National Mission For Sustainable Agriculture

Strategies for Meeting the Challenges of Climate Change

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MINISTRY OF AGRICULTURE
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OVERVIEW

The National Mission for Sustainable Agriculture (NMSA), which is one of the eight Missions under the National Action Plan on Climate Change (NAPCC) seeks to address issues regarding '*Sustainable Agriculture*' in the context of risks associated with climate change by devising appropriate adaptation and mitigation strategies for ensuring food security, equitable access to food resources, enhancing livelihood opportunities and contributing to economic stability at the national level.

The Mission acknowledges that the risks to the Indian agriculture sector due to climatic variabilities and extreme events would be accentuated at multiple levels including at the levels of crop or livestock, farm or cropping system and the food system. Adverse impacts on agricultural production would be severe in the absence of appropriate adaptation and mitigation measures with far reaching consequences in terms of shortages of food articles and rising prices which could endanger the food and livelihood security of our country.

The Mission, therefore, seeks to transform Indian agriculture into a climate resilient production system through suitable adaptation and mitigation measures in the domain of crops and animal husbandry. These interventions would be embedded in research and development activities, absorption of improved technology and best practices, creation of physical and financial infrastructure and institutional framework, facilitating access to information and promoting capacity building. While promotion of dryland agriculture would receive prime importance by way of developing suitable drought and pest resistant crop varieties and ensuring adequacy of institutional support, the Mission would also expand its coverage to rainfed areas for integrating farming systems with management of livestock and fisheries, so that agricultural production continues to grow in a sustainable manner.

The mission identifies ten key dimensions for promoting the sustainable agricultural practices by implementing a programme of action (POA) covering both adaptation and mitigation measures through four functional areas, namely, *Research and Development*,

Technologies, products and practices, *Infrastructure* and *Capacity building*. While modern technologies and research would continue to play an important role in promoting the sustainability of agricultural production, the Mission also recognizes the need to harness traditional knowledge and agricultural heritage for in-situ conservation of genetic resources.

The POA would be operationalised by mainstreaming adaptation and mitigation strategies in ongoing research and development programmes and in flagship schemes including; *Rashtriya Krishi Vikas Yojna (RKVY), National Horticulture Mission (NHM), National Food Security Mission (NFSM) etc.* through a process of selective upscaling and course correction measures which would further be supplemented by introduction of new programmatic interventions. NMSA would also seek convergence with other National Missions and collaborations with key Ministries/Departments for institutionalizing linkages for addressing cross-sectoral issues.

Sustainable agricultural production is the key to ensure food and livelihood security and would require a multi-functional/multi-tier institutional mechanism for ensuring convergence and establishing linkage at all levels. The Mission, therefore, proposes to formulate policies of national importance in consultation with the States in the National Development Council. Similarly, for deliberating cross cutting issues with other Missions as well as Ministries/Departments, an Inter Ministerial Coordination Committee, chaired by Cabinet Secretary is recommended. The Intra-Ministerial platform will function in the Ministry of Agriculture and its collaborative efforts with relevant Departments, NGOs, civil society, knowledge institutions and other stakeholders would be coordinated at the level of Secretary (Agriculture & Cooperation)

The implementation of NMSA upto the end of XII Five Year Plan would require additional budgetary support of Rs.1, 08, 000 crore.

CONTENT

RATIONALE

CHAPTER-I

1.1 The National Mission for Sustainable Agriculture (NMSA) is envisaged as one of the eight Missions *(Box 1.1)* under the National Action Plan on Climate Change (NAPCC) with the objective of promoting *Sustainable Agriculture*. The thrust areas to be addressed under this Mission are dryland agriculture, access to information, bio-technology and risk management[1] *(Box 1.2)*. NAPCC has made a clarion call to '*devise strategies to make Indian agriculture more resilient to climate change*' with focus on '*improving productivity of rainfed agriculture*'[2]. This National Mission would cover both adaptation and mitigation measures in the domain of crops and animal husbandry, including research.

Box 1.1

Eight National Missions on Climate Change:

- *National Solar Mission*
- *National Mission for Enhanced Energy Efficiency*
- *National Mission on Sustainable Habitat*
- *National Water Mission*
- *National Mission for Sustaining the Himalayan Ecosystem*
- *National Mission for Green India*
- *National Mission for Sustainable Agriculture*
- *National Mission on Strategic Knowledge on Climate Change*

[NAPCC 2008]

1.2 Agriculture plays a crucial role in ensuring food security while also accounting for a significant share of India's Gross Domestic Product (GDP). It engages almost two-thirds of the workforce in gainful employment. Several industries such as sugar, textiles, jute, food and milk processing etc. depend on agricultural production for their requirement of raw materials.

[1] National Action Plan on Climate Change (NAPCC), Prime Minister's Council on Climate Change, Govt. of India, New Delhi, India, 2008. p-35.
[2] Ibid, p-5.

On account of its close linkages with other economic sectors, agricultural growth has a multiplier effect on the entire economy.

Box 1.2

The Thrust Areas of NMSA:

Dryland Agriculture

Access to Information

Bio-Technology

Risk Management

[NAPCC, 2008]

Presently, the threat of climate change poses a challenge for sustainable agricultural growth. This threat is compounded due to accumulated greenhouse gas emissions in the atmosphere, anthropogenically generated through long-term intensive industrial growth and high consumption lifestyles and preferences. While the international community is collectively engaging itself to deal with this threat, India needs to evolve a national strategy for adapting to climate change and its variabilities in order to ensure ecological sustainability in its socio-economic developmental priorities.

1.3 Agriculture is crucial for ensuring the food and livelihood security of the country and hence it is important that this sector becomes resilient to increasing climatic variabilities and changes. A resilient agricultural production system is the pre-requisite to sustain productivity in the event of extreme climatic variabilities. Although Indian farmers have evolved many coping mechanisms over the years, these have fallen short of an effective response strategy in dealing with recurrent and intense forms of extreme events on the one hand and gradual changes in climate parameters including rise in surface temperatures, changes in rainfall patterns, increase in evapo-transpiration rates and degrading soil moisture conditions on the other. The need of the hour is, therefore, to synergise modern agriculture research with the indigenous wisdom of the farmers to enhance the resilience of Indian agriculture to climate change. The Mission would also promote preservation of Indian Agricultural Heritage to integrate in-situ conservation of genetic resources based on traditional knowledge for Natural Resource Management.

Box 1.3

Agricultural Heritage

Worldwide, specific agricultural systems and landscapes have been created, shaped and maintained by generations of farmers and herders based on diverse natural resources, using locally adapted management practices. Building on local knowledge and experience, these ingenious agri-cultural systems reflect the evolution of humankind, the diversity of its knowledge, and its profound relationship with nature. These systems have resulted not only in outstanding landscapes, maintenance and adaptation of globally significant agricultural biodiversity, indigenous knowledge systems and resilient ecosystems, but, above all, in the sustained provision of multiple goods and services, food and livelihood security and quality of life.

Food and Agriculture Organization (FAO), United Nations, has identified sites in Peru, Chile, China, Philippines and in other countries for implementing conservation and adaptive management of the Globally Important Agriculture Heritage Systems (GIAHS) and their components. The Koraput region in the state of Orissa, which has a rich assembly of unique floral and faunal diversity, is the first Indian agricultural site to be nominated as potential candidate for inscribing as Globally Important Agriculture Heritage Site by FAO.

(FAO, 2010)

1.4 Climate Change refers to the statistical variations in the properties of the climate system such as changes in global temperatures, precipitation, etc., due to natural or human drivers over a long period of time. Climate change could drastically alter the distribution and quality of natural resources thereby adversely affecting the livelihood security of the people. Thus, to analyse the implications of climate change in the context of sustaining the agricultural production system, it is pertinent to bear in mind the performance of Indian agriculture in the last five decades *(Box 1.4)*.

Box 1.4

Performance of Indian Agriculture in Last Five Decades

Foodgrain production increased from 51 million tonnes (1950-51) to 233 million tonnes (2008-09).

Gross Irrigated Area increased from 23 million ha (1951) to 88 million ha (2008).

Population increased from 361 million (1950-51) to 1029 million (2001)

[GoI, MoA 2009]

1.5 In order to sustain agricultural growth for meeting food requirements, policies and strategies need re-orientation with appropriate response mechanisms that are embedded in the policy spectrum for not only meeting foodgrain and buffer

stock requirements, but also, to ensure livelihood security in times of catastrophic incidents both natural and human driven *(Box 1.5)*.

Box 1.5

Projection for next decade

Projected population (2020) – 1439 million

Foodgrain requirement is estimated to be 276 million tonnes in 2020.

Targeted Foodgrain production in 2020: 313.18 million tonnes.

[IIM(A), 2006]

1.6 Observations of Intergovernmental Panel on Climate Change (IPCC) indicate that the adverse impact of climate change due to rising temperatures and extreme weather events on the food production system could impact agricultural growth. Consistent warming trends and more frequent and intense extreme weather events are being observed across India in the recent decades.

Several areas have been identified as risk prone due to the impacts of climate change *(Box 1.6)*. Among these are the coastal areas, Indo-Gangetic plains and the drought and flood prone regions of the country. Besides production from crops and livestock, fresh water and the marine eco-system is also likely to be affected due to warming of sea surface temperatures. Such climatic fluctuations could adversely affect agricultural sustainability resulting in unforeseen situational shortages which could also impact other economic sectors.

Box 1.6

Projected Change in Future Climate

1. *Mean Kharif Rainfall to increase*
2. *More Frequent Heavy Precipitation Events*
3. *Snow Cover to Contract*
4. *Hot Extremes, Heat Waves to be more Common*
5. *Temperature Rise; 1 deg. C (2020) to 3 deg. C (2100); Less increase in Kharif than Rabi*
6. *Rise in Sea Level*

[IPCC, 2007]

1.7 Vulnerability of India in the event of climate change is more pronounced due to its ever increasing dependency on agriculture, excessive pressure on natural resources and poor coping mechanisms. The warming trend

in India over the past 100 years (1901-2000) is estimated to be 0.4^0C[3]. The projected impact of further warming is likely to aggravate yield fluctuations of many crops. While in the short run the impact might not be severe, most crops are likely to witness yield decline after 2020 when the temperature threshold limit of many crops might get breached. A one degree Celsius rise in mean temperature would likely to affect wheat yield in the heartland of green revolution. There is already evidence of negative impacts on yield of wheat and paddy in parts of India due to increased temperatures, increasing water stress and reduction in the number of rainy days. Crop specific simulation studies, though not conclusive due to inherent limitations, project a significant decrease in cereal production by the end of this century. Parts of western Rajasthan, southern Gujarat, Madhya Pradesh, Maharashtra, Northern Karnataka, Northern Andhra Pradesh, and Southern Bihar are likely to be more vulnerable in times of extreme events. Irrigation requirements in arid and semi-arid regions are estimated to increase by 10% for every 1^0C rise in temperature[4]. Rise in sea level would also likely to have adverse effects on the livelihoods' of fisher and coastal communities (Box 1.7).

Box 1.7

Climate change is likely to create a new community called Climate Refugees comprising of people who have to leave their villages because of loss of livelihood on an aftermath of extreme climatic events. In the event of sea-level rise, the fisher and coastal communities have potential to become Climate Refugees.

1.8 Significant negative impacts are being projected in the medium-term (2010-2039) depending on the magnitude and distribution of warming *(Box 1.8)*. In the long run, the effect could even be more detrimental *"if no adaptation measures are taken"*. The negative impact on agricultural production will imply significant percentage fall in the annual GDP. However, its fallout for livelihood security in the farming sector could be much more severe vis-à-vis other economic sectors.

[3] National Communication Project (NATCOM), GOI, 2004

[4] ICAR, GOI, National Network Research Project on Climate Change, 2009

1.9 While short term mitigation measures would always demand immediate attention, the complexities of abiotic stress on crops and livestock in the long term would require intensive research to effectively address the adaptation processes required for making our production systems resilient to climate change.

Box 1.8

Impacts of Climate Change

Reduction of Agriculture Yields in Medium term (2010-2039): upto 4.5-9%

Fall in GDP growth in Medium Term: upto 2% per annum

Reduction of Agriculture Yield in Long Term (2040 and beyond) : > 25% if no measure is taken

[NNPCC, ICAR, 2009]

1.10 The Mission Document on NMSA has adopted a wider focus to encompass not only the rainfed areas but also the irrigated and coastal regions of the country. Both adaptation and mitigation needs of Indian Agriculture in the light of future climatic changes have been considered for a timeframe that spans from the present upto the year 2017 (i.e till the end of 12th Five Year Plan) as well as a longer time frame extending beyond 2017.

SUSTAINABLE AGRICULTURE AND CLIMATE CHANGE: THE INDIAN CONTEXT

CHAPTER-II

2.1 Sustainable agricultural practices have to balance environmental health and economic profitability in order to promote social and economic equity. Therefore, stewardship of both natural and human resources is of prime importance. In simple terminology, *'Sustainable Agriculture'* involves the processes that would enable us to meet the current and long term societal needs for food, fibre and other resources, while maximising benefits through the conservation of natural resources and maintenance of ecosystem functions. The priority of exalting human capabilities at the individual (farmer) level and ensuring food security at the national level, through efficient and equitable use of resources are compatible with the concept of *'Sustainable Agriculture'*.

2.2 Inter-annual, intra-seasonal, monthly and daily distribution of climatic variables (primarily temperature, precipitation and humidity) play a fundamental role in most of the physical, physiological, chemical and biological processes that drive productivity in agriculture, livestock, forestry and fisheries sectors. Any change in these climatic determinants not only leads to adverse impacts on food security and nutrition, but also affects the livelihood of millions dependent on the farming sector. Agriculture and allied sectors, therefore, exhibit high sensitivity to climatic variabilities and changes.

2.3 While in the long run, climate change is likely to exacerbate current stresses thereby

increasing the vulnerabilities in food production and livelihoods of farming communities, even in the short run climatic variability and occurrence of extreme weather events would affect agricultural production, livestock and fisheries. Climate change is also likely to significantly alter the dynamics of extreme events such as tropical cyclones, associated storm surges and extreme rainfall events; possibly increasing their frequency and intensity. Low lying regions, including small islands, will face the highest exposure to rising sea levels, which will increase the risk of floods bringing more cultivable area under the risk of submergence and degradation.

2.4 A number of environmental, social and economic factors contribute to the '*differential vulnerability*' of diverse farming systems and the communities involved. Rainfed areas, in particular, having complex cropping systems operating under fragile ecological conditions, constitute about 60 % of net cultivated area (140 mha).[5] Poverty levels and high population density are other important factors that increase the vulnerability of Indian agricultural system to climate change. Multiple stresses on natural resources such as soil erosion, salinisation of irrigated lands, degradation of pastures, water pollution and overexploitation of forest stocks contribute to low resilience in the Indian farming systems. Since most of the agricultural production takes place in rural heartlands by engaging people from the marginalized sections of the society, the coping capacity of the farmers during climatic extremities are limited. Coping responses of Indian farmers to shocks such as droughts are often of distress through sale or mortgage of farm assets like livestock or land[6]. Moreover, constraint in accessing institutional or formal financial mechanisms for agricultural credit is another significant factor that contributes to high vulnerability of the sector. Similarly, agricultural markets and food supply chains in India are mainly in the unorganized sector which is often dominated by intermediaries thereby depriving the farmers of their due remuneration. Post-harvest losses due to inadequate storage and transport infrastructure, lack of market information and

[5] MoA, 2009

[6] Binswanger (1980), after studying the risks in agricultural investments, risk averting tendencies of the farmers and available strategies for shifting risk, concluded that farmers own mechanisms for loss management or risk diffusion are very expensive in arid and semi-arid regions.

intelligence reduce the profitability of farming systems. Although there are mechanisms to provide adequate information access on weather and crop management, they often operate on a delayed mode, lack feedback loops, and often function in isolation. To sum up, the combination of high vulnerability and low adaptive capacity makes enhancing resilience in Indian agriculture and allied sectors a challenging task.

2.5 Climate change will dramatically alter the natural balance of local and global ecosystems and will infringe on human settlements. Consequently, vulnerable groups such as poor will face food insecurity, loss of livelihood, hardships due to environmental degradation and extreme events such as drought, floods, storms and cyclones. (Parikh J, 2009). The overall impact of climate change on our food production systems and economy is expected to be high since the agriculture and allied sector still accounts for a large share of gross domestic product (GDP) and employment[7]. Although its contribution to GDP has been falling, it still accounts for a significant share. For States like Punjab, Uttar Pradesh, and Haryana, the percentage share of agriculture and allied activities in state domestic product is more than 30 percent.

Box 2.1

Challenges

- *Need for more food: 310 Million Tonnes of Foodgrains in 2050 **
- *Stagnating Net Sown area: 140±2 mha since 1970***
- *Land share under fallow: 38% increase since 1951***
- *Per Capita land availability: From 0.91 ha in 1951 to 0.32 ha in 2001 and to 0.19 ha is projected by 2050 ***
- *Per capita net sown area: 0.33 ha in 1951 to 0.14 ha in 2001***

[AFC (2003); ** Das (2005)]*

[7] This primary sector consists of crop and animal husbandry, agro processing, forestry and fisheries; significantly supporting economic growth and social transformation in one of the world's largest agrarian economies. Almost 46% of the land area in India is used for agricultural activity and provides employment to almost 58% of the country's workforce (CSO, 2007). The sector along with other allied sectors contributed 18.5% to the total GDP in 2005-06 and also accounted for approximately 10.8% of exports in the same year. In 2001, the total rural population of the country was 742.6 million (72.2 percent) and agricultural work force stood at 234.1 million, with 127.3 million cultivators and 106.8 million agricultural labourers (54.4 percent and 45.6 percent of agricultural workers respectively).

2.6 Indian agriculture now faces the challenge *(Box 2.1)* of ensuring food security amidst constraints such as stagnating net sown area, deterioration of land quality, reduction in per capita land availability etc. As a result, agricultural productivity has been witnessing stagnation in recent years. Besides, issues such as competing demand for water in the context of changing demographics and its various end uses, further aggravates the degree of risks in the agriculture sector. These have considerable implications for food and livelihood security and as agriculture production being risk prone, may lead to migration from rural to urban and sub-urban areas.

2.7 Fostering rapid, sustainable and broad-based growth in agriculture is therefore, a key priority keeping in mind the overall socio-economic development trajectory of the country, especially in the light of existing vulnerabilities that relate to a shrinking land resource base, additional stresses arising from the non-agricultural sector and issues emerging due to changing climate. This necessitates a strategic approach with a renewed vision and redefined focus.

NATIONAL MISSION FOR SUSTAINABLE AGRICULTURE (NMSA): VISION AND OBJECTIVES

CHAPTER-III

3.1 The National Mission for Sustainable Agriculture seeks to *transform* agriculture into an *ecologically sustainable* climate resilient production system while at the same time, exploiting its fullest potential and thereby *ensuring* food security, equitable access to food resources, *enhancing* livelihood opportunities and *contributing* to economic stability at the national level *(Box 3.1)*.

Box 3.1

The Vision of NMSA:

Transform Agriculture into Climate Resilient Production system

Grow and Ecologically Sustain agricultural production to its Fullest Potential

Ensure Food Security and Equitable Access to Food Resources,

Enhance Livelihood Opportunities,

Contribute to Economic Stability at the National Level

3.2 The Mission would focus on the following areas for sustaining agricultural growth: *(Box 3.2)*

3.2.1 To devise strategic plans at the Agro-Climatic Zone level so that action plans are contextualized to regional scales in the areas of Research and Development, Technology and Practices, Infrastructure and Capacity Building.

3.2.2 To enhance agricultural productivity through customized interventions such as use of bio-technology to develop improved varieties of crops and livestock, promoting efficient irrigation systems, demonstration of appropriate technology, capacity building and skill development.

3.2.3 To facilitate access to information and institutional support by expanding Automatic Weather Stations (AWS) networks to the Panchayat level and linking them to existing insurance mechanisms including Weather Based Crop Insurance Scheme (WBCIS) and National Agriculture Insurance Scheme (NAIS), scaling the returns at that level.

3.2.4 To promote "laboratory to land" research by creating Model Villages and Model Farm Units in rainfed and dryland areas.

Box 3.2

Key Focus Areas

- *Strategic Planning at Agro Climatic Zone Level*
- *Customized interventions to enhance productivity*
- *Easy access to Information and Institutional Support*
- *Linking Laboratory to Land*
- *Dry land Farming*

3.2.5 To strategize long term interventions for emission reduction from energy and non-energy uses by way of introduction of suitable crop varieties and farm practices, livestock and manure management.

3.2.6 To realize the enormous potential of growth in dryland agriculture through development of drought and pest resistant crop varieties, adopting resource conserving technologies, providing institutional support to farmers and capacity building of stakeholders.

3.3 The Mission would further devise appropriate strategies by identifying key dimensions of sustainable agriculture and formulating a Programme of Action (PoA) for adaptation and mitigation measures covering research and development, technology and best practices, infrastructure and capacity building. This will be supported by synergizing traditional knowledge, agricultural heritage and modern technology and research.

The Mission would seek 'convergence and coordination' among the key ministries and departments at all levels of governance. Since climate change adaptation in the agriculture sector is a cross sectoral issue, requiring the cooperation of several government departments and integration of their programs and actions, this would also establish linkages with the other National Missions *(Box 3.3)*.

Box 3.3

Integration with other National Missions

- ✓ *National Mission on Water: Water Conservation and Management*
- ✓ *National Mission for a Green India: Soil and Water Conservation, Agro-forestry*
- ✓ *National Mission for Enhanced Energy Efficiency: Energy Pricing, Water Pump Efficiency*
- ✓ *National Solar Mission: Utilizing Solar and Wind Power for agriculture*
- ✓ *National Mission on Strategic Knowledge on Climate Change: R&D and Knowledge Management*

CLIMATE CHANGE RISKS IN INDIAN AGRICULTURE

CHAPTER-IV

4.1 India has a wide range of region specific climatic conditions. The Northern region of the country experiences extreme winters whereas tropical conditions prevail in the Southern peninsular region. The North-eastern regions are characterized by hot and humid climate whereas the North-western regions are characterized by dry and arid conditions. Rainfall during the monsoon season (June-September) is the key element of the Indian climate and continues to be the primary source of water for the large rainfed agricultural regions in the country. Variability in monsoon related weather and climatic conditions is, therefore, regarded as the primary cause of spatial and temporal fluctuations in agricultural yields. The departure in minimum and maximum temperatures above or below the optimum value influences plant physiological conditions viz., respiration, water requirement and growth, thereby affecting yields. Extreme weather conditions such as floods, droughts, heat and cold waves, flash floods, cyclones, hail storms, etc. are constant hazards for agricultural production. Even subtle fluctuations in weather conditions during critical phases of crop development have substantial impact on yields. Since most of the cultivated land in India is rainfed and agricultural production is heavily dependent on the monsoons, agriculture productivity and the well being of the Indian farmer is sensitive to climatic variability. However, while on the one hand, agriculture sector is likely to get affected due to climate change, on the other hand, the sector can also join hands with other sectors in controlling emission of Green House Gases (GHG).

4.2 Risks to the agricultural system from changing climatic conditions can be identified at three levels: the crop (or livestock) level, the farm (or cropping system) level and at the food system level *(Box 4.1)*. Climatic variability directly impacts yields at crop level and also affects soil quality; water resources; brings in pests, diseases and weeds, etc. further aggravating the impact on the cropping system, thereby reducing the yield per hectare of land or per unit of livestock at the farm level. The adverse impact of climatic variability on agriculture production at farm level gets aggregated to the level of the food system in terms of food shortages and rising prices which can also endanger food and livelihood security.

Box 4.1

Climate Change Risks at Three Levels

Crop (Livestock) Level: Productivity and Quality of Produce

Farm (Cropping System) Level: Soil quality, Water resources, Pest & Diseases

Food System Level: Pricing, Food Security

4.3 At the crop level, in the short term, increase in carbon dioxide (CO_2) concentration is likely to compensate the negative effect on yields due to increase in temperature, but as temperature increases further, it would result in yield losses. Most crop simulation studies have predicted a decrease in the yield of crops with an increase in temperature. Further, adverse temperature and moisture conditions affect the quality of food grains *(Box 4.2)*. Climate change is also likely to have significant effect on the quality of plantation and cash crops such as cotton, fruits, vegetables, tea, coffee, aromatic & medicinal plants, etc.

Box 4.2

Impact on Crops

Productivity: 15-17 % decrease in yields of wheat and rice for a 2°C rise in temperature. However, the losses would be partially offset by an increase in the levels of CO_2. Wheat, which is generally grown in the winter, is predicted to be affected more than rice.

Quality of Produce: High night time temperature increases respiration rate, decreases membrane thermal stability and negatively affects the yield in rice. In wheat, grain number and weight is reduced due to prolonged high temperatures and drought conditions.

4.4 The damage to crops caused by pests, pathogens and weeds increases due to higher ambient temperature. Change in climate is likely to bring about a change in the population dynamics, growth and distribution of insects and pests thereby, upsetting crop-pest balance. Drought conditions would increase pathogen and insect survival rate due to change in plant nutrient level and decrease in plant defense system *(Box 4.3)*. These changes could lead to enormous crop losses in altered environment[1].

Box 4.3

Pests, Insects and Diseases

Insects have very high degree of adaptability to climate change.

Climate change would aggravate the adverse impacts of Pests and Insects.

Drought decreases plant defense mechanism and creates more favourable environment for pests and insects.

4.5 The impact of climate change resulting in warming, changes in precipitation patterns, increased frequency of extreme events, rise in sea level etc. would affect the water balance and water quality in different parts of the country. Changes in rainfall patterns can cause water shortages in some regions which, combined with thermal stress due to higher mean temperature, can adversely affect crops. Moreover, change in precipitation patterns and amounts, and variation in temperature may degrade soil quality, reduce soil moisture content and affect microbial diversity, which in turn affect crop growth. An increase in temperature also leads to increased evapo-transpiration (ET), thereby lowering groundwater table and adversely affecting irrigation potential. At some places, increased surface temperature coupled with reduced rainfall may lead to accumulation of salts in upper soil layers. Similarly, a rise in sea level associated with increased temperature may lead to salt-water ingression in the coastal lands, making them

Box 4.4

Impact on Soil and Water Resources

Availability and quality of both surface and ground water would be affected

Reduction in ground water recharge will affect irrigation potentials

Soil quality and moisture content will be degraded

Possibilities of salination of land due to sea water ingress and salt accumulation

[1] IPCC, 2001

unsuitable for conventional agriculture *(Box 4.4)*.

4.6 Impacts of climate change on livestock will be felt in the form of elevated body temperatures, increased respiration rates, decrease in feed intake, etc. Indirect impacts would be observed in the form of reduction in grazing land and water availability, decline in available cattle feed, emergence of new diseases, etc. Thermal or heat stress would impact animal production and profitability in dairying due to lower feed intake, milk production and reproduction. Although small ruminants are more tolerant to climatic extremities than other farm animals, yet empirical evidence[2] indicates adverse impact of heat and cold stress on the growth, production and reproduction performance of these animals. Besides being susceptible to increased heat stress from climate change, the livestock is also exposed to the risks associated with extreme events. India is among 27 countries that are most vulnerable to increase in the frequency and intensity of extreme events such as heat waves, storm surges, droughts, floods, etc[3]. Severe drought conditions are likely to affect livestock due to decline in feed and fodder availability and serious water shortages. The impact of climate change induced decline in pastoral land would further aggravate the severe constraints on livestock farming *(Box 4.5)*.

Box 4.5

Impact on Livestock and Fisheries

Cattle are susceptible to extreme events

Livestock will be affected due to heat stress, new diseases, poor quality of feed and rising fodder prices

Heat stress will reduce milk production by 10-25%

Warming will affect reproductive rates of livestock

Changes in aquatic habitat and ecosystem would impact fisheries.

4.7 Changes in the climate would also affect the fisheries sector in many ways. Climate change would induce changes in the abundance and distribution of exploited species and assemblages. These changes would increase further with the degree of severity of extreme events, such as

[2] Marai et al., 1997,2000; Shelton, 2000; Abdel-Hafez, 2002
[3] UNEP, 1989

floods and storms, which in turn affect fishing operations and infrastructure. Climate change would also indirectly affect aquatic habitats (quantity and quality), ecosystem productivity and the distribution and abundance of aquatic competitors and predators/disease thereby affecting the livelihood and food security of fishing communities. It has already been observed that the breeding of Indian major carps as well as the distribution of important fish species and plankton has been affected due to changes in temperature and rainfall patterns over the catchments of the Ganga[4].

4.8 Agriculture releases a number of Green House Gases (GHG) into the atmosphere *(Box 4.6)*. These GHGs include Carbon dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O). Manure application, digestion process of ruminants and wetland rice cultivation are the main contributors to Methane emissions. Most of the Nitrous Oxide emissions are linked with application of nitrogenous fertilizers. Carbon dioxide emissions arise mainly due to the use of diesel pumps in irrigation. Other sources of carbon dioxide include burning of agricultural wastes for field preparation[5], burning of biomass, microbial decay etc.

Box 4.6

GHG Emissions 2007)

Agriculture: 33.658 Million Tonne CO_2 Equivalent.

India (Grand Total): 1727.06 Million Tonne CO_2 Equivalent.

Contribution of Agriculture: 1.94%

[Greenhouse Gas Emissions- 2007, MoEF 2010]

4.9 Risks associated with climate change threaten livelihood opportunities within the food production sectors mainly in two ways: Firstly, increase in frequency and intensity of extreme weather events would expose the agricultural sector to greater risks to productivity resulting in loss of revenue that could lead to displacement and a whole host of potentially devastating economic and social consequences (Parikh J, 2009); and secondly, changing weather and precipitation patterns would require expensive adaptation measures such as relocating crop

[4] Journal of Thermal Biology (2004): 29: 157-163
[5] IPCC, 1997

cultivation, changing the composition or type of crops and increasing use of inputs such as feed, fertilizers and pesticides which may lead to economic denigration and job loss.

IPCC(2007) projects that small landholder and subsistence farmers, pastoralists and artisanal fisher folk will suffer most due to the complex and localized impacts of climate change (Box 4.7). While the lack of sufficient income to purchase food is a major factor contributing to food insecurity, hunger itself contributes to poverty by lowering labor productivity, reducing resistance to disease and depressing educational achievements[6]. In some areas where livelihood choices are limited, decreasing crop yields may threaten famines, or where loss of landmass in coastal areas is anticipated, migration might be the only solution[7]. Another noteworthy dimension of the problem is the likely implications for global and domestic trading regimes and market prices of farm inputs and outputs under the changing climate scenarios.

Box 4.7

Impact on Livelihoods, Food Security and Economy

"Climate Change is about Economy" -Sunita Narain, 2009

The impact of climate change on agriculture has large detrimental effects on availability of food, livelihoods and the overall economy.

Small and marginal farmers, pastoralists and artisanal fisher folk will be the worst sufferers.

4.10 The agriculture and allied sector in India is exposed to potential risks arising from climate variability and climate change induced stresses *(Box 4.8).* These risks coupled with the existing vulnerabilities such as poverty, high population density, depletion of important natural resources, shrinking cultivable land, insufficient rural infrastructure, etc are expected to exacerbate the stress on Indian agriculture through a range of direct and indirect impacts.

[6] FAO, 2001
[7] ADB, 2009

Appropriate adaptation and mitigation strategies, therefore, have to be mapped for management of risks with the objective of transforming Indian agriculture into a climate resilient system and for ensuring overall food security both in the short and long term *(Appendix-I)*.

Box 4.8

Key risks to Indian agriculture from climate variability and change

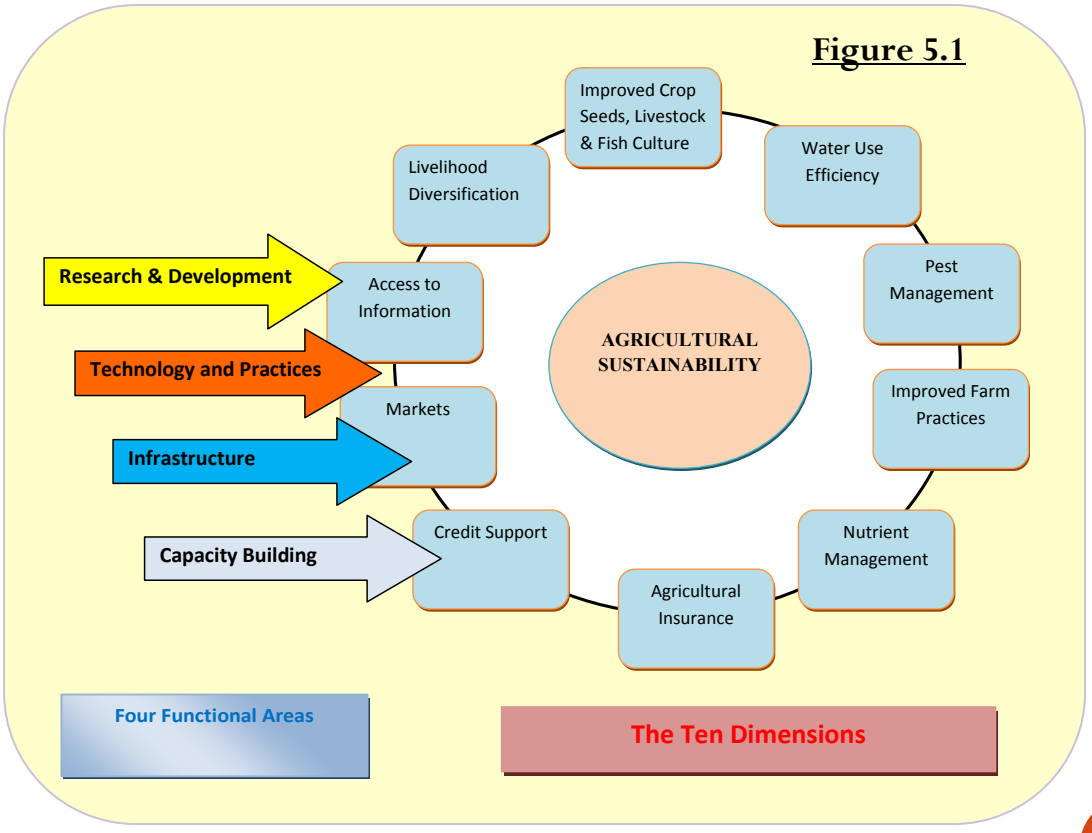
- ✓ *Decline in yields (from direct physiological impact on crop/livestock/fish and indirect impact on soil, water, nutrients, pests, diseases, etc)*
- ✓ *Increased farm expenditure (including post harvest management)*
- ✓ *Reduced farm incomes*
- ✓ *Increased threat of food insecurity and malnutrition*

TEN KEY DIMENSIONS FOR ADAPTATION AND MITIGATION

CHAPTER-V

5.1 Adaptation and mitigation measures needed for transforming Indian agriculture into a climate risk-resilient mode would have to focus on key dimensions in order to synergise strategies for programmatic interventions. These key dimensions (*Figure 5.1*) are the areas that need to be addressed due to the risks emanating from climate change. Each of these dimensions has then to be analyzed in the context of four functional areas viz. *Research and Development*, *Technology and Practices*, *Infrastructure and Capacity Building* for identifying adaptation and mitigation needs in a multi-dimensional and cross-sectoral matrix.

Figure 5.1



Collaborative programmatic interventions in these four areas focusing on the ten key dimensions would effectively address the adaptation and mitigation needs at different levels e.g. crop, farm and food systems. *(Appendix-II)*

5.2 Mission Intervention #1: Improved crop seeds, livestock and fish cultures:

Biotechnology is an important tool for the development of genetic resources with greater adaptive capacity to cope with changing environments. It has huge potential for combating vulnerabilities in crops, livestock and fisheries. Region specific vulnerability and impact assessment studies using crop growth simulation models are necessary to identify and formulate suitable interventions. Research and promotion of higher carbon (C4) pathways in low carbon (C3) plants (NAPCC, 2008) and genetic manipulation of enzymes such as *RuBisco* would help in increasing effectiveness of use of CO_2 and thus helping reduction in GHG emissions. The rich indigenous genetic resources in the crops, livestock and fisheries sectors should be conserved, catalogued and advantageously used while also conserving the agricultural heritage of the country. Relevant technologies should be used for rapid bulking of improved varieties of crops, livestock and fishes. Public private partnerships should be promoted in development, management and dissemination of the improved varieties.

Mission Intervention #1
Improved Crop Seeds, Livestock and Fish Culture

- ✓ *Promoting Use of Biotechnology*
- ✓ *Research and Promotion of C4 pathways in C3 plants*
- ✓ *Conserving Indigenous Genetic resources*
- ✓ *PPP in R&D, Management and Dissemination of Improved varieties*
- ✓ *Conserving 'Agricultural Heritage"*

Strategies under this mission call for continuous efforts in improving genetic traits to sustain productivity, both in the short and long term, with focus on research and development of resilient genotypes. Simultaneously, reforms in policies, regulatory regimes and conformance to standards would also promote large scale research and wider adoption of genetically improved varieties by both producers and consumers. International collaborations with Consultative

Group on International Agricultural Research (CGIAR) institutions would be critical for fostering these activities. Detailed mapping of mission strategies under this dimension is at *Appendix-III-A*.

5.3 Mission Intervention #2: Water Use Efficiency

Two-thirds of the cultivated land in India is rainfed and suffers from water scarcity. Effective management of available water, increasing water use efficiency and establishment of additional sustainable sources of water emerge as the primary issues that need to be addressed. Strategies under this dimension would focus on the application of a range of technologies coupled with demand and supply side management solutions to enhance water use efficiency for irrigation. While some technologies are available for direct application and can be implemented in the short term, there are other emerging areas like recharging of aquifers, conjunctive use of surface and ground water, controlled extractions, etc. that would require collaboration and capacity building for technology absorption before being put into sustainable use. The role of local institutions in managing water allocation and utilization will also be crucial for promoting efficiency. Policy instruments will have to be leveraged to encourage adoption of technologies for enhancing water use efficiency and to promote public-private partnerships. Detailed mapping of mission strategies under this dimension is at *Appendix-III-B*.

Mission Intervention #2
Water Efficiency

- ✓ *Promoting Water Use Efficiency in Irrigation*
- ✓ *Research and Development in the areas of energy efficient water systems*
- ✓ *Developing mechanisms for integrated management of rainwater, surface and ground water*
- ✓ *Policy Instruments for PPP*
- ✓ *Strengthen local institutions in managing water allocation and utilisation*

5.4 Mission Intervention #3: Pest Management

Pesticide consumption in India has increased over time and its injudicious use has created problems like development of resistant strains in insects and plant pathogens, resurgence of pest species, direct exposure to the applicator, destruction of parasites, predators, and other beneficial organisms, accumulation of pesticide residues in agricultural commodities, water, air and soil, etc. Pesticide residues in feed and water affect livestock health due to direct and indirect exposure in the course of pest control measures. Strategies suggested under this intervention have to primarily focus on establishment of decision and information support systems for pest and disease surveillance, demonstration of best practices and quick response mechanism that are at par with the norms to deal with other disasters or natural calamities. Detailed mapping of mission strategies under this dimension is at *Appendix-III-C*.

Mission Intervention #3
Pest Management

- ✓ *Efficient, safe and environmentally sound methods of pest management.*
- ✓ *Incentivizing Research, Commercial Production and Marketing of bio-pesticides*
- ✓ *Developing insect forecasting models*
- ✓ *Decision and Information Support Systems for Pest & Disease Surveillance*
- ✓ *Institutional Mechanism for Quick Response in case of disaster*

5.5 Mission Intervention #4: Improved Farm Practices

The most effective way to address climate change is to adopt a sustainable development pathway by shifting to environmentally sustainable technologies and promotion and accelerated adaptation of energy efficient equipments (Mathur, 2009), renewable energy, and conservation of natural resources. Improved agronomic practices have the potential to help reduce farm level losses through improved soil treatment, increased water use efficiency, judicious use of chemicals, labour and energy and increased soil carbon storage. Targeted resource conserving technologies offer new opportunities for better livelihoods for the resource poor, small and marginal farmers.

The strategies suggested under this intervention largely lean on support and popularization of resource conservation technologies at the farm level and introduction of practices that would support mitigation efforts in time of extreme climatic events or disasters like prolonged dry spells, floods etc. While in the short term, measures like changes in timing of farm operations and improved inputs to the farm can be employed, other measures that include focus on conservation agriculture technologies and other best practices can be explored in the long run. Detailed mapping of mission strategies under this dimension is at *Appendix-III-D*.

Mission Intervention #4
Improved Farm Practices

- ✓ *Improved agronomic practices to reduce farm losses*
- ✓ *Conservation and Precision Farming*
- ✓ *Knowledge Management*
- ✓ *Soil Conservation, Bio-Fertilizer*
- ✓ *Policy Instruments for optimum Land Use*

5.6 Mission Intervention #5: Nutrient Management

Plant nutrient management to increase soil nutrients and thus enhance crop productivity is a major technological challenge for ensuring food security and sustaining rural development. Plant nutrition management is essential to sustain and enhance crop productivity to meet the demand for food and raw materials, and to maintain the quality of land and water resources. To ensure soil health, accurate inventorization of soil resources is a prerequisite. Soil health can be improved through several site and soil-specific management options. Application of integrated nutrient management techniques has been found to increase nutrient use efficiency by integrating and balancing the nutrient dose in relation to nutrient

Mission Intervention #5
Nutrient Management

- ✓ *Strengthening services for promoting production and use of bio-fertilizers*
- ✓ *Developing nutritional strategies for managing heat stress in dairy animals*
- ✓ *Strengthening capacity of existing soil testing labs*
- ✓ *Quality standards and quality control system for raising confidence among users*

status and crop requirements. Detailed mapping of strategies under this dimension is at *Appendix-III-E.*

5.7 Mission Intervention #6: Agricultural insurance

Agricultural insurance is an important mechanism by which risks to agricultural output and income can be addressed. Crop insurance incentivizes farmers to adopt innovative options by spreading the risks over space and time. It also stabilizes farm incomes thereby enabling farmers to repay debts, which not only preserve the viability of formal financial institutions, but also saves huge government expenditures incurred in writing-off agricultural loans. Deficiencies in the existing framework of assessment of crop damage and prompt settlement of claims need to be addressed so that a *disaster mode of operational efficiency* is institutionalized. Research and development activities for developing new insurance products in the light of new risks emerging from climate change also need to be taken up as a medium to long term strategy.

Mission Intervention #6
Agricultural Insurance

- ✓ *Developing various models for risk assessment*
- ✓ *Designing user-friendly decision support systems to help assess risks and develop region specific contingency plans*
- ✓ *Strengthening existing risk cover mechanism under NAIS and Weather Based Crop Insurance Scheme*
- ✓ *Implementing region-specific contingency plans based on vulnerability and risk scenarios*

An effective design and efficient implementation mechanism is required to ensure timely benefits especially to the small and marginalized farmers. Detailed mapping of mission strategies under this dimension is at *Appendix-III-F*.

5.8 Mission Intervention #7: Credit support

Free, untied and timely credit support to farmers is essential for sustaining farm productivity, especially when it comes to small and marginal farmers. Easy and timely financial incentives and credit (and insurance) packages provided to farmers can help in adoption of improved management practices including resource conservation technologies, agro-diversification, post harvest value addition processes, etc. which would contribute to reducing risks and enhancing farm incomes. This dimension emphasizes efforts to augment the flow of credit to agriculture, alongside exploring new innovations in product design and methods of delivery, through better use of technology and related processes. Facilitating delivery through processors, input dealers, NGOs, Self Help Groups (SHGs) etc. would help in providing access to credit to the resource poor farmers, especially the small and marginalized farmers, to help them to manage the additional risks from climate change in a sustainable manner. Detailed mapping of strategies under this dimension is at *Appendix-III-G*.

Mission Intervention #7
Credit Support

- ✓ *Developing new forms of credit assessment and risk management systems*
- ✓ *Promoting micro finance*
- ✓ *Developing mechanisms to enhance the flow of credit to critical infrastructure*
- ✓ *Up-scaling the Kisan Credit Card Scheme (KCCS)*
- ✓ *Designing customised credit policies and programmes to mitigate risks*

5.9 Mission Intervention #8: Markets

Inadequate marketing infrastructure, presence of large number of intermediaries, lack of market information and intelligence and inadequate storage facilities results in huge post harvest losses in the food supply chain. Some of the major initiatives that are to be taken up under this dimension include, reducing quantitative as well as qualitative losses across the supply chain; creating market aligned production systems; strengthening climate resilient post harvest management, storage and marketing and distribution system; strengthening timely access to

farmers to quality inputs; strong farmer-institution-industry interface; and encouraging food processing industries and greater exports.

Detailed mapping of mission strategies under this dimension is at *Appendix-III-H*.

Mission Intervention #8
Markets

- ✓ *To formulate market-aligned Research and Development programmes*
- ✓ *Improving Supply Chain Efficiency*
- ✓ *Creation of new market infrastructure*
- ✓ *Supporting community partnerships in developing food and forage banks*
- ✓ *Strengthening access to quality and timely inputs by farmers for mitigating risks*

5.10 Mission Intervention #9: Access to Information

Effective communication approaches are critical to help farmers adapt to climate change as weather becomes more erratic and less predictable. Fresh strategies for management of information may be required to sustain production levels. This dimension is cross cutting in nature, having implications at all levels in the agricultural production system as well as for all the other key dimensions. At the crop level, the focus needs to be on up-scaling the efforts to link the public and private partners with the Research Institutions so that the laboratory results can get commercialized quickly. At the level of the farm, focus needs to be on enhancing awareness of farmers as well as the developmental agencies with the latest scientific research, market information, and policy initiatives so that they are empowered to take informed decisions for maximizing farm productivity. At a larger scale, at the food system

Mission Intervention #9
Access to Information

- ✓ *Minimizing Information Asymmetry through ICT-based systems*
- ✓ *Public Private Partnership to develop technology based solution for providing farmers with information on price discovery, commodity arrivals, mandi prices etc.*
- ✓ *Building an ICT enabled Knowledge Management network*
- ✓ *To Create, Manage and Develop National Resource Portal*

level, technological and infrastructural research along with interventions required to enhance the adaptive capacity for ensuring food security in the wake of climate change must be investigated. Detailed mapping of strategies under this dimension is at *Appendix-III-I*

5.11 Mission Intervention #10: Livelihood diversification

Livelihood diversification plays a major role in providing options of supplementing income from core agricultural activities through on-farm or off-farm activities, mitigating risks by providing additional support to agricultural income under conditions of climatic and non-climatic stresses, supporting farm-based investments for better productivity, and through income generated by alternate livelihood options.

Mission Intervention #10
Livelihood Diversification

- ✓ *Mitigating risks by supplementing income from Off-Farm activities*
- ✓ *Crop Diversification*
- ✓ *Crop-Livestock-Fisheries Farming System*

The strategies under this dimension would aim to promote diversification of agriculture into other high-value crops and horticulture; research, development and extension of crop-livestock farming systems; increasing focus and development of approaches like sericulture, agro-forestry, crop-fish farming, etc. Detailed mapping of mission strategies under this dimension is at *Appendix-III-J*.

OPERATIONAL STRATEGIES: INSTITUTIONAL NEEDS

CHAPTER-VI

6.1 It is imperative to put in place a functional *Operational and Institutional framework* to support adoption of the strategies. Agriculture, being an ever evolving socio-economic sector, has been witnessing several ongoing initiatives for sustaining growth and improving productivity. Several strategies are already operational as components of various ongoing programmes and schemes. The Mission has identified gaps for devising a climate resilient framework for conceptualizing the Programme of Action (PoA).

6.2 The process of adaptation and mitigation needs to be mainstreamed or embedded in the developmental pathway. *Technology,* global collaborative effort on *Research and Development (R&D),* including adaptive R&D, to enable deployment of available technologies in developing countries and for absorbing resource conserving technology, would be critical in the process of mainstreaming adaptation (Ghosh, 2009).

Further, policy instruments and interventions in infrastructure such as financial institutions, markets instruments, physical infrastructure, access to information (NAPCC, 2008) etc. and customized capacity building measures (NAPCC, 2008) to create awareness and disseminate desired knowledge would be effective when

***Programme of Action (PoA)**:*

Four Functional Areas:

- ✓ *Research and Development*
- ✓ *Technology, Products and Practices*
- ✓ *Infrastructure*
- ✓ *Capacity Building*

they are embedded within the broader strategies of adaptation and mitigation to climate change. Therefore, the Programme of Action (PoA) identifies four key functional areas of 'Research and Development'; 'Technology, Products and Practices'; 'Infrastructure' and 'Capacity Building' [Figure 5.1 (Chapter V) and Appendix IV refers] for operationalising mission strategies. While relevant ongoing Research and Development activities and programmatic interventions under flagship schemes namely; Rashtriya Krishi Vikash Yojna (RKVY), National Horticulture Mission (NHM), National Food Security Mission (NFSM) would require upscaling *(Appendix-IV),* new research activities and schematic interventions would also be necessary for meeting the adaptation and mitigation needs in the long term *(Appendix-V)*.

6.3 Customization of hybrid or high yielding varieties of seeds to the specific needs of each Agro-Climatic Zone (ACZ) would be the main thrust area under the theme of *Research and Development*. An expansion in the scope of livestock research programmes to cover other farm animals besides cattle would prove beneficial in the long run. Research on better fodder and adaptive fish varieties needs to be initiated. Use of biotechnology for the development of plant, animal and fish varieties that are more climate resistant and have higher resistance to biotic and abiotic stresses is an important pre requisite for dealing with climatic variabilities and heat stresses. Development of predictive models for pest and disease surveillance would also be supported and strengthened. At the economic level, research on market requirements and new forms of credit assessment and risk management systems needs to be promoted.

Research and Development

- ✓ *Regional Alignment of R&D: Customization as per Agro Climatic Zones*
- ✓ *Expansion of Livestock Research beyond Cattle*
- ✓ *Research on Fodders*
- ✓ *Use of Biotechnology*
- ✓ *Predictive Models for Pest and Diseases*
- ✓ *Research on Credit and Risk Management*

6.4 The main thrust area under *Technology, products and practices* would be the conservation of natural resource through promotion of resource efficient technologies and practices. Deployment of customized technologies and packages of practices that are specific to regional requirements would be accomplished. Wider dissemination of a larger array of resource conserving technologies and proven products is the need of the hour. Technologies and practices that increase the mitigation potential at the farm level would be propagated and plant and livestock management options that allow for maximum returns would be explored. Product monitoring for quality of farm inputs would be strengthened.

Technology, Products and Practices

- ✓ *Conservation and Management of Natural Resources*
- ✓ *Conservation and Precision Farming*
- ✓ *Customization of Technology as per region specific requirements*
- ✓ *Crop Diversification to maximize farm income*
- ✓ *Adaptation of Technologies and Practices that increase mitigation potentials*

6.5 *Infrastructure Development* is a fundamental need for climate resilient sustainable agriculture. Infrastructure needs to be mainly developed in the water and power sector to promote sustainability of farm operations. End of line connectivity for irrigation water has to be improved for its better availability at the farm level. Dedicated power grids for agriculture should be constructed and access to renewable energy sources to be developed for deployment in agriculture sector. Apart from this, infrastructural requirements to improve rural connectivity for better access to markets and improving supply chain efficiency have also to be met. Creation of additional and

Infrastructure Development

- ✓ *Physical, Financial and Institutional*
- ✓ *Irrigation and Power*
- ✓ *Last mile connectivity in Irrigation*
- ✓ *Dedicated grids for Power*
- ✓ *Rural Connectivity for better market access*
- ✓ *Improving supply chain efficiency through creation of Storage and Post Harvest Facilities'*
- ✓ *Credit and Risk Management*
- ✓ *Safety Net*

improved storage facilities for seeds, foodgrain, alternative markets and auction houses and establishment of terminal markets have to be ensured. Further, in the domain of financial and institutional infrastructure, this dimension would cater to the enhanced need for establishing a safety net through effective risk management, easy access to credit and reducing information asymmetry.

6.6 Current *Capacity Building* initiatives involve training and demonstration activities to farmers and staff/officials. The scope of such initiatives needs to be expanded to cover demonstrations on a larger array of crops specific to regional weather characteristics and market requirements. Demonstrations of innovative crop and region specific technologies and practices would be carried out at a more disaggregated level. A more uniform and feasible structure for training of farmers as well as staff/officials should be outlined. Extension education format would have to be linked to technological development and industry. Access to information would be augmented by introducing mobile telephony based delivery modules for greater outreach. Additionally, farmer-market-industry interfaces should also be strengthened. The details of opportunities for expansion of ongoing schemes and need for new interventions in the above four functional areas are elaborated at *Appendix-IV and V*.

Capacity Building

- ✓ *Customizing capacity building initiatives to suit regional needs*
- ✓ *Demonstrations to focus on innovative crops and region specific technologies*
- ✓ *Mobile telephony based Information System for Farmers*
- ✓ *Strengthening Extension Centres for greater outreach and broad-basing farmer-market-industry interface*

6.7 In accordance with India's proposed target of reducing Green House Gas (GHG) intensities by 20-25 % till the end 2020, the mission acknowledges the need to reduce emission from the agricultural sector. Improved agronomic practices namely, use of improved crop varieties that have better carbon sequestration; avoiding or reducing use of bare (unplanted) fallow, etc. offer

many opportunities to introduce practices that reduce net emissions of GHGs. Nitrogen related emissions would also be controlled by adopting extensive use bio-fertilizers and by providing temporary vegetative cover between agricultural crops. Further adoption of SRI (System of Rice Intensification), setting up household/ farm scale and community anaerobic digestion plants and appropriate change in dietary practices of livestock would reduce the Methane emission from agriculture and livestock sector.

Controlling the Emission of Green House Gases (GHG)

- ✓ *Improved agronomic practices to increase carbon sequestration and carbon soil sink.*
- ✓ *Wider adoption of Bio Fertilizer to reduce nitrogen related emission*
- ✓ *Promotion of SRI (System of Rice Intensification) for reducing emission of methane*
- ✓ *Change in dietary practices of livestock to curb methane emissions from enteric fermentation*

6.8 Innovative research addressing the issues of climate change needs to be translated into effectively deployable technologies. Supporting policy and institutional instruments also need to be put in place for effective implementation at the ground level. Inter-ministerial co-ordination is essential for collectively achieving goals in areas of convergence with other mission priorities and actions. Linking research with capacity building, development of operational framework for suitable farmer-academia-industry collaboration etc., are emerging areas that need to be institutionalized.

6.9 In a multi-functional approach, generation of effective responses for mitigating climate change related risks in order to transform our agricultural production system into a resilient mode would have a multi-tier institutional mechanism. Such framework would ensure coordination, cooperation and collaboration between Ministries, Departments and stakeholders to achieve the desired objectives. A three-tier institutional mechanism for ensuring convergence at all levels with other Missions is an essential pre-requisite under the National Mission for Sustainable Agriculture (NMSA).

6.10 Policy initiatives would need to be developed in consultation with the States and approved at the level of National Development Council. Keeping in view the cross-cutting areas of NMSA with other Missions as well as Ministries/Departments, it would be essential to constitute an *Inter-Ministerial Coordination* committee chaired by the Cabinet Secretary. *Intra-Ministerial Coordination* would be established in the Ministry of Agriculture in a platform that would function under Secretary, Agriculture and include representatives of the relevant Departments and NGOs, civil society, knowledge institutes, private partners and other relevant stakeholders. These bodies would be supported by a Mission Directorate which would function in the Natural Resource Management Division of Dept. of Agriculture and Cooperation. *(Figure 6.1)*

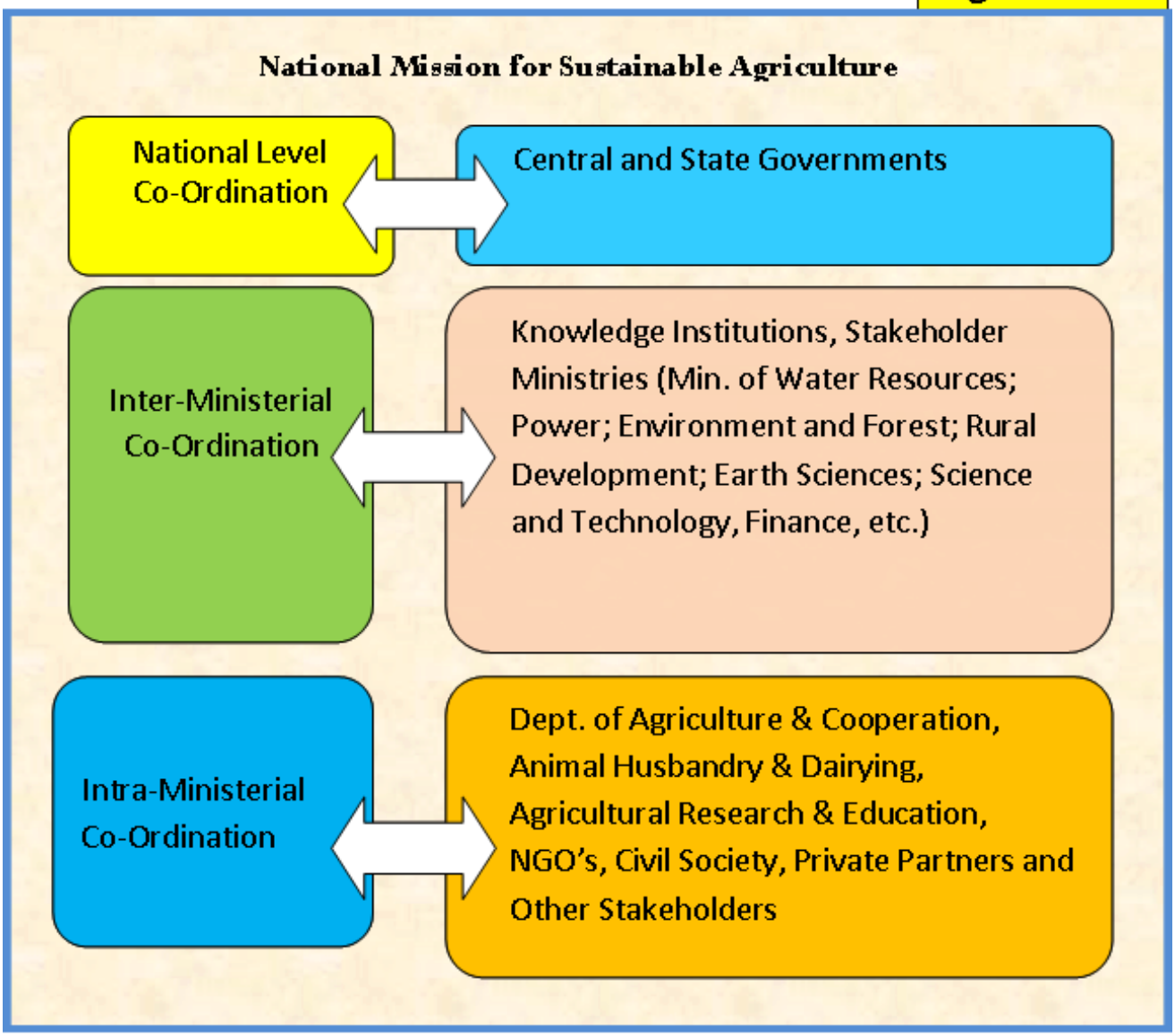
6.11 Areas addressed by other National Missions under the NAPCC can offer substantial co-benefits for the agriculture sector. Convergence with the National Water Mission would be sought for enhancing water use efficiency, water conservation and demand/supply side management methods including rain water harvesting, artificial recharge, watershed development and management practices, waste-water reuse and recycling and resolving issues of water pricing for irrigation. Initiatives like Joint Forest Management (JFM), agroforestry and soil and water conservation measures would be aligned with the National Mission for Green India. Issues like improvement of pump efficiency rates and energy pricing for irrigation could be linked with the National Mission for Enhanced Energy Efficiency. Synergies with the National Solar Mission lie in tapping solar energy or wind power to address energy needs in the agriculture sector. It would also be beneficial to align the research, training and capacity initiatives for the agriculture sector with the

Convergence and Synergies with Other Missions:

- *Agro-Forestry- National Green Mission*
- *Water Pricing, Water Efficiency- National Water Mission*
- *Energy Pricing for Irrigation, Energy Efficiency- National Mission for Enhanced Energy*
- *Knowledge Management-National Mission on Strategic Knowledge for Climate Change*

National Mission on Strategic Knowledge for Climate Change.

Figure 6.1



FINANCIAL IMPLICATIONS

CHAPTER-VII

7.1 The plan outlay for agriculture sector has been witnessing a compound annual growth rate (CAGR) of about 24% since the beginning of X plan period. This has helped catalyzing a sustained level of growth (CAGR-1.4%) of foodgrain production during the same period. However, foodgrain production needs to grow at 1.8% (CAGR) during XII plan period to match the estimated demand growth. It is, therefore, imperative that continual enhancement of plan outlay would be a pre-requisite for further accelerating the growth momentum.

7.2 The proposed adaptation and mitigation strategies would require an additional budgetary support of Rs. 1,08,000 crores[1] at current prices upto the end of XII plan (Appendix-VI). A major portion (60%) would be utilized to adopt technology solutions for mitigating risks related to climate change. Infrastructure development and R&D together will be allocated 35% of the total resources, whereas about 5% of allocation will be deployed for capacity building (Chart 7.1).

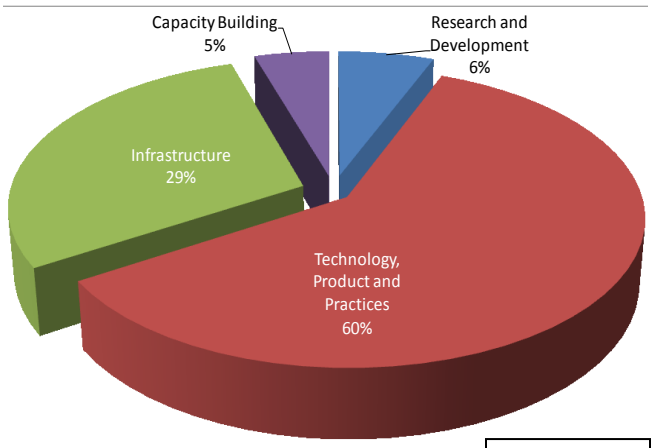


Chart 7.1

Additional Budgetary Support
(2011-12 to 2016-17)

- Technology, Products and Practices: Rs. 65,000 Crores
- Infrastructure including Insurance: Rs. 31,500 Crores
- Research & Development: Rs. 6,500 Crores
- Capacity Building: Rs. 5,000 Crores

Total: Rs. 1, 08, 000 Crores (at current prices)

[1] Estimated at current prices which may require revision depending on inflation

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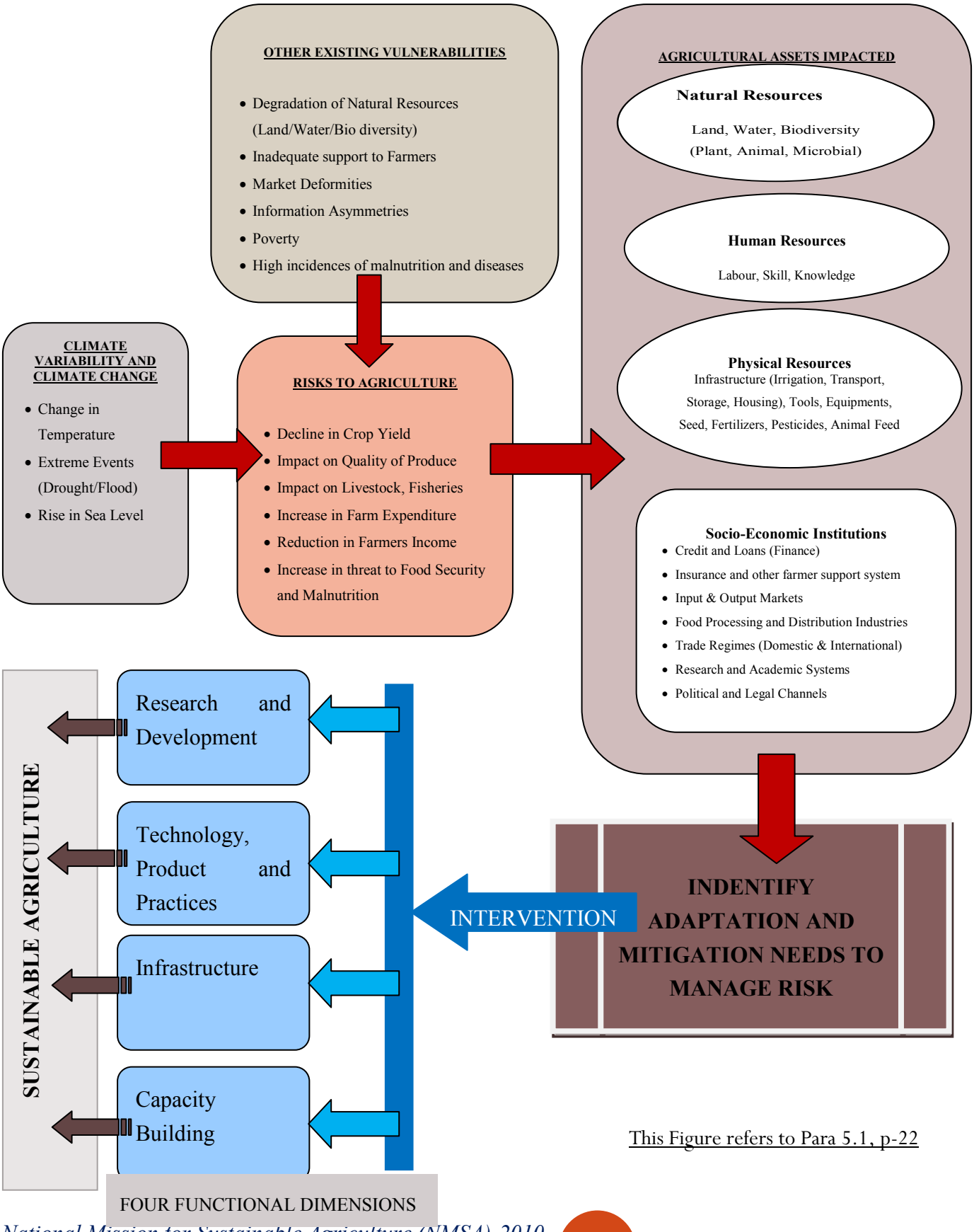
Appendix-I

Mapping Risks with Adaptation and Mitigation Needs for Indian agriculture

Risks from climate variability and change	*Adaptation and Mitigation Needs*
Decline in yields (crops, animal produce, fish catch)	• *Sustain/ enhance yield (crop, animal produce, fish, other agricultural products etc.,)* • *Sustain soil quality* • *Develop genotypes that are heat/ drought/ flood and salt tolerant and pest/disease resistant* • *Maintain the agro biodiversity in regions* • *Check land degradation, soil erosion, uncontrolled grazing and desertification* • *Land use planning; strengthen policy and legal safeguards* • *Ensure adequate supply of irrigation water (both rain-fed and irrigated regions)* • *Strengthen institutional arrangements (policies, finances, markets)*
Increased threat of food insecurity and malnutrition	• *Ensure food security and nutritional quality of food (grain production/ milk and allied products/ meat and fish)* • *Improve storage (buffer stocks) and distribution systems* • *Strengthen institutional arrangements (policies, finances, input and output markets)*
Increased farm expenditures	• *Incentivise sustainable agro-practices* • *Minimise losses (pre-harvest and post harvest)* • *Manage risk* • *Respond to emergency through preparedness* • *Strengthen institutional arrangements (policies, finances, markets)*
Reduced farmer income	• *Reduce social inequalities* • *Increase/sustain farmer household income* • *Promote diverse livelihood opportunities* • *Strengthen institutional arrangements (policies, finances, markets)* • *Manage risk*

This Table refers to Para 4.10, p-20

Functional Dimensions and Dynamics Associated with Climate Change and Sustainable Agriculture



This Figure refers to Para 5.1, p-22

Appendix-III

Strategies for Mission Intervention in Ten Key Dimensions

Appendix-III-A

Mission Intervention #1: Improved crop seeds, livestock & fish cultures **

Areas	Interventions
Research and Development	1. *Development of plant genetic resources to combat changing environments with special focus on plant physiological processes such as flowering, seed development, photosynthesis, respiration, water retentions and plant growth regulation.* 2. *Development of crop varieties tolerant to biotic and abiotic stresses, draught, salinity and high temperature, flood and submergence etc. through market assisted selection process.* 3. *Transgenic approaches to retard senescence in fruits to reduce post harvest losses* 4. *Development of livestock and fish varieties to cope with biotic and abiotic stress levels* 5. *Development of crops with enhanced water and nitrogen use efficiency and CO_2 fixation potential to increase productivity and for reducing emissions of greenhouse gases.* 6. *Building of Soil Carbon Banks through fertilizer trees for enhancing soil nutrient status.* 7. *Screening of indigenous plant and animal gene pools and cataloguing them according to specific traits of agronomic value and conservation and establishment of gene-banks in-situ and ex-situ.* 8. *Strengthening basic research in plant sciences including phenomics and linking basic research to farm level* 9. *Developing and spreading True Potato Seed (TPS) methodology for potato* 10. *Development of hybrid rice strains characterised by hybrid vigour in the development of root system* 11. *Breeding salinity tolerant crops varieties for cultivation in coastal areas, based on genetic engineering techniques*
Technologies and Practices	1. *Use of micro-propagation and tissue-culture techniques for rapid bulking of improved varieties* 2. *Formulation of a dynamic contingent seed production and distribution plan* 3. *Application of modern biotechnology tools such as genetic transformation, marker-assisted selection, doubled haploid, mutation breeding to supplement traditional breeding methods* 4. *In-vitro conservation to conserve critical adaptive genes and genetic traits.* 5. *Shifting the breeding strategy to per-day rather than per crop productivity for wheat.* 6. *Promotion of sea water farming through Agri-Aqua farms and below sea level farming as in vogue in some parts of Kerala.*
Infrastructure	1. *Establishment/strengthening of seed producing farms and treatment plants for producing good quality seeds and planting materials and seed storage facilities* 2. *Strengthening of research infrastructure in SAUs and ICAR institutes* 3. *Strengthening public seed production and distribution system and promoting public private partnerships* 4. *Support to private and public sector for investment in infrastructure for production and management of good quality planting material and facilities for phenomics* 5. *Development of Seed Reserves for implementing alternative cropping strategies and to mitigate risks arising out of extreme events.*

Capacity Building	1. *Demonstration of improved packaging practices, good quality seeds, resource conservation technologies and improved water management practices* 2. *Training through Farmer's Field Schools, exposure visits of farmers/officials of the State, video conferencing, use of print and electronic media and other publicity and awareness generation measures* 3. *Support to ICAR, SAUs for capacity building and training of field functionaries and infrastructure development for training and skill development* 4. *Developing and strengthening farmer-institution-industry interface and sharing knowledge and best practices related to climate change and its impact, adaptation and mitigation needs*

** Illustrative

This Table refers to Para 5.2, p-23

Appendix-III-B

Mission Intervention #2: Water Use Efficiency **

Areas	Interventions
Research and Development	1. *Development of crop variants with high water use efficiency levels such as those capable of regulating stomata closure and opening etc.*
	2. *Exploring structural and technological measures to enhance water use efficiency with reference to various type of crops, soils, agro-climatic zones etc.*
Technologies and Good Practices	1. *Augmentation of water resources through extensive rain water harvesting, artificial recharge of groundwater etc.*
	2. *Use of pre-fabricated water conveyance systems and adoption of ridge & furrow method of irrigation, raised bed method of farming, field bunding, levelling etc.*
	3. *Development of storage structures for off-season use.*
	4. *Waste water treatment and its utilisation.*
	5. *Promotion of watershed development and management practices*
	6. *Improvement of Irrigation efficiency by promoting drip and sprinkler irrigation techniques in place of channel irrigation.*
	7. *Growing of less water demanding crops and adopting resource conservation technologies (RCTs) to economise water use*
	8. *Adopting mixed cropping and agro forestry practices for retaining soil moisture and reducing dependency on irrigation.*
	9. *Intermittent flooding during rice cultivation for aeration of the fields*
Infrastructure	1. *Construction of shallow tube wells to tap potential aquifers and construction of artificial recharge structures in water scarce areas*
	2. *Setting up of National Institutes for training on Agriculture Water Management*
	3. *Establishment of laboratories for testing and developing new technologies for efficient water application technologies*
	4. *Construction of water treatment and recycling plants for use of waste/poor quality water for irrigation purpose*
	5. *Construction of secondary storage structures at tail end of canal networks for storing water during time of excess availability to save wastage and making use at critical periods*
	6. *Strengthen local institutions in managing water allocation and utilization*
Capacity Building	1. *Demonstration, training and exposure visits on efficient on-farm and off-farm water management practices*
	2. *Training on balanced use of nutrients and water resources customised to regional conditions*
	3. *Advisories on agronomic and engineering practices on water management for different agro-climatic conditions and different climatic scenarios*
	4. *Promoting and popularizing participatory role through group/user associations in minor irrigation/water harvesting programmes for allocating water among users and for managing the assets*

This Table refers to Para 5.3, p-23

** Illustrative

Appendix-III-C

Mission Intervention #3: Pest Management **

Areas	Interventions
Research and Development	1. *Providing site-specific weather data to help researchers run predictive pest models and for farmers to make informed decisions on pest management* 2. *Research on pest/insect-crop-weather interactions for developing simple operational and predictive models that can be used in agro-advisory services* 4. *Integrate biotechnology with traditional agricultural practices, metabolomic and bioinformatics systems to design novel insecticide molecules for studying interactions with the DNA and protein models.* 5. *Develop new bio-pesticides and technologies on pest management through sterile insect techniques, new botanical, semiochemicals (repellents, pheromones, allomones etc) and endophytic microbial metabolites for pest control, transgenic insects, pests and disease forecasting*
Technologies and Practices	1. *Develop effective surveillance systems for invasive species based on semiochemicals* 2. *Streamlining the flow of information of pest surveillance and livestock diseases to reduce response time between detection and action to manage and prevent pests and diseases* 3. *Promotion of bio-intensive Integrated Pest Management at large scale* 4. *Strengthening the existing network of veterinary health support services with particular emphasis on preventive health care services including immunisation* 5. *Plant protection measures to be tailored to meets the threat to crops and farm animals arising from outbreak of vector-borne diseases.*
Infrastructure	1. *Strengthening quality assurance system and storage facilities* 2. *Strengthening Plant Quarantine and Bio-Security infrastructure* 3. *Establishment of laboratories and plants for testing and producing bio-pesticides* 4. *Developing market infrastructure for upscaling availability of bio-pesticides to farmers*
Capacity Building	1. *Intensive training and capacity building on integrated pest management*

** Illustrative

This Table refers to Para 5.4, p-24

Appendix-III-D

Mission Intervention #4: Improved Farm Practices **

Areas	Interventions
Research and Development	1. *Promotion of organic agriculture research* 2. *Develop technologies for improvement of water use efficiency* 3. *Develop technologies for management of salt affected soils and water logged areas* 4. *Explore potential of change in sowing time as adaptation strategy*
Technology and Practices	1. *Promoting Agriculture Heritage and traditional methods for conservation and management of resources* 2. *Soil enrichment through inter-crop transfers (use of legumes), promotion of conservation agriculture practices to enhance soil organic carbon, water conservation and minimise soil erosion* 3. *Developing and applying Resource Conservation Technologies (RCTs) like zero-tillage, raised bed planting, laser land levelling etc. for enhancing soil productivities* 4. *Promoting inter-terrace land treatment, emphasis on soil quality, organic farming, promotion of integrated farming systems and other measures that encourage resource conservation* 5. *Introducing improved farm machinery for enabling crops to be grown with minimal tillage (reduced tillage) or without tillage (no tillage) resulting in soil carbon gains* 6. *Encouraging protected cultivation in areas which faces extreme weather conditions.* 7. *Low-cost green houses, along with micro-irrigation and fertigation techniques* 8. *Promoting new technologies such as SRI (System of Rice Intensification)* 9. *Development of contingency plans for farming practices to cope with sudden climatic variability* 10. *Introduction of Post flood agriculture rehabilitation measures such as crops like yellow-flesh-sweet potato, sunflower, fodder, sathi maize etc.* 11. *Developing mangrove and non-mangrove bio-shields to minimize the impact of coastal storms and sea-water inundation*
Infrastructure	1. *Strengthening of agricultural farms of Government / SAUs / ICAR to test and study suitable farm practices for different simulated conditions for future replication to field conditions* 2. *Infrastructure and institutions to make available timely advisories to farmers on farming practices* 3 *Setting up Plants/Centres for manufacturing, testing and training of new tools /machineries / equipments for improved cultivation practices*
Capacity Building	1. *Strengthening capacity to provide complete technical back up support to the farmers to develop precision farming technology* 2. *Establishing technical backstopping through a responsive and efficient extension system, involving both public and private institutions, particularly NGOs active in rural areas* 3. *Popularising practices on resource conservation technologies and fertilizer use efficiency thorough demonstration, training and skill development programmes* 4. *Promotion of plantation programmes of sustainable native species and strengthening the funding mechanisms for the villagers who manage and improve carbon sequestration through agro-forestry.* 5. *Demonstration and training on use of bio-fertilizers and bio-pesticides to promote organic farming*

This Table refers to Para 5.5, p-25

** Illustrative

Appendix-III-E

Mission Intervention #5: Nutrient Management**

Areas	Interventions
Research and development	1. *Enhance understanding of soil nutrient dynamics, crop nutrient requirements and nutrient transformations in soil to increase nutrient use efficiency and to improve the stock of plant nutrients in the soil*
	2. *Economic evaluation of each integrated nutrient management technology and identification of constraints in the adoption of each technology*
	3. *Development of nutritional strategies for managing heat stress in dairy animals.*
Technologies and Practices	1. *Promotion of organic farming to improve the land quality and reduce carbon foot print*
	2. *Improving management of inorganic fertilizers through proper timing of fertilizer application, use of innovative fertilizer material, development of soil testing techniques*
	3. *Developing cultures of micro-organisms and techniques which hasten the process of composting for producing good quality compost*
	4. *Promote efficient management of crop residues in wheat-rice system*
	5. *Promote recycling of crop/farm wastes and their conversion into easily transportable and usable forms for effective utilization in plant nutrient supply*
	6. *Planning the sequencing of crops based on their nutrient demands, nutrient uptake efficiencies and residues*
	7. *Breeding and selection of superior N-fixing legume species and cultivars, short duration pulses and fast growing fodder legumes for green manuring*
	8. *Management of mycorrhiza and other promising beneficial micro-organisms*
	9. *Focussed efforts towards correcting micronutrient deficiencies*
	10. *Use of nitrification inhibitors to reduce chemical use and promote INM*
	11. *Integration of agro-forestry with cropland management to increase sequestration of soil carbon and reduce nutrient leakage*
	12. *Quality labelling and specifying micro-organism application for agriculture, horticulture, green house products etc.*
	13. *Manure management induced methane emissions can be reduced by setting up household/ farm scale and community anaerobic digestion plants.*
	14. *Managing the feeding schedule of animals, especially during hot weather, because feed ferments faster after preparation when air temperatures are high*
Infrastructure	1. *Developing infrastructure for promoting production and use of plant nutrients.*
	2. *Strengthening the capacity of existing soil testing labs and increase their reach*
	3. *Strengthening of existing institutions for nutrient management*
	4. *Establishment of laboratories and plants for testing and producing nutrient-enriched plants*
	5. *Creating infrastructure for ensuring quality assurance and storage facilities*
Capacity Building	1. *Intensive training and capacity building on integrated nutrient management*

This Table refers to Para 5.6, p-26

** Illustrative

Appendix-III-F

Mission Intervention #6: Agricultural insurance**

Areas	Interventions
Research and Development	*1. Developing various models for risk assessment to assess the magnitude of risk exposure and availability of supportive infrastructure including resources in case of climate variability and extreme events*
	2. Developing innovative and new generation agricultural insurance products, such as weather index based insurance, livestock insurance etc
	3. Developing strategies to deal with emerging risks due to climate change such as high intensity rain, heat waves, depletion of ground water, water contamination, etc.
	4. Designing user-friendly decision support systems to help assessing risks and develop region specific contingency plans
Technologies and Practices	*1. Assessing availability of appropriate technologies and their back-stopping support system that has long term effect on reduction of risk mitigation*
	2. Use of crop-weather forecast models to aid field-based planning and operational activities by both farmers and governing bodies
Infrastructure	*1. Setting up of infrastructure and institutional framework for immediate assessment of damage due to climatic extreme events for fulfilment of claims of farmers*
	2. Developing farmer friendly ICT based system for collating and disseminating information relating to weather, soil, water, pests etc. for informed decision making and timely action by all stakeholders to manage risks
	3. Strengthening existing risk cover mechanism under NAIS and Weather Based Crop Insurance by broad-basing their reach, increasing coverage, improving efficiency by benchmarking performance with similar products in India and abroad
	4. Infrastructure support to private sector in agricultural risk management through Public-Private Partnership(PPP) model and thus increasing aggregate insurance coverage and improve viability of the insurance schemes over time
Capacity Building	*1. Awareness campaign and popularization of different crop and livestock insurance schemes among farmers*
	2. Support services to guide and advise farmers to access different insurance products
	3. Capitalizing the outreach and penetration of Self Help Groups (SHGs) and other Farmers Groups to increase the awareness and acceptance of crop insurance

** Illustrative

This Table refers to Para 5.7, p-26

Appendix-III-G

Mission Intervention #7: Credit support**

Areas	Interventions
Research and development	*1. Research on credit assessment and risk management systems* *2. Designing customised credit plans and programmes to mitigate risks and support higher productivity and production drought and flood prone areas.* *3. Designing innovative schemes and products which recognise the varied nature of agri-business and supply chains for different farming systems, food systems, and communities.*
Technologies and Practices	*1. Adoption of a customised approach by financial institutions to cater to specific agricultural credit risks and needs of different agricultural sectors and regions* *2. Creating credit flow for conservation farming, agricultural diversification and value added activities.* *3. Developing credit plans with higher component of direct finance and with a special thrust on small and marginal farmers so as to reduce their dependence on informal credit institutions and money lenders* *4. Providing financial support/ incentives to farmers to enable investment/ adoption of relevant technologies to overcome climate related stress* *5. Up-scaling the Kisan Credit Card Scheme (KCCS) to cover all eligible farmers*
Infrastructure	*1. Enhancing the scope of credit institutions through creation of adequate infrastructural and other support systems, to cover post harvest activities such as storage, transportation, processing and marketing of non-cereal products.* *2. Establishment of credit support, networking and delivery institutions* *3. Promoting micro finance to increase the access to credit by small and marginal farmers and using SHG's and community based structures to widen reach* *4. Developing mechanisms to enhance the flow of credit to critical infrastructure areas such as irrigation, watershed/ wasteland development, wind energy, transport, storage etc.* *5. Encouraging Public Private Partnership for credit flow in agriculture sector* *6. Extension of agricultural credit for availing technology oriented solutions to mitigate additional risks from climate change*
Capacity Building	*1. Creating greater awareness and giving greater publicity to the credit support mechanisms*

** Illustrative

This Table refers to Para 5.8, p-27

Appendix-III-H

Mission Intervention #8: Markets **

Areas	Interventions
Research and Development	1. *To formulate market-aligned Research and Development programmes for developing higher shelf-life varieties, increasing shelf-life through improved packaging technologies etc.*
	2. *To Improve food safety and quality standard through developing domestic standards and/or adopting global standards, strengthening food testing network etc.*
	3. *Developing customized market information, intelligence and forecasting system for farmers*
Technologies and Practices	1. *Improving Supply Chain Efficiency to avoid post-harvest and transition losses*
	2. *To align production systems with market demand for mitigating the risks*
	3. *Strengthening of local market for improving the access of farmers to quality and timely inputs such as seeds, pesticides, fertilizers, credit, insurance and information*
Infrastructure	1. *Strengthening the market infrastructure including rural connectivity to reduce post harvest losses*
	2. *Promotion of food processing and other similar value-addition related industries*
	3. *Creation of new market infrastructure, auction houses, vegetable centres, terminal markets and up-gradation of existing markets*
	4. *Creation of Cold Chains, especially for horticultural produce preferably on PPP model.*
	5. *Supporting community partnerships in developing food and forage banks to manage scarcity and mitigate risks*
	6. *Strengthening of APMC acts to ensure better economic returns to the farmers and also facilitate free movement of agricultural produces both inside and outside the country*
Capacity Building	1. *Popularizing group and primary market activities at village level to avoid distress sale of the farm produce*
	2. *Capacity building and training of farmers to access the web and media based market information system and to make use of it in selling its produce and during procurement of inputs*

** Illustrative

This Table refers to Para 5.9, p-28

Appendix-III-I

Mission Intervention #9: Access to Information **

Areas	Interventions
Research and development	*1. Minimizing Information Asymmetry through focussed attention on developing ICT-based systems and methodologies for quick and timely dissemination of information to rural and remote end users.*
Technologies and Practices	*1. Forging Public Private Partnership to develop technology based solutions for providing farmers with information on price discovery, commodity arrivals, mandi prices etc.* *2. Partnering with civil society organizations for large scale deployment of technology for communicating climate change risks to bring about behavioural changes for adopting agricultural good practices* *3. Preparation of crop / commodity specific advisories for different soil and climatic characteristics for the use of farmers to adopt specific packages suitable to weather conditions*
Infrastructure	*1. Create, Manage and Develop National Resource Portal by Synergising information database of Weather data of Automatic Weather Station (AWS), Automatic Rain Gauge Station (ARG) and Soil Resources and land Use mapping through GIS and Remote Sensing.* *2. Development of comprehensive Kisan Knowledge Management System (KKMS)* *3. Building an ICT enabled Knowledge Management network that would allow farmers to exchange experiences and best practices, across different regions and agro-ecological zones* *4. Establishment of Web/Mobile based information system for quick dissemination of weather forecasting and advisories through dedicated satellite or mobile/wireless/Broadband network.*
Capacity Building	*1. Strengthening farmer-to-farmer extension programme as an effective tool for building confidence in adopting new farm practices, on and off field demonstrations to ensure adoption of high yielding/stress tolerant varieties of crops, resource management technologies and practices available from the latest scientific research.* *2. Providing extensive mass media support to Agriculture Extension and promoting use of Information, Education and Communication (IEC) material as an effective means of reaching out to remote areas and overcoming barriers of illiteracy, lack of infrastructure, social and gender divide.*

** Illustrative

This Table refers to Para 5.10, p-29

Appendix-III-J

Mission Intervention #10: Livelihood diversification**

Areas	Interventions
Research and Development	1. *Development of high productive horticultural crops namely; fruits, vegetables, aromatic and medicinal plants and spices and plantation crops (e.g. coconut, arecanut, cashew, cocoa etc.)*
	2. *Conducting research on risks to specific livelihoods for understanding the changing nature of risk due to climatic and non-climatic stresses (for example, changes in climatic variables, trade patterns, market prices etc. can guide farmers regarding investments in specific crops)*
	3. *Development of decision support system for integrating market information to improve production and trade of horticultural/dairying/fisheries products*
	4. *Extending research on Resource Conserving Technologies (RCT) in the domain of crop production and livestock management.*
Technologies and Practices	1. *Penetration of technologies such as micro-propagation, integrated nutrient, water and pest management, organic farming, immuno-diagnostic techniques for detection of diseases and to improve the productivity of horticultural crops*
	2. *Strengthening technologies and practices that assist in food processing such as value addition and cold storage for horticulture/dairying/fisheries products*
	3. *Adopting region-specific silvicultural and farming practices to optimize food production, carbon sequestration and biodiversity conservation.*
	5. *Refining package of practices for crop-fish farming using locally available resources and resource-efficient practices that reduces input requirements supported by appropriate policy instrument to reduce investments and cost input in terms of feed, manpower and infrastructure.*
	5. *Developing and strengthening low tunnel / poly house farming under controlled condition to sustain livelihood from small land holdings*
Infrastructure	1. *Promotion of groups and associations of farmers to access benefits from various government schemes related to subsidies, inputs and infrastructure support*
	2. *Establishment and management of fodder banks, especially in dryland regions*
	3. *Enabling small producers to compete with organized industries through vertical linkages between them and food processors via contract farming, supply chain management etc.*
	4. *Strengthening local institutions and setting up of micro-enterprises for providing institutional support at local level*
	5. *Promoting micro-finance, insurance, credit/loans etc. through local associations, SHGs, cooperatives, public-private partnerships etc.*

This Table refers Para 5.11, p-29

** Illustrative

Appendix-III-J

Mission Intervention #10: Livelihood diversification (Continued)

Areas	Interventions
Capacity Building	*1. Promoting distance learning and education targeting farmers and agri-entrepreneurs practicing horticulture*
	2. Utilizing components under the National Horticulture Mission (NHM) for horticultural extension education including participatory on-farm demonstrations, training and entrepreneurship development with special focus on women and small and marginal farmers.
	3. Expansion of training and field-level demonstrations with the involvement of SHGs
	4. Use of community radio for sharing of agro-climatic and market information
	5. Training of farmers and producers regarding potential of agro-forestry production and creating awareness about market linkages and insurance mechanisms
	6. Development of agri-livestock extension systems for livestock production in partnership with relevant National Research Institutes and Agricultural Universities
	7. Mobilising farmers for crop diversification and alternate income generating activities supported with adequate skill development programmes
	8. Introducing vocational courses for land based and non-land based income generating activities to supplement livelihoods

** Illustrative

This Table refers to Para 5.11, p-29

Appendix-IV

Programme of Action (POA) for the NMSA

Opportunities for Expansion of Scale/Scope of Existing Interventions

Appendix-IV-A

Functional Area # 1: Research and Development**

Areas	*Existing interventions*	*Opportunities for expansion of scale/scope of existing interventions*
A. Crop Level		
1. *Genetic resources – conservation and development of varieties of crops, livestock, fodder and fisheries*	*1a. Current initiatives are limited to extending support to research institutions for production of breeder, hybrid and high yielding varieties for crops (MMA, RKVY, NADP and NHM).*	*1a. Scale of support to be increased and SAUs are to be assigned to clusters in agro-climatic zones to intensify research & development addressing regional impediments to production and yields*
	1b. In the case of livestock, research is limited towards identification and tagging of superior germplasm and using it to rear high yielding animals under the NPCBB I and II.	*1b. The scope of such programmes to be expanded so as to include other groups of farm animals besides cattle*
	1c. In case of fodder, limited research is being carried out for improvement of quality fodder seeds under the Fodder Development Scheme	*1c. Efforts to be made to isolate and conserve germplasm of resilient indigenous fodder species*
B. Farm level		
1. Information and ICT based Decision support systems	*1. Limited information and decision support systems are in place at present.*	*Dedicated information and decision support system should be in place for all commodities in agriculture sector*
2. Resource Inventories	*2. The Agriculture Census scheme is an inventory of information available at the unit of land holding*	*Increase in periodicity of survey and enhancement of survey parameters*
3. Energy conservation	*3. Limited research on energy management of farm power*	*Widening research in the domain of energy conservation and management*

Appendix-IV-A

(Continued)

Functional Area # 1: Research and Development**

Areas	*Existing interventions*	*Opportunities for expansion of scale/scope of existing interventions*
C. Food System level		
1. Markets	*1. Research on value chains has been initiated as part of the National Agriculture Innovation Project*	*The Project is to be strengthened and the coverage needs to be expanded*
2. New generation agricultural insurance and credit support products	*2. Insurance is covered under the NAIS and the LIS*	*Modification of the NAIS with improvement in assessment of risk/ calculation of threshold yield/ guarantee yield/ reduction of insurance unit to village level etc.* *Development of operational framework for the Index Based Insurance Programme*

This Table refers to Para 6.2, p-31; Para 6.6, p-33

** Illustrative

Appendix-IV-B

Functional Area # 2: Technology, Products and Practices **

Areas	*Existing interventions*	*Opportunities for expansion of scale/scope of existing interventions*
A. Crop level		
1.Good quality seed and planting material	*Support for seeds, planting materials and agricultural inputs including seed treatment*	*Upscaling of interventions under the ongoing programmes would be undertaken*
2. Better seed treatment		
3. Supply of agricultural inputs		
B. Farm level		
1. Resource Conservation / Efficient Technologies and practices	*1a Technologies for conservation of farm inputs are currently promoted under MMA, RKVY, NFSM and NADP for procuring resource conserving implements or machinery at subsidized rate*	*Expansion of the scope and coverage of agricultural mechanization by introducing appropriate implements /machinery, providing higher level of support to users and promoting Custom Hiring to suit the need of small/marginal farmers*
	1b Technologies for conservation and increasing efficiency of water are currently being promoted through distribution of drip and sprinkler irrigation infrastructure for high water consumptive crops and horticulture (NAIP, MMA, MI)	*Expanding the coverage of ongoing interventions to other crops for achieving desired water use efficiency on a holistic level*
	1d. Drainage line treatment through Watershed Development Programmes	*Providing more focus on runoff management measures*
	1e. Renovation, desilting of existing infrastructure (NPRRR, NREGS and SGRY)	*Expanding the pace and periodicity of remedial measures.*
2. Resource Remediation technologies and practices (reclamation of land, water quality etc., animal/plant health)	*2a. Technologies for amelioration of alkaline/acidic soils are promoted under MMA scheme whereas testing of cost effective technologies for increasing productivity of saline and alkaline soils is undertaken by the TDET scheme of MoRD.*	*Expanding the implementation areas and providing higher level of support to farmers for cost effective soil amendments. Promotion of alternate low cost package of practices for rehabilitation of problem soils*
	2b. Development of degraded and waste lands is done under watershed programmes	*Systematic and mission mode approach would be initiated to for intensive watershed development in dryland areas under cultivation*

	2c. Waterlogged areas are developed though biological and mechanical drainage under CAD	*Expanding the scale to achieve more coverage would be necessary.*
3. Improved practices	*3a. Farm mechanization and availability of farm power*	*Targeted approach to promote farm mechanisation through custom hiring, establishing agricultural machinery banks etc.*
	3b. Precision farming and conservation agriculture is practised in a limited scale under the ongoing programmes	*The scheme would be made more acceptable to farmers through appropriate incentives*
4. Organic farming (bio pesticides, green manuring etc. Product quality monitoring (certification and monitoring - new genetic varieties, fertilizer, pesticides etc.)	*4. Organic farming is promoted through encouragement in use of bio pesticides under the NADP and MMA. Practices like green manuring are promoted under programmes like NPMSF, NADP and MMA*	*Upscaling the programme to accelerate the rate of adoption of Organic Farming*
5. Emission reduction technologies and practices	*5. Technologies /practices for reduction of emissions is limited to encouragement for use of less energy consumptive farm implements/ machinery*	*Energy efficient technology and equipment for controlling emission would be promoted*
C. Food System level		
1. Post Harvest Management	*Developed to a limited extent under the existing provisions*	*Programmatic interventions would be promoted for reducing post harvest losses*
2. Storage & grading		
3. Processing and Value addition		

This Table refers to Para 6.2, p-31; Para 6.6, p-33

** Illustrative

Appendix-IV-C

Functional Area # 3: Infrastructure **

Areas	*Existing interventions*	*Opportunities for expansion of scale/scope of existing interventions*
A. Farm level		
1. Irrigation (Coverage and efficiency – surface and groundwater)	*1a. Programmes and projects covering infrastructure development for irrigation are mainly implemented by the Ministry of Water Resources. Ministry of Agriculture extends support for efficient use of water by promoting Micro Irrigation technology*	*1a. Further development and coverage under the CADWM needs to be initiated so as to cover the entire command area in the country in consultation with Ministry of Agriculture* *1b. More focus would be given on developing minor irrigation sources* *1c. NPRRR would be expanded to cover all the districts in the country* *1d. Effective implementation of the already existing Master plan on artificial recharge to groundwater for maximizing recharge and rooftop rainwater harvesting would be given more emphasis*
B. Food System level		
1 Market infrastructure	*Establishment of modern terminal markets in important urban centres under the Terminal Market Complex (TMC) scheme* *The Grameen Bhandaran Yojana promotes the construction of rural godowns through provision of subsidies to all categories of farmers, agricultural graduates, central and state warehousing corporations as well as to individuals, companies.*	*1a. Strengthening of cold chain infrastructure* *1b. Creation of additional storage facilities* *1c. Strengthening of the market infrastructure scheme; standardization and grading, PHT etc.*
2 Insurance	*National Agriculture Insurance Scheme provides insurance coverage and financial support to farmers in event of failure of any of notified crops as a result of natural calamities, pests and diseases & to encourage the farmers to adopt progressive farming practices, high value inputs and higher technology in agriculture and to help stabilize farm incomes, particularly in disaster years.*	*2a. The scheme needs to be upscaled to cover all districts by 2017 with a minimum 35% level of penetration.*

	Weather Based Crop Insurance Scheme (WBCIS)- This pilot Scheme aims to mitigate hardship of insured farmers against the likelihood of financial loss on account of anticipated crop loss resulting from incidence of adverse conditions of weather parameters like un-seasonal rainfall, frost, heat(temperature) etc.	*2b The pilot scheme needs to be extended to all states with adequate allocation of financial resources.*
3 Credit	*The current level of intervention is through Investment in Debentures of State Land Development Banks floated for minor irrigation, horticulture/ plantation, farm mechanization, land improvement, customization of compound walls, cattle sheds, farm houses which are contributed by NABARD, Central and State Governments. On average GOI share workout to 4% to 5% of the total floatation and that of NABARD up to 95%.*	*3a. Enhancing the scope of credit institutions through creation of adequate infrastructural and other support systems, to cover post harvest activities such as storage, transportation, processing and marketing of non-cereal products*

This Table refers to Para 6.2, p-31; Para 6.6, p-33

** Illustrative

Appendix-IV-D

Functional Area # 4: Capacity Building **

Areas	*Existing interventions*	*Opportunities for expansion of scale /scope of existing interventions*
A. Farm level		
1. Demonstrations	*1a. Activities like front line demonstrations of new varieties or new crop growing techniques like SRI are undertaken under MMA, NFSM and NADP*	*The scale as well as scope of these demonstrations would be expanded. The scale would be expanded to cover all panchayats.* *Demonstrations are currently limited to rice, wheat, coarse cereals, pulses, oilseeds and sugarcane. Cultivation techniques and package of practices would be regionally customized for the main crops that are grown in the region*
B. Food system level		
1. Training	*1a. Trainings through farmers' field schools is conducted under the Macro Management of Agriculture programme and also through the National Food Security Mission* *1b. Training at senior and middle level on agri-business management, agri-warehousing and cold chain management and agricultural extension management for input dealers in distance learning mode is currently being conducted* *1c. Extension education institutes (EEIs) for the improvement of skills and competence of field functionaries*	*Introduction of customized professional development courses* *Experts from reputed institutions would be hired for improving effectiveness of the training programme* *Increase in number of Extension Education Institutes to at least one per Agro Climatic Zone (ACZ)*

This Table refers to Para 6.2, p-31; Para 6.6, p-33

** Illustrative

Appendix-V

Programme of Action (POA) for the NMSA

New Interventions **

Areas	New Interventions
Research and development	*1. Development of plant genetic resources with greater adaptive capacity to draught, flood, salinity and high temperarture through modified physiological processes and assisted market selection* *2. Development of crops with enhanced CO2 fixation potential to increase productivity and with less water consumption* *3. Gene manipulation for introducing C4 pathway in important C3 crops* *4. Discovering novel use of RuBisco enzyme that enables conversion of CO2 more quickly and effectively* *5. Development of crops with enhanced water and nitrogen use efficiency for reduced emissions of greenhouse gases in the irrigated agricultural system and utilization of phenomics* *6. Development of crop, livestock and fish varieties tolerant to various abiotic stresses* *7. Establishing Agricultural intelligence System* *8. Development of effective surveillance systems for invasive species in imports* *9. Development of predictive models for agro-advisory services* *10. Development of decision support systems for scenario based planning* *11. Site specific data inventories for predictive models* *12. Development of inventory for all available nutrients* *13. Development of ICT based systems and methodologies for accelerated agricultural growth* *14 Strengthening market research in domestic as well as global demand projections of food, food exports and imports based on climate change variables* *15. Research on new forms of credit assessment and risk management systems* *16. Development of appropriately designed insurance schemes for specific climate change impacts*
Technologies and Practices	*1. Customization of resource conservation technologies (RCT) to suit crop varieties in different agro-climatic conditions* *2. Introduction of improved pest and weed control methods especially to* ***cater vector-borne incidences*** *3. Change in dietary practices of livestock to curb methane emissions from enteric fermentation* *4. Planning the sequencing of crops based on their nutrient demands, nutrient uptake efficiencies and residues to suit specific soil conditions* *5. Recycling of wastes and their conversion into easily transportable and usable forms for their effective utilization in plant nutrient supply* *6. Quality labelling and specifying micro-organism application for agriculture, horticulture, green house products etc.* ***7.** Intermittent flooding during rice cultivation or aeration of rice fields* *8. Management of feeding schedule of livestock* *9. Development of integrated farming system to suit specific location needs* *10. Development of Farm Ponds, Bio-gas plant and a few Fertilizer trees as a combination to improve farm productivity in rainfed areas* *11. Development of Food and Fodder security plan for safeguarding dairy, poultry and other animal based enterprises.* *12. Promoting green house horticulture combined with animal husbandry, agro-forestry for enhancing both livelihood and nutrition security* *13. Launching a dynamic programme in the area of sea-water farming involving salt tolerant varieties, agro-forestry and marine aqua-culture* *14. Promotion of greenhouse horticulture*

Appendix-V
(Continued)

Programme of Action (POA) for the NMSA

New Interventions **

Areas	New Interventions
Infrastructure	*1. Creation of alternative markets, auction houses, vegetable centres, terminal markets etc.* *2. Reuse/recycle of waste water and treatment of poor quality water including saline water for reuse in irrigation purposes.* *3. Web based digitized climatic information and forecasting system along with advisories to end-users* *4. Creating Secondary Storages in tail end of canal commands to store water at the time of excess availability for future use during critical periods* *5. Creating minor irrigation sources including ground water development structure particularly in eastern India* *6. Mobile service to farmers for providing Weather information, agri-advisories and supply of critical inputs* *7. Development of a Safety Net Infrastructure that includes Insurance, Emergency Relief and Debt Waiver* *8. Broad-basing the scope of current credit delivery system and widening its coverage* *9. Development of Seed Bank, Fodder & Feed bank, grain bank at each one of 128 agro-climatic zones.* *10. Development of warehousing and storage capacity for food grains of at least 1 million tonne capacity in each of the 15 major agro-climatic zone.* *11. Development of Fodder and Food Banks with the help of Self-help groups (SHG)*
Capacity Building	*1. Capacity Building of stakeholders of agri-supply chain* *2. Introduction of Mobile phone based information delivery modules fort faster dissemination of knowledge* *3. To achieve synergy between government and non-government initiatives for identification and strengthening collaboration in cross-cutting areas* *4. Building of strong farmer-institution- interface for quick dissemination of knowledge and faster technology absorption* *5. Promotion of farmers' participation in professional breeding programmes* *6. Establishment of Research and Training Centre for Climate Risk Management in each of the 128 Agro-climatic zones with facilities such as village resource centre with satellite connectivity with the help of ISRO and other agencies, a self-contained meteorological station etc.*

** Illustrative

This Table refers to Para 6.2, p-31; Para 6.6, p-33

Appendix-VI

Financial Implications

FINANCIAL ASSESSMENT OF ADDITIONAL BUDGETARY SUPPORT FOR MITIGATION AND ADAPTATION MEASURES (2011-12 TO 2016-17)			
Functional Areas	**Components of Mission Interventions**	**Component Wise Assessment for additional budgetary support (at current prices) for the period 2011-2017**	
		Rs. In Crores	**Rs. In Crores**
Research and Development	Use of Biotechnology (Crop, Livestock, Fisheries)	**4,000**	**6,500**
	Dryland Agriculture: Research in Network Mode, Establishment of Model Farm Units	**1,000**	
	Access to Information: Agriculture Intelligence and Market Research	**500**	
	Risk Management: Risk and insurance modelling	**1,000**	
Technology, Products and Practices	Crop Sector (Crop Diversification, SRI, Contingency Cropping)	**3,000**	**65,000**
	Seeds (Quality Management, Storage, Distribution Chain)	**3,000**	
	Horticulture	**3,000**	
	Livestock and Fishery	**5,000**	
	Natural Resource management (Water Harvesting, Watershed Dev., land development)	**4,500**	
	Water Use Efficiency (Micro irrigation and efficient water management)	**37,500**	
	Soil Health Management	**2,500**	
	Pest, Disease and Weed management	**1,000**	
	Farm mechanization	**2,500**	
	Precision and Conservation Farming, Farming System and Alternate Livelihood Support System	**3,000**	
Infrastructure	Creation of additional storage facilities	**2,000**	**14,500**
	Improving Market Infrastructure including developing new Terminal Markets	**3,000**	
	Strengthening Marketing Infrastructure Scheme, Standardization and grading machinery, quality systems etc.	**2,000**	
	Development of Cold Chain (Cold Storage, Transportation, Distribution)	**2,000**	
	Agriculture Credit (Interest holiday to farmers in case of extreme events)	**4,000**	
	ICT (Mobile, Broadband) Based Knowledge Network for reaching Farmers	**750**	
	Expansion of weather /crop information system	**750**	
Capacity Building	Expansion of Farmer-Institution-Industry Interface mechanism	**1,000**	**5,000**
	Front line Demonstration of resource conserving technology	**1,000**	
	Strengthening and expanding the coverage of Training Institutions including Farmer's Schools	**2,500**	
	Knowledge Management and dissemination of best practices	**500**	
	TOTAL (Without provision of Insurance)		**91,000**
	Safety net Mechanism (Insurance & Relief): NAIS, MNAIS, WBCIS	**17,000**	
	TOTAL (With Insurance provision)		**1,08,000**

**** Infrastructure including Safety Net Mechanism: Rs. 31, 500 Crores**

This Table refers to Para 7.2, p-37

GLOSSARY

Abiotic stress: Abiotic stress is defined as the negative impact of non-living factors on the living organisms in a specific environment. Abiotic stress is essentially unavoidable.

Aquifers: An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using a water well.

Allomone: An allomone is any chemical substance produced and released by an individual of one species that affects the behaviour of a member of another species to the benefit of the originator but not the receiver. Production of allomones is a common form of defence, particularly by plant species against insect herbivores.

Bio drainage: Bio drainage is defined as "pumping of excess soil water by deep-rooted plants using their bio-energy." The bio drainage system consists of fast growing tree species, which absorb water from the capillary fringe located above the ground water table. The absorbed water is translocated to different parts of plants and finally more than 98% of the absorbed water is transpired into the atmosphere mainly through the stomata.

Carbon sequestration: It is a geo-engineering technique for long-term storage of carbon dioxide or other forms of carbon to mitigate global warming. It is a way to mitigate accumulation of greenhouse gases in the atmosphere, which are released by burning fossil fuels.

Crop diversification: Crop diversification is intended to give a wider choice in the production of a variety of crops in a given area so as to expand production related activities on various crops and also to lessen risks. Crop diversification in India is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops.

Chromosome: A chromosome is an organized structure of DNA and protein that is found in cells. It is a single piece of coiled DNA containing many genes, regulatory elements and other nucleotide

sequences. Chromosomes also contain DNA-bound proteins, which serve to package the DNA and control its functions.

Doubled haploid: A doubled haploid (DH) is a genotype formed when haploid cells undergo chromosome doubling. The haploid cells are often monoploid, and the term doubled monoploid is often used for these. Conventional inbreeding procedures take six generations to achieve approximately complete homozygosity (see below), whereas doubled haploidy achieves it in one generation.

Dryland Farming: Dryland farming is practiced in areas which are characterized by low & scanty rainfall with erratic distribution, leading to wide fluctuations in crop production.

Efficient water management: In agriculture, efficient water management means getting the right amount of water to the crops at the right time with minimum labor and expense.

Enteric fermentation: Enteric fermentation is fermentation that takes place in the digestive systems of ruminant animals

Endophytes: Microbes that colonize living, internal tissues of plants without causing any immediate, overt negative effects

Evapo-transpiration(ET): ET is the measurement of moisture that plants and land lose through evaporation and transpiration processes due to heat, humidity and wind. This amount is what should be replaced while irrigating.

Forage: Food of any kind for animals, especially for horses and cattle, as grass, pasture, hay, corn, oats.

Fertigation: It is the application of fertilizers, soil amendments, or other water soluble products through an irrigation system.

Haploid: A set of chromosomes containing only one member of each chromosome pair.

Homozygosity: It is the state of possessing two identical forms of a particular gene, one inherited from each parent.

Integrated farming system: Integrated farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate.

Metabolomics: It is the "systematic study of the unique chemical fingerprints that specific cellular processes leave behind" - specifically, the study of their small-molecule metabolite profiles.

Monoploid: Monoploid is a cell having only one chromosome set or an organism composed of such cells

Mycorrhiza: This is a class of different types of fungi that symbiotically feed off of plants. This symbiosis provides a jointly beneficial relationship between the fungus colony and its host.

Mulching: Application of mulch improves the water use efficiency and helps in water saving by reducing the ET losses and increased yields of a number of field crops during summer months.

Photoperiodism The term "photoperiodism" describes a plant's ability to flower in response to changes in the photoperiod, i.e., the relative lengths of day and night. Because flowers produce seeds, flowering is crucially important for the plant to complete its life cycle.

Pressurized irrigation : Pressurized irrigation systems are designed to deliver water with the flow rate and pressure required by the farm irrigation systems, sprinkling or micro-irrigation, and respecting the time, duration and frequency decided by the farmers.

Pheromones: A chemical secreted by an animal, especially an insect, that influences the behavior or development of others of the same species.

Photosynthesis: It is a process that converts carbon dioxide into organic compounds, especially sugars, using the energy from sunlight.

Phenomics: This is the study of the physical and biochemical traits of organisms as they change in response to genetic mutation and environmental influences.

Senescence: Senescence or biological aging is the change in the biology of an organism as it ages after its maturity. Such changes range from those affecting its cells and their function to that of the whole organism.

Semiochemicals: A chemical emitted by a plant or animal that evokes a behavioral or physiological response in another organism. Semiochemicals determine insect life situations such as feeding, mating, and egg-laying and are thus potential agents for selective control of pest insects.

Silviculture: Silviculture is the art and science of growing and maintaining trees.

Stomata: Stomata is a microscopic pore on the surface (epidermis) of land plants. It is surrounded by a pair of specialized epidermal cells called guard cells, which act as a valve that open and close the pores in response to given environmental conditions.

System of Rice Intensification (SRI): SRI is a methodology for increasing the productivity of irrigated rice cultivation by changing the management of plants, soil, water and nutrients. SRI practices lead to healthier, more productive soil and plants by supporting greater root growth and by nurturing the abundance and diversity of soil organisms.

Transgenic: Transgenic plants are plants possessing a single or multiple genes, transferred from a different species.

Watershed: A watershed is a geographical area that drains to a common point, which makes it an ideal planning unit for conservation of soil and water.

Water use efficiency: Water use efficiency means lowering the water needs to achieve a unit of production in any given activity.

Zero tillage: No-till farming (sometimes called zero tillage) is a way of growing crops from year to year without disturbing the soil through tillage

Zygosity: It refers to the similarity of genes for a trait (inherited characteristic) in an organism. If both genes are the same, the organism is homozygous for the trait. If both genes are different, the organism is heterozygous for that trait.

ABBREVIATIONS

ACZ	Agro-Climatic Zone
AWS	Automatic Weather Station
CAD	Command Area Development
CADWM	Command Area Development and Water Management
ET	Evapo-transparation
GIS	Geographic Information System
ICT	Information and Communication Technologies
IEC	Information, Education and Communication
IPCC	Intergovernmental Panel on Climate Change
IWMP	Integrated Watershed Management Programme
INM	Integrated Nutrient Management
IPM	Integrated Pest Management
ICT	Information and Communication Technology
KCCS	Kisan Credit Card Scheme
KKMS	Kisan Knowledge Management System
MI	Micro Irrigation
MMA	Macro Management of Agriculture
MGNREGA	Mahatama Gandhi National Rural Employment Guarantee Act
NADP	National Agriculture Development Programme
NAIS	National Agricultural Insurance Scheme

NAP	National Agricultural Programme
NAIP	National Agricultural Innovation Project
NPRRR	National Project for Repair, Renovation and Restoration of Water Bodies
NFSM	National Food Security Mission
NHM	National Horticulture Mission
NPMSF	National Project on Management of Soil Health and Fertility
NPCBB	National Project for Cattle and Buffalo Breeding
NREGS	National Rural Employment Guarantee Scheme
PHT	Post Harvest Technology
PIM	Participatory Irrigation Management
PPP	Public Private Partnership
RKVY	Rastriya Krishi Vikash Yojana
RCT	Resource Conservation Technology
SAU	State Agricultural University
SGRY	Sampoorna Grameen Rozgar Yojana
SHG	Self Help Group
SRI	System of Rice Intensification
TDET	Technology Development, Extension and Training
TMC	Terminal Market Complex
WBCIS	Weather Based Crop Insurance Scheme
WHS	Water Harvesting Structure