Agricultural Extension and Sustainable Development Goals

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DEDICATION

TO

EXTENSION PRACTITIONERS AND FARMING COMMUNITY

FROM

SARVAREDDY VENKUREDDY FOUNDATION FOR DEVELOPMENT (SVFD)
H.No.2-6-41/75, Sathsang Colony, Upperpally, Hyderabad – 500 030

FOREWORD

Food and nutrition security,poverty reduction, economic growth, sustainable natural resource management and climate change are among the world's most pressing challenges. Most of the world's poor and food insecure are rural and depend on agricultural livelihoods. At the same time agriculture is a major user of natural resources and source of greenhouse gas emissions while the most vulnerable poor rural households are those with least access to resources and the most likely to suffer from the effects of climate change.

These interlinked challenges are embodied in the Sustainable Development Goals of Agenda 2030 agreed by UN Member Countries in 2015. The connections between the challenges of agricultural and rural development and the SDG targets are very clear. The multi-pronged strategy for agriculture development needs to contribute to agricultural and rural income growth through the sustainable use of soil and water improving the socio-economic conditions of farmers and paying attention to off-farm but food system-related employment creation for livelihood security.

The sustainable development goals agenda represents the most comprehensive negotiated statement of current global challenges with concrete target for countries individually and collectively. Nations across the globe agree to work towards these goals and targets that build on experience and represent a degree of consensus on practices along the three dimensions of sustainable development: economic social and environmental.

Agricultural Extension needs to play a significant role in all of this. Conventional extension needs revitalisation in order to achieve the objectives of food and nutrition security and contribute to sustainable livelihoods and resilience to climate change.

I am very pleased that Professor S.V. Reddy and his team are working on the sustainable development goals through new approaches.

This book is one of the contributions of the National Conference held during April 2017 on ***"Revisiting Agricultural Extension Strategies for Enhancing Food and Nutritional Security Sustainable Livelihoods and Resilience to Climate Change".*** *I appreciate the editors' diligence and dedication towards the extension discipline.*

I congratulate Professor S.V. Reddy and Professor M. Suryamani for this effort and I am certain that this book will provide important insights to students academicians and extension practitioners.

Daniel Gustafson
Deputy Director-General (Programmes)
Food and Agriculture Organization
of the United Nations (FAO)

PREFACE

The agriculture sector is a critical component of the Indian economy with over 60 per cent of the country's population dependent on agriculture for their livelihoods. With the huge and disparate climatic and crop diversity across India it is a challenge to keep farmers informed about the best practices in agricultural development. Achieving sustainable agricultural development requires transformative changes in several domains of development such as social economic policy and environment etc.

Securing inclusive social and economic development as well as environmental sustainability is the avowed objective for all nations and this is vital to the 17 Sustainable Development Goals (SDGs) with 169 targets set by member countries of United Nations. The fact is that without a strong and sustainable agriculture sector it will not be feasible to realise these goals. In addition to its direct impact on hunger and malnutrition our food system is also linked to other developmental challenges addressed in the SDGs.

Agriculture has a direct link with different aspects of Sustainable Development Goals (SDGs) such as food and nutritional security, formal, non-formal and lifelong learning sustainable use of natural resources and livelihoods, conservation of biodiversity, adaptation and resistance to climate change and ultimately the peace and well-being of farming communities.

It is an established truth that the philosophy principles approaches and methods of Extension Education have played a pivotal role in agricultural development across the globe. Extension system has evolved in tandem with the development perspective of India and has been facilitating the attainment of development goals.

Keeping the above concerns in view a National Conference was organised by Sarvareddy Venkureddy Foundation for Development

(SVFD) and Participatory Rural Development Initiatives Society (PRDIS) in collaboration with Professor Jayashankar Telangana State Agricultural University (PJTSAU) during April 2017. The topic of the conference is ***Revisiting Agricultural Extension Strategies for enhancing Food and Nutritional Security Sustainable Livelihoods and resilience to climate change—Towards Transforming Agriculture*** at PJTS Agricultural University, Rajendranagar, Hyderabad, India. Some of the selected papers received under the five major concerns namely: Agricultural Extension and SDGs, Food and Nutritional Security, Sustainable Livelihoods, Adaptation and Resilience to Climate Change, Peace and Wellbeing of Farming Communities were categorised and are presented in this book.

Therefore much importance is given to Agricultural Extension and SDGs wherein relevant extension methods/approaches and extension systems are discussed. In addition extension advisory services farming systems and value chain and strategies for doubling farmers income are also included. The important aspects of Food and Nutritional Security, livelihood skills and opportunities adaptation to climate change and peace and well-being of farming communities address the major concerns of sustainable development goals and therefore have been considered to be suitable to for inclusion in this book.

We are privileged to share the views and research of scientists, university professors, policy makers, administrators and peace and well-being practitioners in bringing the reference book. The book will be useful for agricultural extension academia research scholar's development personnel and extension practitioners in agriculture and allied sectors.

The editors are grateful to all the authors for their outstanding contribution. We are indebted to Dr. Daniel Gustafson, DDG (Programme), FAO, ROME for providing his foreword to this book. We are grateful to SVFD, PRDIS and PJTSAU for supporting the conference. All knowledge partners and sponsors are gratefully acknowledged. We acknowledge the efforts of Mrs.C.Maria Victoria, Mrs.C.Sarika and Mrs. V.K.Prasanti.M for their assistance in formatting the contents of this book.

Editors

ABBREVIATIONS

ACABC	Agri-Clinics and Agri-Business Centres
AICRPs	All India Coordinated Research Projects
AMUL	Anand Milk Federation Union Limited.
APMC	Agriculture Produce Market Committees
ARMM	Amylase Rich Malted Mixes
ARYA	Attracting and Retaining Youth in Agriculture
ASC	Aqua Service Centres
ATIC	Agricultural Technology Information Centers
ATMA	Agriculture Technology Management Agency
AWW	Anganwadi workers
BCFTF	Better Cotton Fast Track Fund
BCI	Better Cotton Initiative Programme
BPL	Below Poverty Line
BRGF	Backward Regions Grant Fund
BTT	Block Technology Team
CBI	Central Bank of India
CCI	Cotton Corporation of India
CDAC	Centre for Development of Advanced Computing
CDAP	Cask Data Application Platform
C-DAPs	Comprehensive District Agriculture Plan
CDR	Corel Draw Vector
CESA	Cotton Eco System Analysis
CGIAR	Consultative Group on International Agricultural Research
CIG	Commodity Interest Group

CIPHET	Central Institute of Post Harvest Engineering and Technology
CIWA	Central Institute for Women in Agriculture
COB	Congressional Budget Office
CSA	Climate-smart Agriculture
CSC	Common Service Centers
CVD	Counter Vailing Duty
DAC	Department of Agriculture Cooperation
DAESI	Diploma in Agriculture Extension Services for Input Dealers
DAY	Deen Dayal AntyodayaYojana
DFI	Doubling Farmers Income
DFID	Department for International Development
DOE	Directorate of Extension
DSR	Direct Seeded Rice
EAS	Emergency Alert System
EAS	Extension Advisory Services
EDP	Electronic Data Processing.
EFSA	European Food Safety Authority
e-NAM	National Agriculture Market
EPRF	Electronic Patient Report Form
FAO	Food and Agriculture Organizations
FDP	Fertilizer Deep Placement
FLS	Farmer Life Schools
FPOs	Farmers Producer Organisations
FSANZ	Food Standards Australia New Zealand
FSGs	Food Security Groups
FSSAI	Food Safety and Standards Authority of India
FYP	Five Year Plan
GDP	Gross Domestic Product
GEM	Global Entrepreneurship Monitor
GES	General Extension Service
GIF	Growth and Innovation Fund
GOI	Government of India
HRD	Human Resource Development

IAAP	Intensive Agricultural Area Programme
IARI	Indian Agricultural Research Institute
IAUA	Indian Agricultural Universities Association
IBDC	Integrated Bee Keeping Development Centres
ICAR	Indian Council of Agricultural Research
ICDS	Integrated Child Development Scheme
ICDS	Integrated Child Development Services
ICM	Integrated Crop Management
ICMR	Indian Council of Medical Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information Communication Technology
IDWG	Inter Departmental Working Group
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
GNRM	Genetic and Natural Resource Management
IGNRM	Integrated Genetic and Natural Resources Management
IGS	Indian Grameen Services
IIMR	Indian Institute of Millets Research
IKS	Indigenous Knowledge System
ILO	International Labour Organization
IMD	India Meteorological Department
IMOD	Inclusive Market Oriented Development
IMF	International Monetary Fund
INM	Integrated Nutrient Management |
INRM	Integrated Natural Resource Management
IOM	International Organization for Migration
IoT	Internet of Things
IP	Implementing Partner
IPC	International Popular Commission
IPCC	Inter-governmental Panel on Climate Change
IPM	Integrated Pest Management
IPMFFS	Integrated Pest Management Farmer Field School
IPY	International Polar Year

ITK	Indigenous Technical Knowledge
IWMP	Integrated Watershed Management Programme
JFM	Joint Forest Management
JRY	Jawahar Rojgar Yojana
KCC	Kisan Call Centres
KDP	Knowledge Delivery Pathways
KRAs	Key Result Areas
KVK	Krishi Vigyan Kendra's
LBSM	Location Based Social Media
LCC	Leaf Colour Chart
LGs	Learning Groups
MAHA	Midwest Asian Health Association
MANAGE	National Institute of Agricultural Extension Management
MDM	Mid Day Meal
MNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
MOA & FW	Ministry of Agriculture and Farmers Welfare
MoHFW	Ministry of Health and Family Welfare
MoWCD	Muskingum Watershed Conservancy District.
MSP	Minimum Support Price
MUDRA	Micro Units Development and Refinance Agency Bank
NABARD	National Bank For Agriculture and Rural Development.
NAIP	National Agricultural Innovation Project
NAM	National Agriculture Market
NAM	Non-Aligned Movement.
NASSCOM	National Association of Software and Services Companies
NATP	National Agricultural Technology Project
NCD	Non Communicable Diseases
NeGP-A	National e-Government Plan Agriculture
NFSB	National Food Safety Board
NFSM	National Food Security Mission
NGOs	Non-Government Organisations
NICRA	National Initiative on Climate Resilient Agriculture
NIN	National Institute of Nutrition

NMAET	National Mission on Agriculture Extension & Technology
NRLM	National Rural Livelihood Mission
NSDC	National Skill Development Corporation
NSSO	National Sample Survey Organization
NYKs	Nehru Yuvak Kendras
OAS	One Stop Aqua Shop
OBCs	Other Backward Classes
PC	Personal Computer
PDS	Public Distribution System
PESP	Pesticide Environmental Stewardship Program
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
PPM	Project Planning and Management
PPP	Public Private Partnership
PRDIS	Participatory Rural Development Initiatives Society
PRI	Panchayat Raj Institutions
PTD	Participatory technology development
PUFA	Polyunsaturated fatty acids
R&D	Research & Development
RFDs	Rapid Framework Documents
RFID	Radio Frequency Identification
RKC	Rural Knowledge Centre
RKVY	Rashtriya Krishi Vikas Yojana
RSETIs	Rural Self-Employment Training Institutes
RTC	Ready to Cook
RTE	Read to Eat
SAMETIs	State Agricultural Management & Extension Training Institutes
SDGs	Sustainable Development Goals
SES	Specialized Extension Service
SIFOR	Smallholder Innovation for Resilience
SLF	Sustainable Livelihoods Framework
SMAE	Sub-Mission on Agricultural Extension
SMS	Subject Matter Specialists
SPV	Special Purpose Vehicle

SREP	Strategic Research Extension Plan
STRY	Skill Training of Rural Youth
T&V	Training and Visit
TCS	Tata Consultancy Services
TK	Traditional Knowledge
TPDS	The targeted public distribution system
UN	United Nation
UNDP	United Nations Development Programme
USDA	United States Department of Agriculture
USFDA	United States Food and Drug Administration
VFC	Village Forest Committee
VKS	Virtual Knowledge System
VPEW	Village Level Para Extension Worker
VSAT	Very Small Aperture Terminal
WB	World Bank
WFP	World Food Programme
WMO	World Meteorological Organization
WTO	World Trade Organization

EPIGRAPH

The publication is a composition of exchange of global and national experiences through presentation of papers and case studies of academicians, scientists and extension practitioners about relevant Sustainable Development Goals.

The book is divided into five major chapters which address the agriculture and extension related sustainable development goals. All these areas provide latest and implementable information technological interventions and Extension Strategies.

It begins with aligning agricultural strategies strengthening the Agricultural Extension Systems and approaches use of unique ITC sand prophesy to innovations. The thrust areas of the present context viz. Doubling farmers incomes, Food & Nutritional Security and value chain. It also deals with sustainable livelihoods and adaptation to climate change interventions and strategies for protection of Indigenous Technical Knowledge (ITKs) finally ethics and values in Extension services and peace and wellbeing of the civil farming societies.

The book is forwarded by Dr. Daniel Gustafson, DDG Programmes, FAO,Rome who is instrumental in promoting Sustainable Development Goals across the world.

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Climate Change Adaptation and Mitigation Strategies for Sustainable Crop Production

Dr. AVR Kesava Rao, Dr. Suhas P Wani and Dr.K Srinivas

INTRODUCTION

Climate change is the main environmental problem facing humanity. Evidences over the past few decades show that significant changes in climate are taking place all over the world as a result of enhanced human activities through deforestation emission of various greenhouse gases and indiscriminate use of fossil fuels. Carbon dioxide (CO_2) Methane and Nitrous Oxide are the major greenhouse gases. CO_2 enters the atmosphere mostly through burning fossil fuels. Methane emissions also result from livestock and other agricultural practices and Nitrous Oxide is emitted during agricultural and industrial activities. Global atmospheric concentration of CO_2 has increased from pre-industrial level of 280 parts per million (ppm) to 408 ppm in Feb 2018. Global projections indicate higher temperature of 1.5 to 4.5°C by the year 2050 as a result of enhanced greenhouse gases. There is medium confidence in that the Indian summer monsoon circulation weakens but this is compensated by increased atmospheric moisture content leading to more rainfall. There is medium confidence in an increase of Indian summer monsoon rainfall and its extremes throughout the 21st century under all RCP (Representative Concentration Pathways) scenarios.

Sixty per cent of agriculture in India is rain fed supporting livelihoods of millions of small farm-hold er families for achieving food and nutritional security. Changes in climate affect agriculture and

water demand of an area. Changed rainfall patterns lead to frequent extreme conditions like floods droughts and cyclones. Changes in temperatures impacts crop yields increase crop water requirements and change the length of the growing period; all these necessitates changes in crops varieties and management practices at specific regions for sustainable agricultural production.

Region-specific adaptation strategies need to be identified for increasing resilience of agricultural production to climate change. Identifying and promoting climate change mitigation technologies and providing incentives for practicing mitigation measures will help stabilize greenhouse gas emissions and restrict future climate change. Enhancing awareness on climate change and its impacts on agriculture among the various stakeholders through knowledge-sharing is important.

CLIMATE VARIABILITY AND CHANGE IN INDIA

Temperature

Various studies show that climate change in India is real and it is one of the major challenges faced by Indian Agriculture. Indian annual mean (average of maximum and minimum) maximum and minimum temperatures showed significant warming trends of 0.51 0.72 and 0.27 °C 100 yr^{-1} respectively during the period 1901–2007 (Kothawale et al. 2010). However accelerated warming was observed in the period 1971–2007 mainly due to intense warming in the recent decade 1998–2007. Based on data for sixty years (1951-2010) Rathore et al (2013) reported significant increasing trends in mean maximum temperature over all states in India except those in the Indo-Gangetic plains wherein spatially coherent decreasing trends were observed in the annual mean maximum temperature with significant decrease over Haryana (-0.02 °C/year) and Punjab (-0.01 °C/year). Maximum increase in annual mean maximum temperature was observed in Himachal Pradesh with a rate of change of about +0.06 °C/year. Rate of increase in annual mean minimum temperature was highest in Sikkim (0.07 °C/year) while the rate of decrease was highest in Uttarakhand (-0.03 °C/year).

India Meteorological Department (IMD 2017) reported that the annual mean temperature for the country in the year 2016 was +0.87 °C

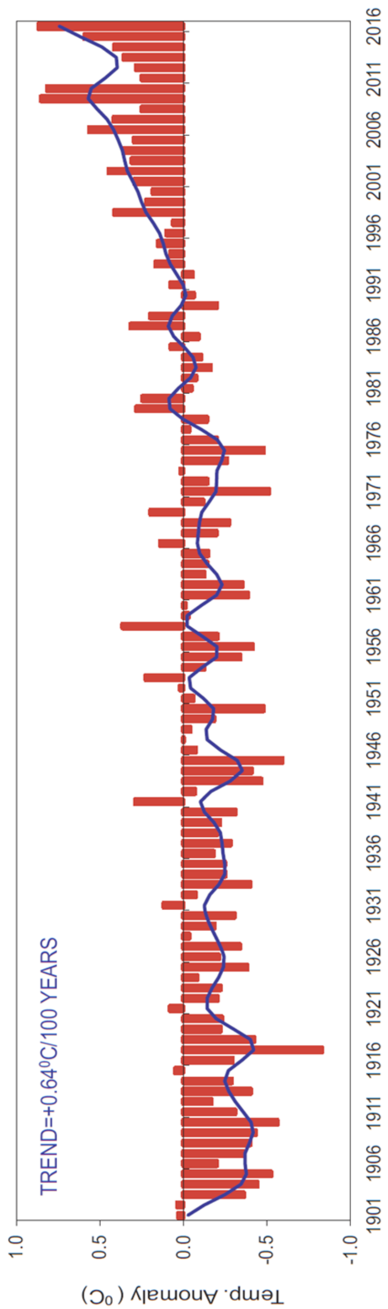

Figure 1 Observed annual temperature anomalies in India

above the 1971-2000 average thus making the year 2016 as the warmest year on record since 1901 (Figure 1). Eight warmest years in the past few years on record in order were: 2009 2010 2015 2006 2002 2007 and 2014). During 1901-2016 the annual mean temperature showed an increasing trend of 0.64 °C/100 years with significant increasing trend in maximum temperature (1.04 °C/100 years) and relatively lower increasing trend (0.25 °C/100 years) in minimum temperature.

The India Meteorological Department's (IMD) draft climate summary says that 2017 was the fourth warmest year on the trot after 2016 2015 and 2014 as the average temperature across the country was 0.71 °C above the 1971-2001 average. The post-monsoon period (Oct-Dec) in 2017 was the third warmest since 1901. Annual mean temperatures rose by 0.66 °C per hundred years during 1901-2017 with maximum temperatures rising faster than the minimum. In 2017 the average temperature in winter was close to three degrees higher than the baseline of 1900-1930. These findings indicate that warming is more pronounced than expected.

Rainfall

At the country scale no long-term trend in the onset date of southwest monsoon over Kerala and total monsoon rainfall over whole country was observed. Long-term mean of the date of onset of southwest monsoon over Kerala is 01 June with a standard deviation of 7-8 days. The onset varied widely as the earliest was on 11 May 1918 and the most delayed was on 18 June 1972. Analysis of data on onset and total monsoon rainfall for 137 years (1881-2017) indicates that onset of southwest monsoon over Kerala appears becoming earlier; however this is not statistically significant. Though the total monsoon rainfall over India in the past 137 years did not show any significant trend slight reduction is seen from 1950s onwards.

Kundu et al (2014) have analysed trend of rainfall for 141 years (1871 to 2011) of India by analyzing 306 stations of India divided into seven regions of Homogeneous Indian Monsoon Core-Monsoon India North West India West Central India Central Northeast India North East India and Peninsular India. Except for core-monsoon and north-east India other five regions have shown decreasing trend. Change per centage for 141 years had shown rainfall variability throughout India with the highest increase in North-West India (5.14 %) and decrease in Core-monsoon India (−4.45 %) annually.

Changes in Areas Under Climate Types

Geographical boundaries of climatic zones vary with time when changes in temperature and rainfall become considerable. Climate change is a major issue for sustainable agriculture and thus there is a need to review the areas under the different climatic zones.

A study carried out by ICRISAT under the National Initiative on Climate Resilient Agriculture (NICRA) project based on the gridded rainfall and temperature data of India Meteorological Department quantified the changes in areas under different climates in India. The study indicated a net reduction in the dry sub-humid area (10.7 m ha) in the country of which about 5.1 Million ha (47%) shifted towards the drier side and about 5.6 Million ha (53%) became wetter comparing the periods 1971-1990 and 1991-2004 (Kesava Rao et al. 2013). Results for Madhya Pradesh have shown the largest increase in semi-arid area (about 3.82 Million ha) followed by Bihar (2.66 Million ha) and Uttar Pradesh (1.57 Million ha). Relatively little changes occurred in AP; semi-arid areas decreased by 0.24 Million ha which were shifted to both towards drier side (0.13 Million Ha under arid type) and wetter side (0.11 Million Ha under dry sub-humid type). Results indicated that dryness and wetness are increasing in different parts of the country in the place of moderate climates existing earlier in these regions.

Similar work using data up to 2015 for Uttar Pradesh has shown that when compared to the 30-year period 1956-85 in the recent 30-year period (1986-2015) areas under semi-arid climate have increased by 3.25 Million ha mostly at the expense of Sub humid dry climate areas. These results indicate that areas under climate types are drastically changing in certain States of India and highlighting the need for detailed and comprehensive studies on climate change quantification in India.

Future Climate Projections

Projections of future climate are based on the output of atmosphere / ocean general circulation models and are used to simulate conditions in the future based on projected levels of greenhouse gases. There are several models available with different spatial resolutions. Majority of projections of future climate come from Global CirculationModels which vary in the way they model the climate system and so produce different projections about what will occur in the future.

The Centre for Climate Change Research Indian Institute of Tropical Meteorology (CCCR-IITM) has generated an ensemble of high resolution downscaled projections of regional climate and monsoon over South Asia until 2100 at 50 km horizontal resolution (CCCR 2017) by driving the regional model with lateral and lower boundary conditions from multiple global atmosphere-ocean coupled models from the Coupled Model Inter comparison Project Phase 5 (CMIP5). Future projections are based on three RCP scenarios viz. RCP 2.6 RCP 4.5 and RCP 8.5 of the IPCC. Results indicate that the all India mean surface air temperature change for the near-term period 2016–2045 relative to 1976–2005 is projected to be in the range of 1.08°C to 1.44°C and is larger than the natural internal variability. It is projected to increase in the far future (2066–2095) by 1.35 ± 0.23°C under RCP 2.6 2.41 ± 0.40°C under RCP 4.5 and 4.19 ± 0.46°C under RCP 8.5 scenario respectively. The semi-arid North-West and North India will likely warm more rapidly than the all India mean. Monthly increase in temperature is relatively higher during winter months than in the summer monsoon months throughout the 21st century. The models project substantial changes in temperature extremes over India by the end of the 21st century with a likely overall decrease in the number of cold days and nights and increase in the number of warm days and nights. Although the all India annual precipitation is found to increase as temperature increases precipitation changes throughout the 21st century remain highly uncertain. Precipitation extremes are projected to increase with intensification of both dry and wet seasons along the West coast of India and in the adjoining peninsular region.

Climate Change Impacts on Crop Production

Crop-growing season period is likely to be reduced in future climate situation mainly due to increase in temperature rate and the accelerated growth stages of wheat. It is likely that both grain and straw yields will be affected in future due to climate change. Studies indicate that in addition to air temperature rainfall amount and intensity are likely to change in future. These will impact the amount of water that can be stored as soil moisture and lost as runoff thereby changing the water availability to agricultural crops at critical stages. Thus agricultural crop production would become more challenging under future climatic conditions.

Rise in the mean temperature above a threshold level will cause a reduction in agricultural yields. A change in the minimum temperature is more crucial than a change in the maximum temperature. Grain yield of rice for example declined by 10% for each 1 °C increase in the growing season minimum temperature above 32 °C (Pathak et al. 2003). Climate change impact on the productivity of rice in Punjab (India) has shown that with all other climatic variables remaining constant temperature increases of 1 °C 2 °C and 3 °C would reduce the rice grain yields by 5.4% 7.4% and 25.1% respectively.

MS Swaminathan has projected that an increase of 2 °C in temperature could decrease rice yields by about 0.75 ton/ha; and a 0.5 °C increase in winter temperature would reduce wheat yield by 0.45 ton/ha. Developing crop cultivars tolerant to higher temperature and popularizing them is a major step for sustainable rice and wheat production in northern states of India where rice and wheat are major crops.

Reduction in yields as a result of climate change is predicted to be more pronounced for rainfed crops as opposed to irrigated crops because of no coping mechanism for rainfall variability. Eastern regions in India are predicted to be most impacted by increased temperature and decreased radiation resulting in relatively fewer grains and shorter grain filling durations. Although additional carbon dioxide can benefit crops this effect is likely to be nullified by an increase in temperature.

Climate change impacts weather conditions which affect seasonal crops and reduce available growing time for rice and sugarcane crops in Uttarakhand and Uttar Pradesh (Kumar etal. 2011). Increase in winter temperatures may increase cane growth however with more irrigation. Warmer climate also increases prevalence of insect pests diseases and weeds. Changing rainfall patterns due to climate change may result in water stress induced by drought. Average maximum temperature in summer and average minimum temperature in rainy season have a negative and statistically significant effect on sugarcane productivity (Ajay Kumar and Pritee Sharma 2014).While sugarcane productivity positively get affected with increasing average maximum temperature in rainy season and winter seasons. Their study concluded that there is a non-linear relationship between climatic factors and sugarcane productivity in India. At ICRISAT crop-growth simulation with projected climate data indicated that groundnut pod yields would reduce by 9

to 13 per cent and pigeon pea yields would reduce by about 11 per cent. In both the crops runoff is likely increase leading to more soil erosion and nutrient loss.

Climate change affects dynamics and interaction among species and affect and change the pattern of pest damage and pest control strategies. Several insect-pests that were important in the past or considered as minor pests are likely to become more devastating with global warming and climate change (Sharma 2014). Studying data gathered in India after the rainy season revealed a higher incidence of dry root rot in chickpea varieties that resist Fusarium wilt in years when temperatures exceed 33°C (Ghosh *et al*. 2013). This is consistent with the greenhouse experiments where different soil moisture levels and temperatures were manipulated showing that *R. bataticola* infected chickpea plants and caused dry root rot faster at 35°C with soil moisture levels ≤ 60% (Sharma *et al*. 2010; Sharma and Ghosh Raju 2017). Increase in temperature may increase the need for application of pesticides and may reduce pesticide effectiveness and increase residues. Rising temperatures are likely to result in availability of new niches for insect pests. Climate change is likely to make sleeper weeds to become invasive and promotes expansion of weeds into higher latitudes and altitudes.

There is a huge lacuna in expertise in India on modelling crop and pest/disease incidence and spread and a knowledge gap exists in areas like potential risk mapping of pests and diseases under climate change and understanding of host x pest/pathogen interactions under projected climate conditions. Addressing these will help location and crop specific IPM strategies and to provide appropriate and timely pest management recommendations to farmers and other stakeholders.

Climate Smart Agriculture

Climate Smart Agriculture (CSA) is a way to achieve short-and-long-term agricultural development priorities in the face of climate change and serves as a bridge to other development priorities. Climate-smart agriculture includes practices and technologies that sustainably increase productivity support farmers' adaptation to climate change and reduce levels of greenhouse gases. Climate-smart approaches can include many diverse components from farm-level techniques to policy and finance mechanisms.

Climate Change Adaptation

Climate change adaptation refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage to take advantage of opportunities or to cope with the consequences. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished including anticipatory and reactive adaptation private and public adaptation and autonomous and planned adaptation. Adaptation strategies need to be identified properly for increasing resilience of agricultural production to climate change. Several improved agricultural practices are evolved over time and in various regions. Management practices that are being followed under conditions of weather aberrations could also become potential adaptation strategies for climate change.

Resilience to climate change requires identifying climate smart crops and management practices and degree of awareness of community. Intercropping with grain legumes is one of the key strategies to improve productivity and sustainability of rainfed agriculture. Productive intercropping options identified to intensify and diversify rainfed cropping systems are:

- Groundnut with maize
- Pigeonpea with maize
- Pigeonpea with soybean

Some opine that the Green Revolution which resulted in food security in India has reduced production and consumption of millets. Millets are drought tolerant and less impacted by climate change. Government of India has decided to include millets in the public distribution system for which it is procuring these grains at federally fixed minimum support prices. Millets are naturally rich source of vitamins and micro-nutrients. Providing millets to poor households at a cheaper price and through school mid-day meals will improve nutrition uptake among poor and also boost incomes of small farmers.

ICRISAT reports that some millets and sorghum varieties could increase their yields up to three times their current potential. In the face of climate change water scarcity and longer periods of drought millets and sorghum may be valuable nutritious and hardy alternatives

to provide sustainable food security for people living in increasingly dry climates. A return to millets and sorghum means a return to food that is good for you good for the planet and good for the farmer.

ICRISAT and Mahatma Phule Krishi Vidyapeeth Rahuri Maharashtra India have jointly developed a high-iron variety of pearl millet called ***Dhanashakti*** which was released in 2012 in Maharashtra and later in 2013 across India making it the first mineral biofortified product of any crop cultivar released in India. ICRISAT-bred biofortified sorghum line ICSR 14001 with 50% higher iron and zinc compared to the existing varieties is becoming popular. Groundnut variety ICGV 03043 developed by ICRISAT has the highest oil content of 53% compared to normal variety have 48% which results to higher prices for produce by farmers.

Government of India has rolled out a programme called "Nutri-cereals" under the National Food Security Mission (NFSM) to increase production of millets like sorghum pearl millet finger millet and other small millets. Indian government has declared 2018 as the "National Year of Millets". Establishing processing clusters of millets in major producing areas will link production with processing value addition and marketing in rural and urban niche health markets.

Agro-climatic analysis at watershed level (Rao AVRK et al. 2008) coupled with crop-simulation models and better seasonal and medium duration weather forecasts help build resilience to climate variability / change. Farmers having access to climate and weather information are more likely to take better crop management actions. Simulation studies using CROPGRO Peanut model in Anantapur district (Andhra Pradesh India) revealed that groundnut yields can be increased (under climate change projections of four Global Circulation Models) on an average by 1% 5% 14% and 20% by adopting adaptation options of heat tolerance drought tolerant cultivars supplemental irrigation and a combination. Spatial patterns of relative benefits of adaptation options were geographically different and the higher benefits can be achieved by adopting new cultivars having drought tolerance and with the application of supplemental irrigation at 60 days after sowing.

Some of other climate change adaptation strategies are ridge planting systems:

seed treatment; Integrated Pest Management (IPM); adoption of climate-smart cultivars improved production technologies; promoting community-based seed production groups and market linkages. Farmers need to be encouraged to practice seed treatment with Trichoderma spp. and fungicides for managing seedling diseases and IPM options. Improved water use efficiency through IWM is the key in rainfed agriculture. Alternative sources of irrigation water are the carefully planned reuse of municipal wastewater and drainage water. More initiatives on waste water management in rural areas would enhance recycling and reuse of treated water for irrigation.

Temperature-humidity stress on livestock: is projected to increase sustainable meat and milk production better shelter management is the key. Major management options are providing shade improved ventilation and sufficient quantity of drinking water for livestock and poultry. Trees buildings or sunshades can provide shade. Ventilation can be provided for air movement by fans and windows. Sunshades should be high enough to allow air movement.

ICRISAT's research findings showed that Integrated Genetic and Natural Resources Management (IGNRM) through participatory watershed management is the key for improving rural livelihoods in the SAT (Wani et al. 2002 and Wani and Rockström2011). Even under a climate change regime crop yield gaps can still be significantly narrowed down with improved management practices and using Germplasm adapted for warmer temperatures (Wani et al. 2009 and Cooper et al. 2009). Integrated Watershed Management (IWM) comprises improvement of land and water management integrated nutrient management including application of micronutrients improved varieties and integrated pest and disease management for substantial productivity gains and economic returns by farmers. The goal of watershed management is to improve livelihood security by mitigating the negative effects of climatic variability while protecting or enhancing the sustainability of the environment and the agricultural resource base. Greater resilience of crop income in Kothapally Ranga Reddy district (Telangana) during the drought year 2002 was indeed due to watershed interventions. While the share of crops in household income declined from 44% to 12% in the non-watershed project villages crop income remained largely unchanged from 36% to 37% in the watershed village (Wani et al. 2009).

ICRISAT and Microsoft Joint Project: A pilot under the Andhra Pradesh **"*Rythu Kosam*"** Project for disseminating sowing and other crop-management advisories to rainfed groundnut farmers of Devanakonda in the year 2016. Farmers' Group Meetings were organized and 175 farmers have registered their mobile phone numbers for receiving sowing advisories. Advisories were prepared both in Telugu (local language) and in English and were disseminated to the registered farmers during the groundnut crop-growing period of 2016. Advisories included recommendations on land preparation soil-test based fertilize application FYM application sowing seed treatment optimum sowing depth preventive weed management maintaining proper plant density applying nutrients if needed harvesting shade drying of harvested pods and storage. Weather advisories brought climate awareness among groundnut farmers and encouraged them to initiate sowing at the optimum time. They followed weather-based agro advisories for proper crop management and obtained better yields and are out of loss compared to some farmers who have sown earlier. Some registered farmers who have sown as per our advisory have obtained about 30 per cent increase in groundnut yields compared to some of the non-registered farmers who have sown in the first week of June 2016.

Climate Change Mitigation

Strategies for mitigating methane emission from rice cultivation could be alteration in water management particularly promoting mid-season aeration by short-term drainage; improving organic matter management by promoting aerobic degradation through composting or incorporating it into soil during off-season drained period; use of rice cultivars with few unproductive tillers high root oxidative activity and high harvest index; and application of fermented manures like biogas slurry in place of unfermented farmyard manure.

Methane emission from ruminants can be reduced by altering the feed composition either to reduce the percentage which is converted into methane or to improve the milk and meat yield. The most efficient management practice to reduce nitrous oxide emission is site-specific efficient nutrient management. The emission could also be reduced by nitrification inhibitors such as nitrapyrin and dicyandiamide (DCD).

Direct Seeded Rice (DSR) is an alternative method that can reduce the labour and irrigation water requirements. In the face of increasing population and growing demand for food the upgrading of rainfed areas through DSR can help in soil and water conservation and deal with risks arising from climate change. Conservation agriculture technology helps to cope with climate change impacts.

Legume-based systems are more sustainable than cereal only systems on Vertisols. Several soil and crop management practices affect C sequestration in the soil. Among them conservation tillage regular application of organic matter at high rates integrated nutrient management restoration of eroded soils and soil and water conservation practices have a relatively high potential for sequestering C and enhancing and restoring soil fertility in the longer-term.

Leaf Colour Chart (LCC) is an easy-to-use and inexpensive tool for determining nitrogen status in plants. Use of the LCC promotes timely and efficient use of N fertilizer in rice and wheat to save costly fertilizer and minimize the fertilizer related pollution of surface water and groundwater. It is a promising eco-friendly and inexpensive tool in the hands of the farmers.

Renewable energy and farming are a winning combination. Wind solar and biomass energy can be harvested forever. Among various renewable sources of energy biomass which is produced right in the villages offers ample scope for its efficient use to carry out domestic production agriculture livestock rising and agro-processing activities through thermal and bio-conversion routes. Usage of solar energy is slowly increasing in rural India with solar cookers for cooking solar drier for drying agriculture produce solar water heaters and solar photovoltaic systems for pumping devices which are used for irrigation and drinking water. Farmers can lease land to wind developers use the wind to generate power for their farms or become wind power producers themselves.

CONCLUSIONS

India ranks first among the countries that practice rainfed agriculture in terms of both extent and value of production. Rainfed agriculture is practiced under a wide variety of soil types agro-climatic and rainfall conditions. Various studies show that climate change in India is real and it is one of the major challenges faced by Indian Agriculture. All aspects of food security are potentially affected by climate change including food access utilization and price stability. Feed security is as important as food security for India. The overall risks of climate change impacts can be reduced by following suitable adaptation strategies and limiting the rate and magnitude of climate change.

Identifying and developing crop cultivars with enhanced water use efficiency tolerance to both drought and floods is the need. Implementing Integrated Watershed Management Programme in a holistic way can mitigate the adverse effects of climate variability and change and enhance the capacity of small-farm holders to manage extremes of drought and floods in a sustainable way. Scaling-up of issue of weather-based agro-advisories for better crop management using new ICT tools to reach the farming community will enhance resilience to climate variability and change.

Climate change adaptation involves adjustments to decrease the vulnerability of agriculture to current climate variability and to future changes. It is necessary that farmers possess the requisite skills to implement an alternative production technique. Under the climate change scenario due to uncertainty in rainfall conditions and occurrence of extreme weather farmers need to be supported with both climate and weather information for sustainable crop production. Agriculture extension system plays a very important role in enhancing the knowledge and skills of farmers for improving agricultural productivity as lack of awareness among farmers about good agricultural practices is always been a key limiting factor for improving productivity levels. Establishing Farmer Field Schools for climate smart agriculture is a major step. It is important to rejuvenate the existing Agricultural Extension Systems by including training of extension staff to acquire new knowledge and skills in climate risk management and with innovative ICT models for knowledge generation and dissemination to make them truly innovative. Adaptation to climate variability and change and providing incentives to climate change mitigation actions must become an important policy priority.

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