and Environment, Power Sector, Labour and Municipal Administration. He was research guide for several PhD, M.Phil and M. Sc Students. Dr Shetty is associated with many National and International organisations including the Scientific Advisory Board of a Journal of Springer on "Philosophy and Technology''. He has conducted several India-centric seminars/conferences/discussion meetings in areas of agriculture and also advances in Science & technology. He has received several awards in recognition of his work including the prestigious Karnataka State Rajyostava Award (2007), Government of Karnataka and the Kempe Gowda Award (2011), the Bruhat Bangalore Mahanagara Palike, Government of Karnataka and Pratibha Puraskar Award (2012), the Karnataka Rajya Vokkaligara Directory, Bangalore.

Dr. S. AYYAPPAN

Dr. S. Ayyappan is currently the Secretary, DARE & Director General, ICAR. Earlier he served as the Deputy Director General (Fisheries) – 2002-09, Director, CIFE (Deemed University) – 2000-2002, Director, CIFA, Bhubaneswar – 1996-2000. Dr. Ayyappan entered the ARS System as a Scientist in Central Inland Fisheries Research Institute, Barrackpore (1978-84) and grew as a Principal Scientist, 1984-95. He has made significant contributions to administration and research management of the National Agricultural Research system since 1996. Under his leadership CIFA received the 'Best ICAR Institution Award, 1996. The agricultural research and education programmes in the country got a new direction with his innovative guidance. He is the Founder Chief Executive of the National Fisheries Development Board.

Dr. Ayyappan has over 200 publication in reputed journals/proceedings and books. He also has two patents and one design in his name. He has received a number of prestigious awards and honours such as Zahoor Qasim Gold Medal, 1996-97; ICAR Award for Team Research for 1997-98; and V.G. Jhingran Gold Medal, 2002. He is Fellow and Vice president of National Academy of Agricultural Science, India; Fellow of National Academy of Biological Science, 2012 Asian Fisheries Society, Manila, Philippines, 2004-2010; Vice President, Indian Society of Coastal Agricultural Research, 2008-2011; award in the International Conference on Ecosystem Conservation and Sustainable (ECOCASD-2011) at Addis Ababa, Ethiopia and Dr B.P Pal Memorial Award – 2012 During 99th Session of Indian Science Congress by Hon'ble Prime Minister, Dr. Man Mohan Singh and conferred D. Sc. (*Honoris causa*) by prestigious institution such as BHU, Varanasi, JNKVV, Jabalpur and UAS, Dharwad. Dr. Ayyappan has been serving as Member/Chairman on the Boards of Several International Institutions / organization such as a Network of Aquaculture Centers in Asia-Pacific (NACA), Bangkok, Thailand; World Fish Center, Malaysia and ICRISAT of the CGIAR. He has also served in different capacities on important Committees viz. Chairman of High level Expert Committee for development of Freshwater Aquaculture in the country, Govt. of India; Chairman of the Working Group of Fisheries for Eleventh Plan, Planning Commission; Chairman of the Task Force on Aquaculture and Marine Biotechnology, Department of Biotechnology, 2006-2009; Member of the Project Steering Committee on 'More Crop and Income per Drop of Water' , Ministry of Water Resources, Govt. of India, 2006-2007; Member of the Mid-Term Review (MTR) Committee of Agriculture and Allied Sectors for the XIth Plan (2007-2012), Planning Commission, Govt. of India.



Professor M. S. SWAMINATHAN

Professor M S Swaminathan has been acclaimed by the TIME magazine as one of the twenty most influential Asians of the 20th century and one of the only three from India, the other two being Mahatma Gandhi and Rabindranath Tagore. He has been described by the United Nations Environment Programme as "the Father of Economic Ecology" because of his leadership of the ever-green revolution movement.He was Chairman of the UN Science Advisory Committee set up in 1980 to take follow-up action on the Vienna Plan of Action. He has also served as Independent Chairman of the FAO Council (1981-85) and President of the International Union for the Conservation of Nature and Natural Resources (1984-90). He was President of the World Wide Fund for Nature (India) from 1989-96. He also served as President of the Pugwash Conferences on Science and World Affairs (2002-07), President of the National Academy of Agricultural Sciences (1991-96 and 2005-07) and Chairman, National Commission on Farmers (2004-06).

He served as Director of the Indian Agricultural Research Institute (1961-72), Director General of Indian Council of Agricultural Research and Secretary to the Government of India, Department of Agricultural Research and Education (1972-79), Principal Secretary, Ministry of Agriculture (1979-80), Acting Deputy Chairman and later Member (Science and Agriculture), Planning Commission (1980-82) and Director General, International Rice Research Institute, the Philippines (1982-88). A plant geneticist by training, Professor Swaminathan's contributions to the agricultural renaissance of India have led to his being widely referred to as the scientific leader of the green revolution movement. His advocacy of sustainable agriculture leading to an ever-green revolution makes him an acknowledged world leader in the field of sustainable food security. Professor Swaminathan was awarded the Ramon Magsaysay Award for Community Leadership in 1971, the Albert Einstein World Science Award in 1986, the first World Food Prize in 1987, and Volvo and Tyler Prize for Environment, the Indira Gandhi Prize for Peace, Disarmament and Development in 2000 and the Franklin D Roosevelt Four Freedoms Medal, the Mahatma Gandhi Prize of UNESCO in 2000 and the Lal Bahaclur Sastri National Award (2007). Professor Swaminathan is a Fellow of many of the leading scientific academies of India and the world, including the Royal Society of London and the U S National Academy of Sciences. He has received 56 honorary doctorate degrees from universities around the world. He currently holds the UNESCO Chair in Ecotechnology and Emeritus Chairman at the M S Swaminathan Research Foundation in Chennai (Madras), India. He is a Member of the Parliament of India (Rajya Sabha), to which position he was nominated by the Government of India in May 2007 in recognition of his contributions in the field of agricultural research and development.