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CCAP- 2017

Souvenir

National Conference on

Climate Change and Agricultural Production

Adapting Crops to Climate Variability and Uncertainty

April 6–8, 2017

Organized by
BIHAR AGRICULTURAL UNIVERSITY
Sabour, Bhagalpur (Bihar)

in Collaboration with
INDIAN ECOLOGICAL SOCIETY
Ludhiana (Punjab)

Editors
S. Sheraz Mahdi
Sanjay Kumar
Ashok K. Dhawan

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Conference on Climate Change & Agricultural Production

CCAP- 2017

Souvenir

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Climate Change and Agricultural Production

Adapting Crops to Climate Variability and Uncertainty

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Editors
S. Sheraz Mahdi
Sanjay Kumar
Ashok K. Dhawan

Guidance
Dr. Ajoy Kumar Singh
Vice-Chancellor, BAU, Sabour

Technical Support

Dr. R.K. Sohane
Director Extension Education, BAU, Sabour and
Chairman Local Organizing Committee, CCAP Conference-2017

Dr. R.P. Sharma
Associate Dean-cum-Principal, BAC, Sabour and
Convener, CCAP Conference-2017

Editors
S. Sheraz Mahdi
Sanjay Kumar
Ashok K. Dhawan

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शमीमा सिद्दिकी
SHAMIMA SIDDIQUI
भारत के राष्ट्रपति की उप प्रेस सचिव
Deputy Press Secretary
to the President of India

सत्यमेव जयते

राष्ट्रपति सचिवालय,
राष्ट्रपति भवन,
नई दिल्ली-110004.
PRESIDENT'S SECRETARIAT,
RASHTRAPATI BHAVAN,
NEW DELHI - 110004.

Message

The President of India, Shri Pranab Mukherjee, is happy to know that the Bihar Agricultural University, Sabour in collaboration with Indian Ecological Society (IES), Ludhiana is organising a National Conference on "Climate Change and Agricultural Production-Adapting Crops to Increased Climate Variability and Uncertainty" during April 6-8, 2017 at Sabour, Bhagalpur, Bihar.

The President extends his warm greetings and felicitations to the organisers and participants and sends his best wishes for the success of the Conference.

Deputy Press Secretary to the President

New Delhi
March 16, 2017

Tel. (O) : 91-11-23793528 (Direct), 91-11-23015321 Extn. 4442 , Fax : 91-11-23010252
E-mail : message-rb@rb.nic.in

सत्यमेव जयते

प्रधान मंत्री कार्यालय
नई दिल्ली - 110011

PRIME MINISTER'S OFFICE
New Delhi - 110011

Message

The Prime Minister is happy to learn that Bihar Agricultural University, Sabour in collaboration with Indian Ecological Society is organising National Conference on the theme 'Climate Change and Agricultural Production- Adapting Crops To Increased Climate Variability and Uncertainty' from 6th- 8th April, 2017.

On this occasion, best wishes for the organisers and participants.

(Chandresh Sona)
Deputy Secretary

New Delhi
March 06, 2017

RAM NATH KOVIND
GOVERNOR OF BIHAR

RAJ BHAVAN
PATNA-800 022
Ph. 0612-2217626 Fax 2786184

12 January, 2017

Message

I am pleased to know that Bihar Agricultural University, Sabour, in collaboration with Indian Ecological Society (IES), Ludhiana, Punjab is organizing a National Conference on '*Climate Change and Agricultural Production-Adapting Crops to Increased Climate Variability and Uncertainty*' from 6-8th April, 2017 at Sabour, Bhagalpur Bihar.

Available evidences show that there is high probability of increase in the frequency & intensity of climate related natural hazards due to climate change. The State is highly vulnerable to hydro-meteorological natural disasters, with North Bihar in general being highly flood-prone, and South Bihar being highly drought prone. In the absence of state level climate models and/or vulnerability studies, as well low community awareness, Bihar is potentially more sensitive and vulnerable to the climate change and its impacts.

I hope that the scientists, academicians and other stakeholders participating in the conference will share their valuable views and experiences towards mitigating the impacts of climate change in the country and the state and will arrive at a fruitful conclusion.

I extend good wishes for the grand success of the Conference.

(Ram Nath Kovind)

Nitish Kumar
CHIEF MINISTER
BIHAR

Residence : 1, Anne Marg
Patna - 800001

Letter No. ....

Date : 26.12.2016

Message

I am happy to know that Bihar Agricultural University, Sabour in collaboration with Indian Ecological Society (IES), Ludhiana, Punjab, is organising a National Conference on 'Climate Change and Agricultural Production-Adapting Crops to Increased Climate Variability and Uncertainty' from 6th April - 8th April, 2017 at Sabour, Bhagalpur, Bihar.

Climate change will have wide ranging effects on the environment, and on socio-economic and related sector, including water resources, agriculture and food security, human health, terrestrial, ecosystems and biodiversity. Changes in rainfall pattern are likely to lead to severe water shortages and/or flooding. Temperature increases will potentially severely increase rates of extinction for many habitats and species.

Climatic change of Bihar and adjoin developing state of India compelled us to mitigate the issues relating to disasters in the State. Include the recurring nature of the main event categories-Earthquake, floods and droughts.

I appreciate the efforts taken by Bihar Agricultural University, Sabour, in organising the conference on climate change. I hope fresh and innovative approaches will be generated during the conference, for mitigating the impact of climate change issues and development of standard of living of people of the country and the state.

I convey my best wishes for the success of the conference.

(Nitish Kumar)

राधा मोहन सिंह
RADHA MOHAN SINGH

D.O. No. 75 /AM

सत्यमेव जयते

कृषि एवं किसान कल्याण मंत्री
भारत सरकार
MINISTER OF AGRICULTURE & FARMERS WELFARE
GOVERNMENT OF INDIA

06, **January, 2017**

Message

I am happy to know that Bihar Agricultural University, Sabour, Bihar, in collaboration with Indian Ecological Society (IES), Ludhiana, Punjab, is organizing a National Conference on 'Climate Change and Agricultural Production – Adapting Crops to Increased Climate Variability and Uncertainty' from 6-8th April, 2017 at Sabour, Bhagalpur, Bihar.

The Indian agriculture, despite making significant progress, is facing the challenges of stagnating net sown area, reducing per capita land availability, deteriorating soil health and diminishing natural resources. Additionally, climate variability and changes are the emerging challenges being faced by this sector for ensuring national food security and making agriculture sustainable.

India needs 320 MT of food gains by the year 2025. For a country like India, sustainable agricultural development is essential not only to meet the food demands, but also for poverty reduction through economic growth by creating employment opportunities in non-agricultural rural sectors. Assessing vulnerability of agriculture to climate change is the pre-requisite for developing and disseminating climate-smart technologies to achieve the target.

I am sure that the conference will bring together well acclaimed national level scientists, professors, entrepreneurs and policy makers to discuss the latest climate smart technologies and their application in all spheres of agriculture and allied sectors, to find newer solution and achieve the goals.

I convey my best wishes for the success of the conference.

Radha Mohan Singh

(Radha Mohan Singh)

Office : Room No. 120, Krishi Bhawan, New Delhi-110 001 Tel.: 23383370, 23782691 Fax : 23384129

तेजस्वी प्रसाद यादव
Tejashwi Prasad Yadav

बिहार सरकार

उप मुख्यमंत्री
बिहार सरकार
Deputy Chief Minister,
Govt. of Bihar

No.: 129
Dated: 24th Jan 2017

Message

It gives me immense pleasure to know that Bihar Agricultural University, Sabour, Bihar, in collaboration with Indian Ecological Society (IES), Ludhiana, Punjab is organizing a National Conference on 'Climate Change and Agricultural Production-Adapting Crops to Increased Climate Variability and Uncertainty' on 6-8th April, 2017 at Sabour, Bhagalpur, Bihar.

The phenomenon of climate change caused by human activities has emerged as the prime area of concern amongst the global challenges related to environment and sustainable development. Its impacts have spectrum of manifestations over regional and local scales with mostly adverse implications related to human comfort, safety and agricultural productivity of the country and the state.

Global climate change is a serious threat to water resources systems and wetlands. The climate change in Bihar is indicating a gradual increase in temperature and decrease in rainfall, especially after 1970, which is a very disturbing situation, creating natural disasters like drought and flood, hampering the socio-economic condition of the people of the state.

I express my earnest appreciation to organizers for organizing the Conference and hope that in-depth and comprehensive study will be done during the program and corrective action will be taken accordingly for mitigating the impact of climate change issues.

I wish the conference a grand success.

(Tejashwi Prasad Yadav)

आवास: 5, देशरत्न मार्ग, पटना- 800 001, टेलीफैक्स: 0612 - 2215888, ई- मेल: E-mail: dycmbihar@gmail.com
Residence: 5, Desh Ratna Marg, Patna- 800 001, Telefax: 0612 - 2215888, E-mail: dycmbihar@gmail.com

राम विचार राय
मंत्री
कृषि विभाग
बिहार सरकार, पटना

कार्यालय
द्वितीय तल, विकास भवन
बेली रोड, पटना (बिहार)
फोन : 0612-2231212 (का)
फैक्स : 0612-2215526 (का)
मो० 9431818702, 9934953852

पत्रांक : ....

दिनांक : ....

Message

I feel pleased to know that Bihar Agriculture University, Saber, Bihar in collaboration with Indian Ecological Society (IES), Ludhiana, Punjab is organizing a National Conference on 'Climate Change and Agricultural production-Adapting Crops to Increased Climate Variability and Uncertainly' on 6-8th April, 2017 at sabour, Bhagalpur, Bihar.

Crop production is inherently sensitive to climatic variability and change. Temperature and carbon dioxide are two important parameters related to climate change which affects crop yield of a particular region the consequences of agriculture's contribution to climate change, and of climate change's negative impact on agriculture, are severe which is projected to have a great impact on food production and may threaten the food security and hence, require special agricultural measures to combat with.

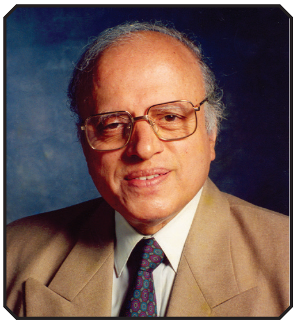
To address climatic change and its vulnerability, decision-makers need to prioritize their responses for different regions as the resources are limited. The decision-makers should plan climate adaptation strategies based on climate change impacts on agriculture crops in the state.

I extend my heartiest congratulations all the delegates participated in the conference and to the organizers and convey my best wishes for the grand success of Conference.

रामविचार राय
(Ram Vichar Roy)

M.S. SWAMINATHAN RESEARCH FOUNDATION

M.S. Swaminathan
Founder Chairman
Ex-Member of Parliament (Rajya Sabha)



Message

Among the new and important threats to food security is climate change leading to adverse changes in temperature, precipitation and sea level. Therefore the conference on climate change and agricultural production is a timely one which should provide a blue print for ensuring food security in future as well as the achievement of the UN sustainable development goals. I commend the conference for your participation.

M S Swaminathan

3rd Cross Road, Taramani Institutional Area, Chennai (Madras) - 600 113, India
Phone: +91-44-2254 2790, 2254 1698 Fax: +91-44-2254 1319
E-mail: founder@mssrf.res.in, swami@mssrf.res.in

अंजनी कुमार सिंह, भा०प्र०से०
मुख्य सचिव
Anjani Kumar Singh, I.A.S.
Chief Secretary

बिहार सरकार
मुख्य सचिवालय, पटना - 800 015
GOVERNMENT OF BIHAR
Main Secretariat, Patna - 800 015
Tel. No. : 0612-2215804 (O), Fax : 0612-2217085
E-mail : anjani41@yahoo.com

Message

I am glad to know that Bihar Agriculture University, Sabour, in collaboration with Indian Ecological Society (IES), Ludhiana, Punjab, is organizing a National Conference on "Climate Change and Agricultural Production-Adapting Crops to Increased Climate Variability and Uncertainty" from 6-8th April, 2017 at Sabour, Bhagalpur, Bihar.

Climate such as changes in temperature and precipitation is the greatest environmental challenge facing the world today and agriculture sector is the most sensitive sector to the climate changes. Agricultural productivity is affected by climate damage due to changes in temperature, precipitation and CO_2 levels and indirectly, through changes in soil, distribution and frequency of infestation by pests, insects, diseases and weeds.

Right kind of technologies and policies are required to strengthen the capacity of communities to cope effectively with both climate variability and changes. Adaptive actions and innovative agricultural practices and technologies should be taken to overcome the adverse effects of climate change on agriculture.

I appreciate the efforts taken by Bihar Agricultural University, Sabour, in organizing the conference on climate change. I am confident that the conference will generate innovative strategies for mitigating the impact of climate change on agriculture and improve the standard of living of people of the state and county.

My best wishes for the success of the conference.

Akm
26/1/16

(Anjani Kumar Singh)
Chief Secretary, Bihar.

त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक
TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001
GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
KRISHI BHAVAN, NEW DELHI 110 001
Tel.: 23382629; 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

Message

I am glad to know that Bihar Agricultural University, Sabour in collaboration with Indian Ecological Society (IES) is organizing a National Conference on 'Climate Change and Agricultural Production-Adapting Crops to Increased Climate Variability and Uncertainty' on 6-8 April, 2017 at Sabour, Bhagalpur, Bihar.

Climate change, and in particular, the emission of greenhouse gases into the atmosphere has emerged as the biggest developmental challenge for the planet according to the assessment of the Intergovernmental Panel on Climate Change as it impacts on ecosystems and biodiversity on a global scale. India too has experienced substantial changes in climatic conditions. For instance, prominent increase has been observed in the number of hot days, night-time temperature, and growing degree days during the period of 1951-2015. Such climatic variability, impacts food production, water supply, health, energy, etc. and therefore scientific understanding as well as coordinated action at national and global level is warranted.

I hope that the discussions and deliberations during this 3-day Conference would help in developing innovative and decisive role in shaping the future research on climate change keeping the issues for farmers' welfare and environmental security.

I wish the Conference, a grand success.

(T. MOHAPATRA)

Dated the 30th September, 2016
New Delhi

कृषि वैज्ञानिक चयन मंडल
(भारतीय कृषि अनुसंधान परिषद)
कृषि अनुसंधान भवन–I, पूसा, नई दिल्ली 110 012
AGRICULTURAL SCIENTISTS RECRUITMENT BOARD
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
Krishi Anusandhan Bhavan-I, Pusa, New Delhi-110 012
Telephone: (O): 011-25843295, 25841272 Fax: 25846540
E-mail: gurbachansingh@icar.org.in, chairman@asrb.org.in

डा॰ गुरबचन सिंह
अध्यक्ष
Dr GURBACHAN SINGH
CHAIRMAN

Message

It is indeed great pleasure to know that Bihar Agricultural University, Sabour, Bhagalpur, Bihar, in collaboration with Indian Ecological Society (IES) is organizing a National Conference on 'Climate Change and Agricultural Production-Adapting Crops to Increased Climate Variability and Uncertainty' from 6-8th April, 2017 at Sabour, Bhagalpur, Bihar.

The Indian agriculture, despite making significant progress, is facing the challenges of stagnating net sown area. With only about 2.3% of world land area, 4% water and 0.3% grazing lands, India supports 17% of the human and11% world livestock population. As a result our natural resources are at increasing risk from soil degradation, deforestation, contamination, biodiversity losses and population pressure. Ecosystem degradation is taking place at an accelerated rate due to human greed and faulty cultivation practices. Crop residue burning is in practice in a huge area in Indo-Gangetic belt. Climate change is also making agriculture a risky occupation. Extreme poverty, hunger, malnutrition, infant and maternal mortality is still a big problem in this part of world.

India needs 320 MT of food grains by the year 2025. For a country like India, sustainable agricultural development is essential to meet the food demands and poverty reduction. The vulnerability of agriculture to climate change is well acknowledged. Frequency of cold and heat waves, droughts, floods, cyclones and tsunami etc. has markedly increased in the recent past and has started impacting agricultural production and productivity. The impact of climate change is more prominent on rainfed agriculture practised mostly by small and marginal farmers, who suffer the most. Food and water security are the major casualties of climate change. Assessing vulnerability of agriculture to climate change is the pre-requisite for developing and disseminating climate-smart technologies to achieve the target.

I am sure that the conference will bring together well commended scientists, entrepreneurs and policy makers to discuss the latest climate smart technologies and their application which will help in mitigating the food and nutritional security.

I convey my best wishes for the success of the conference.

(Gurbachan Singh)

डॉ. जीत सिंह सन्धू
उपमहानिदेशक (फसल विज्ञान)
Dr. Jeet Singh Sandhu
Deputy Director General
(Crop Science)

भाकृ अनुप
ICAR

भारतीय कृषि अनुसंधान परिषद्
कृषि भवन, डा. राजेन्द्र प्रसाद मार्ग, नई दिल्ली - 110001
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI BHAWAN, DR. RAJENDRA PRASAD ROAD, NEW DELHI-110001

Message

I am delighted that Bihar Agricultural University, Sabour, Bhagalpur, Bihar, in collaboration with Indian Ecological Society (IES), Ludhiana, Punjab, is organizing a National Conference on 'Climate Change and Agricultural Production-Adapting Crops to Increased Climate Variability and Uncertainty' on 6-8th April, 2017 at Sabour, Bhagalpur, Bihar.

Green Revolution we inherit in the 21st century represents some of the greatest achievements of human civilization. Paradoxically, current production scenario represents some of the greatest threats to agricultural sustainability too. We have travelled successfully from insufficiency to self sufficiency in food production. The Rainbow revolutions including the Green, Blue, White and Yellow Revolutions are the examples of remarkable accomplishments. Today, globally food systems contribute between 19-29% of global anthropogenic green house gas emission and conventional agricultural systems have contributed significantly to land degradation, soil health decline as well asdestruction of natural habitats and wild biodiversity. Therefore, indeed the very foundations on which current production systems were built becoming fragile. In other words, current agronomical production technologies are failing to sustain the people and resources on which itrelies and has come to represent an existential threat to itself.

It is important that need based technologies and policies are required to strengthen the capacity of communities to cope effectively with changing climate. Innovative agricultural practices should be taken to overcome the adverse effects of climate change on sustainable agriculture.

I sincerely appreciate the efforts taken by Bihar Agricultural University, Sabour, in organising the conference on climate change and hope that anticipate innovative approaches will be generated during the conference, for mitigating the impact of climate change issues and development of food and nutritional security.

I convey my best wishes for the grand success of the conference.

(**JS Sandhu**)

December 26, 2016
New Delhi

Ph. : (Off.) 23382545 Fax : 23097003 E-mail : ddgcs.icar@nic.in

प्रो० हरिश्चन्द्र सिंह राठौर
कुलपति
Prof. H.C.S. Rathore
Vice-Chancellor

दक्षिण बिहार केन्द्रीय विश्वविद्यालय
केन्द्रीय विश्वविद्यालय अधिनियम 2009 के अन्तर्गत स्थापित
CENTRAL UNIVERSITY OF SOUTH BIHAR
Established under Central Universities Act, 2009

Message

It is indeed a matter of great pleasure to note that the Bihar Agricultural University, Sabour, Bihar, in collaboration with the Indian Ecological Society (IES) is organizing a National Conference on 'Climate Change and Agricultural Production-Adapting Crops to Increased Climate Variability and Uncertainty' from 6-8th April, 2017 at Sabour, Bhagalpur, Bihar.

Agriculture is a risky venture due to its vulnerability towards various climatic parameters. Still more than 70% of our population is pursuing this profession and feeding around 17.6% of the global human population. To achieve food security for future generations, the agriculture has to be made more resilient towards the climate which is currently having severe variability with respect to its different parameters like temperature, precipitation etc. There are projections that by the end of 2050, the mean annual surface temperature will rise by 2.5-3.5°C all around the Indian subcontinent with respect to the baseline year (1961-1990), whereas monsoon rainfall may not fall significantly except in some parts of southern peninsula during the same period.

So, how to shape our future agriculture to cope up with such changes in climatic parameters can be discussed at length in this conference for making the State and Indian agriculture climate-smart to deal effectively with challenges posed due to climate change and sustain the growth of agriculture production to provide food security in times to come.

I not only congratulate the organisers for choosing such a relevant theme for this conference but also convey my best wishes for the grand success of this mega event.

(Prof. H.C.S. Rathore)

Patna Office : BIT Campus, P.O. - B.V. College, Patna - 800014, (BIHAR, INDIA)
Gaya Office : Mohalla - Vinova Nagar, Chandauti Police Station, Magadh Medical College, Ward No. 29, Gaya - 823001 (Bihar), Telephone : 0631-2210224
Website : www.cusb.ac.in, E-mail : vc@cusb.ac.in, Tel./Fax : 0612-2226535 (Patna)

डॉ० रमेश चन्द्र श्रीवास्तव
कुलपति
Dr. R. C. Srivastava
M.Tech., Ph.D. (IIT, Kgp)
FNAAS, FIASWC, FISAE, FIE, FCHAI
Vice-Chancellor

डॉ० राजेन्द्र प्रसाद केन्द्रीय कृषि विश्वविद्यालय
पूसा (समस्तीपुर) - 848 125, बिहार
Dr. Rajendra Prasad Central Agricultural University
Pusa (Samastipur) – 848 125, Bihar

No. .... / Dr.RPCAU (VC) Date : ....

Message

I am very happy to know that Bihar Agricultural University, Sabour, Bhagalpur, in collaboration with Indian Ecological Society (IES), Punjab, is organizing a National conference on 'Climate change and Agricultural Production-Adapting crops to Increased Climate Variability and Uncertainty' from 6-8th April, 2017 at Sabour, Bhagalpur, Bihar.

Climate change caused by human activities has emerged as the prime area of concern amongst the global challenges related to environment and sustainable development. Being a global phenomenon, its impacts have spectrum of manifestations over regional and local scales with mostly adverse implications related to agricultural productivity, human comfort, safety and environmental security.

Indian economy and majority of our population are highly dependent on agriculture, animal husbandry, fisheries, etc. Climate change is the greatest environmental challenge today, affecting these sectors. As a consequence, there is high probability of increase in the frequency and intensity of climate related natural disasters both in the country and the state, posing severe threat to the development of the country.

The effect of climate change will have larger implications in case of developing and transforming economics. Bihar being an agriculture dependent state, the impacts of climate change and climate variability will be much more on the livelihood options of the people and consequently on the state economy. It is highly vulnerable to hydro-meteorological disasters, with North Bihar in general being highly flood-prone, and South Bihar being highly drought prone. Rainfall during the monsoon season (June-September) is the key element of Bihar's climate and continues to be primary source of water for the large rainfed agricultural regions in the state. Moreover, continuous rise in temperature during *rabi* season along with terminal heat as a result of abrupt rise in temperature owing to dry westerly wind that generally blows during reproductive phase of wheat crop is a cause of concern for the farmers and policy makers. Accordingly, adaptation and mitigation strategies need to be devised to cope with negative impacts of climate change on crop production.

I appreciate the efforts taken by Bihar Agricultural University, Sabour in organizing the conference on climate change and hope innovative approaches will be generated during the conference, for mitigating the impact of climate change issues and development of standard of living of people of country in general and state of Bihar in particular.

I convey my best wishes for the success of the conference.

(R. C. Srivastava)

Phone : 06274-240226(O), 06274-240264 (R), Fax : 06274-240255, Mob. : 09040033323, Email : vcraupusa@gmail.com, website : www.pusavarsity.org.in

BIHAR AGRICULTURAL UNIVERSITY, SABOUR
BHAGALPUR - 813210 (BIHAR)

Dr. Ajoy Kumar Singh
Vice Chancellor

Phone : 0641-2452606 (O)
: 0641-2452605 (R)
Fax : 0641-2452604
Patna : 0612-2222267 (O)
Fax : 0612-2225364
Mob. No. : +91-8902750693
Email ID : vcbausabour@gmail.com
URL : www.bausabour.ac.in

Ref. :.......................   Date. :.....................

Message

I am pleased that Bihar Agricultural University, Sabour in collaboration with Indian Ecological Society, Ludhiana, Punjab is organizing a National Conference on "Climate Change and Agricultural Production-Adapting Crops to Increased Climate Variability and Uncertainty" from 6-8th April, 2017 at Sabour, Bhagalpur, Bihar.

Climate change is now reality as evident from the significant increase in the CO_2 concentration (406.42 ppm as on March 2017) which has caused most of the warming and has contributed the most to climate change. Due to increase in anthropogenic activities, global temperatures have shown a warming trend of 0.87°C over the period 1880-2015. Annual surface air temperatures over India also have shown increasing trends of similar magnitude during the period 1901-2015 making 2015, the warmest year in the period of instrumental data.

Bihar state in India has been traditionally vulnerable to hydro-meteorological natural disasters, with north Bihar being highly flood-prone and south Bihar being highly drought-prone. The northern and southern Bihar were assessed to be most vulnerable regions to climate change in the Indo-Gangetic Plains (IGP) owing to high exposure, high sensitivity and low adaptive capacity of people. Trend analysis of 45 years of weather data for a set of climate extreme indices from representative centre falling in different Agro climatic zones of Bihar revealed the signs of climate change induced variability in intensity, frequency and duration of temperature and rainfall events. The climate projections of Bihar for 2050 further revealed increasing trends in both maximum and minimum temperatures by 2-4°C coupled with much more variability (-25 to + 30%) in the monthly rainfall patterns which will have large implications on the agriculture, food security and livelihoods of the rural masses.

To abate the negative impacts particularly when climate changes are relatively small, many current agronomic and breeding techniques developed by the scientists of this university are available to help farmers in combating the impacts of climate change. Because of variation in magnitude of vulnerability to climate change in all regions, site-specific cropping systems and management practices will be needed to match yield potential with inputs, soil fertility and the range of climate variability in each area.

Our learning, understanding and knowledge are developed in participation with others. I am delighted by the overwhelming participation of delegates from across the country and abroad in this conference. I hope that the pro-active participation and on-going deliberations in the conference will further chart a clear road map for shaping the future research aiming to look on climate change issues for farmers' welfare and environmental security.

It is my privilege to welcome and greet all the participants and speakers at BAU, Sabour for this novel cause and I wish conference a grand success.

(Ajoy Kumar Singh)

THE INDIAN ECOLOGICAL SOCIETY
PUNJAB AGRICULTURAL UNIVERSITY
Ludhiana–141004, India

Dr A.K. Dhawan
President
Indian Ecological Society

Message

I am pleased that Bihar Agriculture University, Sabour in collaboration with Indian Ecological Society is organizing three day conference on "***Climate Change and Agricultural Production-Adapting Crops to Climate Variability and Uncertainty***" from 6-8. April, 2017.

The climate change has significant impact on natural resources. The importance of these natural resources- land, water and vegetation, is higher than ever before to ensure sustainability in agriculture growth in the face of depleting natural resources like land, water, soil health due to changing climate and declining resource productivity. Climate variability has significant on erosion of natural resources, land, water, forest, biodiversity, livestock and fisheries which are the root causes of the agrarian crisis. The continuing degradation of India's natural resource base is now reflected in slow pace of growth rate in agriculture. Loss of cultivated land, organic matter and C in most of the arable lands in India, groundwater depletion, water loss due to salinity and alkalinity, increase in losses due to insect pests, diseases and weeds are the areas of serious concern in view of changing climate during the last decade. There urgent need to evolve technologies to mitigate the impact of climate on agriculture, livestock and fisheries. More emphasis is required for creating awareness about impact of climate on agriculture.

I hope the deliberations of the conference will be a step toward the aim of developing climate resilient technologies for increasing productivity and sustaining natural resource base. I wish for successful organization of conference and strong believe that work presented by experts on various themes; deliberations and recommendations of conference will update the current scenario of "**Indian Agriculture**" under changing climate scenario.

A.K. Dhawan

Mobile No.: +9814110675; Fax No.: 0161-4629027
Web site: www.indianecologicalsociety,com; email: indianecologicalsociety@gmail.com

Dr. Syed Sheraz Mahdi

Organizing Secretary, CCAP Conference-2017

Assistant Professor, Agronomy, BAU, Sabour,
Bhagalpur (Bihar)

Message

I regard it a great honor to have an opportunity to organize the National Conference on "Climate Change and Agricultural Production-Adapting Crops to Climate Variability and Uncertainty" which is being organized by Bihar Agricultural University, Sabour, Bhagalpur, Bihar in collaboration with Indian Ecological Society, Ludhiana, Punjab from 6-8 April, 2017. The organizing committee is thankful to the delegates, guests, professionals and budding scientist, research scholars and students who have come from different national and international institutes to participate in the conference.

At this point of time, climate change disaster is biggest threat to global economy. Earth's temperatures in 2016 were the hottest ever recorded. It is the second year in a row that the annual global temperature has been more than 1 Celsius degree higher than the pre-industrial level, and shows that the world is moving ever closer to the warming threshold of 1.5 Celsius degrees, beyond which many scientists have concluded the impacts of climate change will be unacceptably dangerous. Extreme high temperatures were seen from India - where the city of Phalodi, Rajasthan recorded temperatures of 51 degrees Celsiu in May, a new national record - to Iran, where a temperature of 53 degrees Celsius was recorded in Delhoran on July 22, 2016. Why does this matter? Because a change of even 1 degree Celsius–which may sound like a small amount can upset the delicate balance of ecosystems, and affect plants and animals that inhabit them. The loss of life and property on account of climate change has been immense. Glaciers have shrunk, ice on rivers and lakes is breaking up earlier, plant and animal ranges have shifted and plants/trees are flowering sooner. Both developed and developing nations have been equally affected. The range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time. So it is imperative that the problem of changing climate is collectively addressed by all regions/countries. In a recently held Paris UN Climate Change Conference on December, 2015 where over 196 countries reached an agreement to limit the emissions below 1.5°C. In many ways, it represents a recognition of the fact that the impacts of climate change are already being felt in many parts of the world. India's pledge to the United Nations Framework Convention on Climate Change (UNFCCC), prior to COP21, reflects a commitment towards encouraging sustainable alternatives, and the government of India, through its policies like the National Action Plan on Climate Change (NAPCC) and its target of generating 175 GW of renewable energy by 2022, might spur the growth of a green economy in India.

With this background, this National Conference on "Climate Change and Agricultural Production" was also organized and is one of the effective reflections of its scientific, academic, and social contribution. Not only does it allow us to meet, greet, and eat but it also provides a unique forum for exchange of ideas, offers and opportunities.

There are several innovative steps taken in this conference. The information about the conference was largely sent online using the Internet. However, the conventional postal method was also used for those who requested. The online submission of extended abstracts though must have been uncomfortable for many, has forced them to acquire minimum computer proficiency. The often casual approach in submitting abstract has largely been avoided as all the abstracts have been reviewed by four internal and two external reviewers . Getting the 695 extended abstracts and reviewed by editors was a mammoth task yet it could be achieved because of 24x7 work culture of our team and the great co-operation from President, Indian Ecological Society. In addition, we created opportunities for all scientists/ scholars for the submission and publication of full length papers in an Indian Journal of Ecology-(Special Issues) published by Indian Ecological Society, collaborator in this conference. This first effort brought kudos from several national and international scientists/ scholars. I wish this becomes the regular practice in the conferences/ seminars. Besides the 9 different sessions based on Climate Change, Its Impact and Adaptations in Agriculture, the conference is programmed to conduct two special Sessions (IRRI and CIMMYT collaborative). To raise the climate and environment awareness among students/ children's, a drawing and photograph competition from 5th to PG standard was also conducted before the two days of the conference, where about more 300 students participated.

It is heartening to know the great interest of scientists /scholars from all over the nation and abroad. we have nearly 500 scientists, who are attending this conference not only for interaction but with the intent of building a long lasting collaboration with institutions/ laboratories. Financial support provided by ICAR, SERB-DST, IRRI and CIMMYT is duly acknowledged.

We look forward to frank discussions, debate and guidance in our efforts. Every attempt is being made from our side to make your visit pleasant and useful. All our best wishes to all of you for a joyful stay and journey ahead.

With Warm Regards

Dr. Syed Sheraz Mahdi
Organizing Secretary,
CCAP Conference-2017

Assistant Professor, Agronomy,
BAU, Sabour, Bhagalpur (Bihar)

Special Acknowledgement

The necessary financial support provided for organizing the National Conference on Climate Change and Agricultural Production (CCAP) by the Indian Council of Agricultural Research (ICAR), Science and Engineering Research Board, Department of Science Technology, (SERB-DST), New Delhi, International Rice Research Institute (IRRI), Philippines and International Maize and Wheat Improvement Center (CIMMYT), Mexico is duly acknowledged.

National Conference on

Climate Change and Agricultural Production

(Adapting Crops to Increased Climate Variability and Uncertainty)

Sabour, Bhagalpur (Bihar) India

April 6–8, 2017

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Dr. Shweta Shambhavi	Asstt. Prof.-cum-Jr. Scientist, Soil Science	Member
Mr. BamBam Bole Nath	Artist, Soil Science	Member

Contents

Climate Change Impact on Agriculture and Forest Sector in Bangladesh

Md. Farid Hossain
Bangladesh Open University, Gazipur–1705, Bangladesh
E-mail: faridhossain04@yahoo.com

Abstract: This review paper aims to discuss (I) the changing trend of climatic factors; temperature, rainfall (II) climate change impact on agriculture and forest sector and (III) mitigation techniques in Bangladesh. Several studies indicated that the climate is changing and becoming more unpredictable every year. Temperature has been increased significantly over the last 20–30 years. Yearly average maximum and minimum temperature are increasing at a rate of 0.0186°C and 0.0152°C per year, respectively. A number of reports revealed that the rainfall patterns have already been changing across the country. The total rainfall showed increasing trend for monsoon and post-monsoon seasons, while decreasing trend for the winter. Pre-monsoon rainfall did not show any significant change. Bangladesh is an agricultural country and forests its important natural resource. Land and plants are affected by climate change in several ways. Agriculture and forest are always vulnerable to unfavorable climatic conditions. Rice yield may hamper for only fluctuations of climatic parameters. Increase of winter temperature can reduce the environmental suitability for wheat, potato and other temperate crops grown in winter season (October-March). Natural disaster, salinity and sedimentation are the major causes of deforestation and forest degradation in *'Sunderban'* mangrove forest. Forest degradation directly leads to lower rainfall and higher temperatures. To mitigate the prevailing climate change situation, it is necessary to develop and use of drought, salinity and flood tolerant crop varieties. Integrated soil fertility management, efficient irrigation system, diversified crops cultivation and trees plantation practices are needed to minimize the losses due to disasters. Some agronomic practices, mechanical measures, afforestation programs, laws and the policies can minimize the adverse effect of climate change. Vulnerabilities assessment, disaster management, enhanced structure design, institutional reform and anti extreme climate engineering are some feasible adaptation policies in Bangladesh. The Government of Bangladesh has taken necessary steps and attached special importance to its protection and improvement due to adverse impacts.

Keywords: Climate Change, Disasters, Climatic Factors, Agriculture, Forest, Bangladesh

INTRODUCTION

The international community recognizes that Bangladesh ranks high in the list of most vulnerable countries (Climate Change Cell, 2008). Global climate has been changing due to natural forcing as well as anthropogenic activities, especially emissions of greenhouse gases and land use changes in recent decades. Climatic factors such as temperature, rainfall, atmospheric carbon dioxide, solar radiation etc. are closely linked with agriculture production. Rice production would be major concern in recent years due to changing climatic conditions, because there is a significant amount of rice yield may hamper for only fluctuations of those climatic parameters (Basak, 2010). Ecosystem loss and degradation are major causes of the greenhouse gas emissions that cause climate change. Despite a large global conservation effort, biodiversity decline is increasing (Butchart *et al*., 2010). In recent years, due to global warming, Bangladesh environment is under threat. Besides the frequent disasters like drought, flooding, tornado, cyclone and tidal surge, Bangladesh is also susceptible to sea-level rise and large scale inundation of its low lying land due to global warming (MoEF, 2005). The impact of climate change on agricultural production is global concerns and for that matter Bangladesh, where lives and livelihoods depend mainly on agriculture, is exposed to a great danger. These observations are particularly significant in the context of Bangladesh where agriculture is heavily dependent on temperature and rainfall patterns. Climate is one of the major controlling factors for the well-being of the residents of the world. Global climate has been changing due to natural forcing as well as anthropogenic activities, especially emissions of greenhouse gases and land use changes. These observations are particularly significant in the context of Bangladesh where agriculture is heavily dependent on temperature and rainfall patterns. In view of these changes, it is necessary to regularly and systematically compile, monitor and analyze the relevant climatic parameters for assessing the impacts of climate change (Basak *et al*., 2013) affecting agricultural and forest sectors of Bangladesh. The objective of the review was therefore, to focus the changing trend of climatic factors and their impact on agriculture and forest sector in Bangladesh. The information and the data included in this publication are mostly from the secondary sources and efforts have been made to include the latest data wherever possible.

LOCATION AND CLIMATE OF BANGLADESH

Bangladesh is situated in the north eastern part of South Asia between 20°34' and 26°38' north latitude and between 88°01' and 92°41' east longitude bordered by India and Myanmar. It is located at the apex of the Bay of Bengal with an area of 147, 570 sq. km. The climate of Bangladesh is tropical with a mild winter from October to March, and a hot, humid summer from March to June. The average temperature across the country usually ranges between 11°C and 29°C in winter months and between 21°C and 34°C during summer months. Annual rainfall varies from 160 cm to 200 cm in the west, 200 cm to 400 cm in the southeast and 250 cm to 400 cm in the northeast (Rashid, 1991). It is noted that the mean annual temperature in Bangladesh is about 26°C, mean annual rainfall is 254 cm and maximum summer temperatures varies between 38°C and 41°C (BBS, 2009).

TEMPERATURE AND RAINFALL PATTERN IN BANGLADESH

North-Western Region of Bangladesh comprises the area of Bogra, Joypurhat, Dinajpur, Thakurgaon, Panchagar, Rajshahi, Noagaon, Natore, Nawabgonj, Rangpur, Gaibandha, Kurigram, Nilphamari and Lalmonirhat districts. In this region, the production increase with time, the rainfall shows decline trend while the temperature shows a prominent trend to production (Zakaria *et al*., 2014). The trend (1976–2008) of variation of yearly average maximum temperature was found increasing at a rate of 0.0186°C per year, whereas the rate was 0.0152°C per year for yearly average minimum temperature. Analysis of monthly average maximum temperature also showed increasing trend for all months except January and April. The increasing trend was particularly significant for May to September and February. Monthly average minimum temperature data also showed increasing trend for all months except January and November. Analysis of rainfall data showed that for a large majority of stations, the total rainfall showed increasing trend for monsoon and post-monsoon seasons, while decreasing trend was observed for the winter; pre-monsoon rainfall did not show any significant change (Basak *et al*., 2013). Monthly maximum temperature shows a positive trend of increase at a rate of 0.5°C per 100 year. The maximum increase occurred during November at a rate of 2.05°C per 100 year. However, monthly minimum temperature shows more statistically significant trend of increase at a rate of 1.40°C per 100 year. The maximum increase occurred during February at a rate of 2.73°C per 100 year. Monthly mean temperature shows a positive trend of increase at a rate of 0.8°C per 100 year. It was found that monthly minimum temperature increased significantly during the winter season (October to February) over the last sixty-three years. This also reveals that temperature has been increasing predominantly over the last 21 years (1990–2010) than last 63 years (1948–2010) (Hasan and Rahman, 2013). The yearly total rainfall trend of seven stations covering 2002–2011 did not show any linear increase or decrease. The yearly total amount of rainfall widely varies over the seven stations of the country. Comparatively lower amount of rainfall occurred in the west-central part and higher amount was occurred in northeast & southeast part. Increasing trend was observed from west to east part of the country. Considering the rainfall data of 2002–2013 years, highest yearly rainfall occurred in Sylhet region in 2002, 2003, 2004, 2005, 2006, 2008, 2010, 2011 and Chittagong region in 2007, 2009 and 2011. Lowest amount of rainfall was observed in all the years (2002–2011) except 2006 at Rajshahi station (Figure 1). Some earlier studies have shown that the rainfall of Bangladesh have been increasing during the recent decades (Choudhury *et al*., 2003; Karmakar and Shrestha, 2000). The monthly total country average rainfall was highest in July followed by June, August and September and lowest in January followed by December and February. The highest rainfall occurs in monsoon season (June-September) and lowest rainfall in winter season (December-February). Summer monsoon rainfall widely varies over different parts of the country (Hossain, 2014). The overall evidence does not suggest any changing pattern of monsoon rainfall within Bang ladesh (Rahman *et al*., 1997). A number of reports revealed that rainfall patterns have already changed across Bangladesh (Ahmed and Hussain, 2009; Selvaraju, *et al*., 2006). While the total annual rainfall of the country has largely remained unchanged (Choudhury *et al*., 2003; Rahman *et al*., 1997; Mondal and Hossain, 2009). The northwestern part of Bangladesh is prone to drought mainly because of rainfall variability in the pre-monsoon and the post-monsoon periods. Inadequate pre-monsoon showers, a delay in the onset of the rainy season or an early departure of the monsoon may create drought conditions in Bangladesh (MoEF, 2005).

CLIMATE CHANGE AND AGRICULTURE

The amount of rainfall received over an area is an important factor in assessing availability of water to meet various demands for agriculture. The distribution of rainfall in time and space is, therefore, an important factor for the economic development of a country (Hasan *et al*., 2012). The precipitation patterns are of great importance for an agro-based economy of country, like Bangladesh. Variations in rainfall pattern over the growing period affect rice yield and water requirement. Increasing temperatures have been found to reduce the duration of physiological maturity of the rice varieties (Basak *et al*., 2013). In North-Eastern regions *Aman* rice (June-November) production is proportional to rainfall and maximum temperature does not prominently vary which indicate that the rainfall effects the rice production prominently. In the South-Eastern region rainfall and maximum temperature both are in repetitive and show less effect on production which indicates other variables are prominent in this region. In North-Western region *Aman* production increased though rainfall decreased so significantly also average maximum temperature was high in this region. It implies that maximum temperature is the dominant factor in this region which increases the *Aman* rice production significantly. So, effect of maximum temperature becoming the dominant variable continuously for *Aman* rice production in the last decade of Bangladesh (Zakaria *et al*., 2014). Increase of winter temperature can reduce the environmental suitability for wheat, potato and other temperate crops grown in *rabi* season (October-March). The trend of daily minimum temperature is higher in north and central parts of the country. During the winter and pre-monsoon season (March-May) wheat and *Boro* rice

(December-April) mainly grow in the north and central parts of the country. Therefore, changes of climate will severely decline growth of various winter crops in the north and central parts of the country (Islam, 2009). A certain amount of *Boro* rice production varied at different locations in Bangladesh for different climatic conditions and hydrological properties of soil. Comparing the simulation results of rice production on location-wise, it is clear that Rajshahi is the most vulnerable rice-growing region where climatic parameters play the dominant factors and significant fluctuation of day and night temperature in winter season in Bangladesh (Basak, 2010).

CLIMATE CHANGE AND FOREST

The Hill Forest mainly situated in the districts of Chittagong, Cox's Bazar, Rangamati, Khagrachari, Bandarban and Sylhet. The area of the Hill Forest is 4.54% of total area of Bangladesh. 'Sundarban' is the world's largest contiguous natural mangrove forest in Bangladesh covers an area of 4.07% of total area of Bangladesh. The 'Sundarban' has been declared as 'World Heritage site' by the UNESCO in 1997. The plain land '*Sal*' forest is situated mainly in the district of Gazipur, Tangail, Mymensingh, Sherpur, Jamalpur, Netrokona, Naoga, Rangpur, Dinajpur and Panchagar. The total area of Sal Forest is 0.81% of total area of Bangladesh. Poverty, profit-making, forest management, natural disaster, salinity and sedimentation are the major causes of deforestation and forest degradation in 'Sunderban' mangrove forest area (Ahmed, 2008). Forest is a very important renewable resource in Bangladesh accounting 17.37% of the total area. Natural calamities, such as floods, tropical cyclones, tornadoes, and tidal bores occur almost every year, combined with the effects of deforestation, soil degradation and erosion. Land degradation is a common problem in Bangladesh. The country is losing a significant level of her remaining forest and agricultural land areas annually. Land degradation means loss in the capacity of a given land to support growth of useful plants on a sustained basis (Singh, 1994). Ecosystem loss and degradation are major causes of the greenhouse gas emissions that cause climate change. Despite a large global conservation effort, biodiversity decline is increasing (Butchart *et al*., 2010) and losses are also recorded in protected areas (Craigie *et al*., 2010). It provides materials like timber, pulp, pole, fuel wood, food and medicine, habitat for wildlife and primary base for biodiversity. The forest sector with its increasing trends towards deforestation will have significant impacts on agriculture, urban settlement, water level and coastal areas (Islam, 2005). Forest provides important ecosystem services in the region. Over one million people directly or indirectly depend on the forest for their livelihood and the forest contributes great amount of Gross Domestic Product (GDP) in Bangladesh (Giri *et al*. 2008). It provides important ecosystem services in the region as well as protects coastal people from many natural disasters. Mangrove forests are believed to be the shield of the coasts as all the natural storms originated from the Bay of Bengal first hit the mangrove forest. All the cyclones those have hit Khulna coast caused a devastating damage to the ‘Sundarbans’ mangrove forest. Cyclonic storms in 1991 and SIDR in 2007 caused a great damage to flora and fauna of the ‘Sundarbans’ (Ahmed, 2008). All the cyclones first hit the coastal areas cause a devastating damage to the mangrove forest. Having no alternative to fuel other than natural vegetation and gradual increase of fuel demand and economic depression of the region accelerated rapid destruction of forests or plants, which resulted environmental imbalance in nature. Less rainfall than needed created havoc of drought year after year and rapid destruction of forest brought inevitable consequence of desertification. Like other tropical forests, the forests of Bangladesh are brimming with life. However, the human activities are increasingly in conflicts with the forest existence. As a results the forests area of Bangladesh are decreasing day by day. Forest degradation directly leads to lower rainfall and higher temperatures. Forest degradation and deforestation are closely related to each other. The occurrence of deforestation is widespread and serious in Bangladesh. Annual deforestation is about 0.3 million ha and the country is losing about 3% of her remaining forest areas annually (Ahmed, 2008). Climate change will change rainfall patterns. In many regions groundwater recharge will be affected. Deforestation and the degradation of forestry systems will increase the vulnerability of the water sector. On the other hand, reduced water supplies will affect forest ecosystems. Temperature increase may lead to an increased photosynthetic activity of plants. It will also cause high level of transpiration, leading to additional water loss. The impact of increased concentration of carbon dioxide in the atmosphere depends on the plant species and the surrounding ecosystem. Increased CO_2 concentration in the atmosphere has often a fertilizing effect of stimulating photosynthetic activity. High CO_2 concentrations can also increase the water efficiency of plants. On the negative side, CO_2 concentrations may affect the plant tissue with potential detrimental effects on the metabolism of the affected plants (IPPC, 2000).

MITIGATION OF CLIMATE CHANGE

To mitigate the prevailing climate change situation, development and use of drought, salinity and flood tolerant crop varieties with proper management practices is an urge now. Cultivation of diversified crops in the same field with crop rotation schedule should be practiced. Make the River bank stabilization and shelterbelt in coastal area against flash flood erosion. The Government of Bangladesh has promulgated the National Forest Policy and approved the Forestry Sector Master plan with the emphasized of the afforestation programme through co-ordinate efforts of GO-NGOs and active participation of the people. Bangladesh should also prepare adaptation policies to minimize the adverse effects of climate change. Vulnerabilities assessment, disaster management, enhanced structure design, institutional reform and anti extreme climate engineering are some feasible adaptation policies in Bangladesh due to increasing temperature (Hasan and Rahman, 2013).

CONCLUSION

Agriculture and forest are always vulnerable to unfavorable climatic conditions. It is clear that monthly minimum temperature has been increased significantly during the winter season (October to February) than that of summer season (June to August) and increase predominantly over the last 20–30 years. Several studies indicated that climate is changing and becoming more unpredictable every year in Bangladesh. Hazards like floods, droughts, cyclones and salinity intrusion are likely to be aggravated by climate change and sea level rise. Problem like flood and water logging in the central region, flash-flood in the northeast region, drought in the northwest and southwest region and salinity intrusion and inundation in the coastal region would be more acute in future in Bangladesh. Crops and land are affected by climate change in different ways. Therefore, changes of climate will severely decline grown of various crops in the north and central parts of the country. In view of the various adverse impacts on environment, the Government of Bangladesh has attached special importance to its protection and improvement. In general, awareness and the environmental law involve conservation of natural resources for their better use by the present and the future generations.

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Natural Resource Management: Ecological Perspectives

A.K. Dhawan, S.K. Chauhan, S.K. Bal and S.S. Walia

Indian Ecological Society, Punjab Agricultural University,
Ludhiana–141004, India
E-mail: indianecologicalsociety@gmail.com

Natural Resources Management (NRM) refers to the sustainable utilization of major natural resources, such as land, water, air, minerals, forests, fisheries, and wild flora and fauna. NRM should contribute to poverty alleviation, and that natural resources should be used in a sustainable manner to enhance human welfare. Without poverty alleviation, the environment in developing countries will continue to degrade, and without better NRM, poverty alleviation will be undermined. Ecological processes maintain soil productivity, nutrient recycling, the cleansing of air and water, and climatic cycles. Soils are the foundation of agriculture, which in turn is the basic building block in the livelihoods of all people. At the genetic level, diversity found in natural life-forms supports the breeding programs necessary to protect and improve cultivated plants and domesticated animals. The natural resource foundation is coming under increasing pressure from both increasing population and higher levels of per capita economic activity. During the period 1990 to 2030 the world's population is likely to grow by 3.7 billion. This will often entail an accelerated use of natural resources, both as inputs to the economy, and as recipients of waste. However, the relationship between economic growth and environmental stress is not a linear one, as growth also generates resources to better manage natural resources.

Since independence India has made commendable progress in agriculture besides providing food security, it has also transformed in raising the standard of living of large section of the urban and rural population. The gains in food grain production during pre/post green revolution phases is attributed to the improved high yield of crop varieties and optimum use of production inputs of which water and nutrients constitute key components. The best lessons of green revolution in India can be had from its states like Punjab, Haryana, Uttar Pradesh, Tamil Nadu and Andhra Pradesh. In view, the high growth rate of the population and urge for promotion of export inducted by trade liberalisation in India. There is a strong need to continue to maintain high growth rate in agriculture. However, the increase in agricultural productivity has come at the expense of deterioration in the natural resource base on which farming systems depend and that this trend needs to be reversed by encouraging farmers to adopt sustainable methods of farming that will have long-term benefits in environmental conservation and sustaining livelihoods security (Abrol and Sangar, 2006). The sustainable natural resource management is critical in reducing poverty. If productive capacity continues to erode, then the potential to satisfy future food needs will be seriously compromised. The poorest people will suffer the most, through increased food costs and greater vulnerability to their livelihood. Further, increased agricultural production and productivity and enhanced farmers' incomes provide more resources in the long run for addressing environmental problems. Improvements in natural resources facilitate farmers' transition to production systems that are better matched to the available natural and human resources, can respond to market signals, and are more profitable, stable, and sustainable one. Good natural resource management also expands income and employment opportunities throughout the wider community—for instance, through eco/agrotourism or through agro-forestry production that attracts downstream processing industries.

Food demand and dietary pattern are influenced by several factors such as population, per capita income, consumer preferences and level of urbanization. Prices are other important factor affecting demand. According to a survey by NSSO on Consumer Expenditure, the total demand for cereals in the country may reach 262 million tonnes by 2020-21. Demand for pulses would grow between 16 and 19 million tonnes. Demand for milk and milk products is projected to increase to 142 million tonnes by 2020-21. Total consumption of eggs in India is expected to increase to more than 81 billion during the next 16 years. Projection of demand for other commodities for the year 2020-21 are 10.9 million tonnes of meat, 11 million tonnes of fish, 54 million tonnes of oilseeds, 127 million tonnes of vegetables, 86 million tonnes of fresh fruits and 345 million tonnes of sugarcane.

Over the years, the composition of agricultural trade has also changed significantly. The share of fruits and vegetables, flowers, cotton, sugar and molasses, and livestock products have considerably increased in the agricultural export basket of India. Rice, both basmati and non-basmati, oilmeals, fruits and vegetables, spices, cotton, sugar and molasses, livestock, and marine products are the major items of agricultural exports of India. Among these, the exports of non-basmati rice, fruits and vegetables, sugar and molasses, raw-cotton, and livestock products have registered a growth of more than 10%, per annum in real terms, which is really noteworthy. The share of agricultural exports in the total national exports is around 10%, about one percent of the global agricultural trade. The wide range of agro-climatic conditions in our country and rich floral and faunal diversity, need to be harnessed for diversifying the crop cultivation in different regions and to meet the demands of the international market. The strengthening of horticulture sector needs to be given priority attention.

Sustainable natural resource management is important to agricultural development as a basis for:

General Agricultural Productivity: The agriculture is the major user of most available land and water resources. However, many farmers lack essential knowledge, resources, and technical know how to manage intensive farming operations. So, this leads to the use of inappropriate technologies and unsustainable practices will result in depletion of natural resources and environmental pollution.

Off-farm Agricultural Uses: Many agricultural systems rely on "off-farm" natural resources, such as livestock grazing on roadsides and woodlots. Forests provide building materials for farms and homes.

Non-farm Employment: Natural resources provide off-farm income through employment in industries (such as fishing, timber extraction, and tourism) and through other uses, such as power generation. This income generated may be used for the purchase of production inputs to maintain the productivity of the farming system.

Risk and Vulnerability Reduction: Sustainable natural resource management reduces the vulnerability of both farm and urban communities to natural resource disasters, such as droughts, landslides, and floods and to the loss of biodiversity from overgrazing and deforestation. A healthy resource base helps to mitigate vulnerability for climate variability and reduces risks of failed harvests.

Pollution Reduction: Pollution from agricultural production and processing can have major impacts on "off-site" natural resource quality. Water pollution from agricultural chemicals and livestock manures is a potential health hazard; irrigation can cause salinity problems; and the burning of crop residues may affect air quality and human health.

Environmental Services: Improved natural resource management provides extensive downstream benefits in the form of "environmental services" such as hydrologic function, sediment control, nurseries for fisheries, and biodiversity conservation. Environmental resources contribute to the health of the global ecosystem, because wild races of the major food crops and semi domesticated crops, located in forest reserves and natural ecosystems, are important sources of genes for crop improvement programs, and semi domesticated crops represent new market opportunities. Maintaining tree cover and following appropriate hillside grazing and crop cultivation practices will preserve soil and water resources and enhance the hydrologic functions of watershed areas. Coastal zone protection, mangrove and wetlands preservation, and border areas of parks and protected areas are important for the maintenance of environmental services.

Cultural Integrity: Indigenous cultures use land and other natural resources in unique ways which often help to define national identities, even in industrial countries. Indigenous technical knowledge coupled with scientific research provides significant scope for management innovations to conserve natural resources and develop new marketable products (for example, nutraceuticals).

Biodiversity: Biodiversity can be represented as having two broad dimensions: wild biodiversity, and agricultural biodiversity. The former represents the biodiversity that is present in natural, uncultivated ecosystems (e.g. forests), while the later involves biodiversity that is used within agriculture. There is a lot of interaction across the two domains. The biodiversity operates at three different levels. Intra-specific diversity refers to the diversity at genetic level within species; inter-specific diversity refers to the diversity between or among species; diversity on ecosystem basis. It is estimated that over the next 25 years, Asia will lose a higher proportion of species and natural ecosystems than any other region of the world. With respect to biodiversity, it is estimated that over the next 25 years, Asia will lose a higher proportion of species and natural ecosystems than any other region of the world.

One of the principal components of natural resources within agricultural systems is the biodiversity that is available within agriculture. Agricultural biodiversity, comprises all the elements, from genes to agricultural ecosystems, that are used in food production. The importance of maintaining this diversity and the balance among its various components lies in the benefits that accrue to users in terms of agricultural productivity, food security, socioeconomic and nutritional value and environmental sustainability. Biodiversity is a unique asset to rural communities. Many herbs are used for medicinal purposes; plant extracts can be used as biopesticides; roots and tuber crops contain novel carbohydrates for use as functional food ingredients; and many woody species produce polymers of interest to industry. Indigenous ethnic groups and rural women have extensive knowledge and management skills relating to plant and animal biodiversity.

CLIMATE CHANGE

Food security in India has become a challenge determined by climate and non-climate induced stressors which operate independently or in combinations. In recent years, climatic change/variability is the biggest challenging factor that affects various ecosystems in India and elsewhere and concern has been expressed by world community regarding its potential effects on agricultural productivity. In addition, the climate change induced other abiotic and environmental stresses cause negative impact across sectors of agriculture with non-optimal environmental factors those may act independently or in multiples. The overall state of the global climate is determined by the amount of energy stored by the climate system, and in particular the balance between energy the Earth receives from the Sun and the energy which the Earth releases back to space, called the global energy balance. How this energy balance is regulated depends upon the flows of energy within the global climate system. Major causes of climate change involve any process that can alter the global energy balance and the energy flows within the climate system. Climate change is expected to influence crop production, hydrologic balances, input supplies and other components of agricultural systems. Expanding urban agglomerations and industrialization are further contaminating water and land with organic pollutants and heavy metals. Likewise increasing CO_2 and other green house gases are increasing ambient temperature and UV radiation, which not only threaten crops, livestock but also the human beings. Only 9% of the world area is conducive for crop production, while 91% is afflicted by various stressors. As per the current estimates (ICAR, 2010), 120.8 million ha constituting 36.5 per cent of geographical area in India are degraded due to soil erosion, shallow soil, salinity/ alkalinity, soil acidity, water logging and other edaphic problems.

The basic principle of crop production lies with how vegetation interacts with atmosphere and soil as a growing medium. The system acts as a SPAC (Soil-Plant-Atmosphere Continuum), the main path-way which regulates the intake of water, nutrients and gas exchanges. Thus any change in the quality and quantity of atmospheric variables will certainly affect the SPAC through changes in atmospheric and edaphic factors. Besides these, climate change is also adding salt to the wound by aggravating the extreme weather events. The volume of loss of crop produce due to extreme weather events will be more as compared to global warming effects (IPCC, 2013). In quantitative and qualitative terms, effect of aberrant changes in atmospheric variables on agriculture can be conjectured and most of them are estimated to be negative.

WATER SCARCITY

Water is one of the most important natural resources, and is becoming an increasingly scarce commodity in many parts of the world. According to predictions, around 50 countries, affecting some 3 billion people will experience water stress by 2025. Fresh water resources are a critical input for agriculture as well as many other economic activities. With 60% of the irrigated farming relying on ground water, India has become the largest ground water based food growing country in the world. However, with overexploitation of ground water resources, water scarcity is one of the major challenges, threatening livelihoods of people and environment. Unfavourable climatic factors such as erratic rainfall, higher evaporative demand, and several droughts, among others, contribute to the increasing water scarcity. Therefore, our concerns for future trends and scenarios should centre on enhanced water productivity, sustainability of irrigated ecosystems, livelihood. Similarly about 58% of the net sown area in India continues to be rainfed that contributes 40% of the food grain production and supports two-thirds of livestock population. However, the average productivity of the rainfed areas continues to stagnate around 1.1 t ha^{-1} against 4.5 t ha^{-1} from irrigated areas where the food production is severely affected by frequent droughts that continue to be a recurring problem for these areas and are expected to increase under the climate change scenario. Though technologies have been put forth for drought proofing with best compatible cropping patterns and soil and water conservation techniques, yet the large yield gaps continue to exist.

India is in the midst of regular drought in the states of Rajasthan, Gujarat, Karnatake, Andhra Pradesh, Maharashtra, Odisha and many more. The phenomenon like delayed monsoon, monsoon break, unusual distribution has become a common phenomenon in the recent years (Rajeevan *et al.,* 2008). Three-quarters of India's annual rainfall comes from the summer monsoons that occur between June and September. Once the rains begin, India's farmers sow their summer crops, both in irrigated and rainfed area. The best signal till date that monsoon rains might be particularly weak during a given year, may be linked to warm sea surface temperatures related to an El Niño in the Pacific Ocean. With climate change, wetter regions may get wetter; dry ones may become drier and with the monsoon season, some rainfall may be distributed less evenly. We may see larger extremes, more intensity.

ATMOSPHERIC STRESSES

One of the pre-eminent and incontrovertible manifestations of the global climate change is the increase of greenhouse gases (GHGs) in the earth's atmosphere. During ice ages, CO_2 levels were around 200 parts per million (ppm) and in 2013, CO_2 levels surpassed 400 ppm for the first time in recorded history. If fossil-fuel burning and other human interventions continue at a business-as-usual rate CO_2 will continue to rise to levels of order of 1500 ppm (Dlugokencky *et al.,* 2014; NOAA, 2014). Increased concentration of GHGs' in the earth's atmosphere are influencing the natural carbon balance of terrestrial ecosystems, leading to an increase in the average temperature of the earth's surface.

The annual global combined land and ocean surface temperature is 0.62°C above the 20^{th} century average of 13.9°C. This marks the 37^{th} consecutive year (since 1976) that the yearly global temperature was above average (NOAA, 2015). The globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85°C over the period 1880 to 2012. With increase in ambient temperature, the evaporative demand of the atmosphere will increase and rate of evaporation and soil water depletion will increase (IPCC, 2013). Higher temperatures reduce net carbon gain by increasing plant respiration more than photosynthesis. The predicted increase in average global temperature will accelerate crop development rates, and the negative effect tend to be larger for grain yield than for total biomass. This temperature rise will shift the agro-ecological zones northward along with aggravating complexities including pest and weed infestation. Increasing temperatures, holding other factors constant, decreases crop yields while increases in precipitation lessen or offset this result. There are likely to be regional winners and losers from climate change, given that the potential for net reductions in crop yields is greatest in warmer, low latitude areas and semi-arid areas of the world. Whereas, it is expected that global warming may increase the amount of arable land in high-latitude region by reduction of the amount of frozen lands. However, reports about the impact of global warming on higher latitude agriculture indicate conflicting probable effects: the benefit of northward extension of farmable lands may be compensated with the possible productivity losses due to increased risk of drought (Fisher *et al.,* 2007). Sites which are already at the limit with respect to water supply under current conditions are likely to be most sensitive to climate change, leading to an increase in the need for irrigation in dry areas, while more humid areas may be less affected. This negative effect of climate warming may be counteracted by effects of elevated CO_2 on the crop tolerance to water stress.

EXTREME WEATHER EVENTS

Extreme weather events are part of a new pattern of more extreme weather across the globe, shaped in part by human-induced climate change which cause a great damage to standing crops even though these occur for a very short duration. As the climate has warmed, some types of extreme weather have become more frequent and severe in recent decades, with increases in extreme heat, severe storms, intense precipitation, drought and hailstorm. Heat waves are longer and hotter. It is likely that human influence has more than doubled the probability of occurrence of heat waves in some locations. Food crops are highly sensitive to heat. Extreme heat exposure will undoubtedly lead to crop losses in India. Heavy rains and flooding are more frequent. In a wide swing between extremes, drought, too, is more intense and more widespread. Recent detection of increasing trends in extreme precipitation and discharge in some catchments implies greater risks of flooding at regional scale (IPCC, 2013). There are likely more land regions where the number of heavy precipitation events has increased than where it has decreased. The warmer atmospheric temperatures observed over the past decades are expected to lead to a more vigorous hydrological cycle, including more extreme rainfall events (Joshi and Rajeevan, 2006). This increase in precipitation intensity would probably result in greater risks of erosion and soil degradation, whilst at the same time providing soil with better hydration, according to the intensity of the rain. Besides these hailstorm has widened its horizon. These events have sparked popular interest in understanding the role of global warming in driving extreme weather. The recent trails of unusually widespread and untimely hailstorm events in India during 2014 and 2015 took everyone by surprise as the phenomenon, direction, locale and the coverage was hitherto unnoticed (Bal *et al.,* 2014).

DEGRADED LAND AND EDAPHIC STRESSES

Though Indian agriculture has registered a phenomenal growth during the past four decades with the overall result that the fruit production has now overtaken the total food production, country is still facing the challenge of meeting fruit demands of the ever increasing population amidst abiotic and biotic constraints. The emerging nutrient deficiencies along with acidity, salinity and pollutants are the most common chemical stresses. Among the physical stresses, severe soil erosivity, shallow soil, soil hardening and low water holding capacity continue to threaten the soil productivity. Latter specifically holds for the most fruit contributing states of Maharashtra and Andhra Pradesh where about 40% of the soils are shallow basaltic/red soils and those are mainly used for rainfed farming since only about one-fifth area is under irrigation. Though unfit for deeper rooted fruit trees since the hard mineral matter provide absolute barriers for root growth and water percolation but with the zeal to get higher economic gains, farmers are increasingly resorting to the orchards under such hostile environment. Nevertheless, the productivity potential of shallow soils continues to be low and these are often frequented by droughts during which a large scale damage even mortality of horticulture orchards is visualized. In addition to this, the climate change induced rainfall aberrations resulting in decrease the number of rainy days and increase in the frequency of high intensity rainfall have started showing immediate impacts on fruit productivity and shallow soils continue to be the most vulnerable. Heavy precipitation leads to erosion of the top surface soil layers that contain the majority of soil organic matter, soil organisms as well as nutrients. The loss of these components will reduce the nutrient availability to the plants/crops. In case of shallow soils, the chances of permanent loss of the few inches of top soil available will worsen the situation.

Economic and Environmental Viability of Short Rotation Forestry

The survival and well being of a nation depends upon sustainable development. It is a process of social and economic betterment that satisfies the present need and value of all interest groups without foreclosing the future options. The present forest resources with growing stock about 5658 million cubic meter (54cum ha^{-1}) with an average annual increment of growing stock as 80.9 million cubic meter cannot meet the much needed demands of fuel wood, timber and raw material to industries and domestic use in large quantities under inflating population pressure (Anon., 2013). The National Forest Policy 1988 has many restrictions on forest tree feelings, which have been reinforced by the Honourable Supreme Court for ban on green felling to preserve the green wealth.

Number of initiatives have been taken (Green Indian Mission, Agroforestry Policy, Biofuel policy, Agroforestry and Bamboo Mission, etc.) to reduce pressure on the traditional forest area, enhance growing stock level and forest productivity. Nation commits to creation of additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030. Therefore, more attention on production forestry, which involves raising plantations of fast growing species under short rotation intensive management would not only benefit to bridge the gap between demand and supply but save he deteriorating environment as well. There are number of potential fast growing tree genera (mostly exotics) like *Populus, Eucalyptus, Leucaena, Salix, Robinia, Cryptomeria, Sesbania, Prosopis, Bamboo, Paulownia, Ailanthus, Melia, Anthocephalus, Acrocarpus, Chukresia, Casuarina, Acacia, Gmelina*, etc., which can be exploited under short rotation forestry (Chauhan *et al.*, 2008). Since short rotation forestry is in juvenile phase, comparatively, very little work has been done in this regard. Their suitability under stress and adverse conditions (water logged, drought, salinity, acidity, climate vagaries, etc.) is added advantages with sustainable economic viability. Short rotation forestry ensures protection and improvement in the environment and safeguard the forests and wildlife of the country by meeting requirements outside traditional forests.

Investment in tree plantations always remained relatively low in India, inspite of the fact that the existing forests cannot continue to meet our wood requirements and tree farming is ecologically as well as economically more viable than traditional agriculture. However, realizing the existing problem, the expenditure on afforestation has been increased enormously from fifth five year plan onwards but still the results on the land are not encouraging and we have not been able to increase forest cover as well as the productivity. The misery caused to the entire nation due to this unprecedented eco-degradation is enormous and warrants immediate remedial measures. To counteract this impending crisis, use of fast growing tree species managed with intensive cultural operations especially in tree farming have opened new vistas in wood biomass production. The short rotation forestry has attained a success and many private concerns have initiated plantation activities. *Populus deltoides, Eucalyptus tereticornis, Acacia mangium*, *Ceiba pentendra, Gmelina arborea*, *Leucaena leucocephala,* etc. have been exploited by the private companies in the country because of their fast growth. Private companies have been offering spectacular returns through investment in teak plantation programme. With the view to improve the productivity and profitability of plantations and making farm forestry an attractive landuse option, focus on genetic improvement of planting stock and improvement of practices in silviculture are required. Major gain in plantation productivity can be achieved within a short span through the application of vegetative and cloning techniques for gainful exploitation of the existing useful variations. The productivity of the hybrid clones of *Eucalyptus grandis* x *Eucalyptus urophylla* in Brazil have been reported around 55 m^3 ha^{-1} yr^{-1} and some others clones under ideal site conditions with intensive management practices have recorded extremely high productivity of 100 m^3 ha^{-1} yr^{-1} ((Bertolucci *et al*., 1995). Productivity of *Eucalyptus* clones and poplar plantations have achieved record productivity in north-western states exceeding 50 m^3 ha^{-1} yr^{-1} compared to less than 1 m^3 ha^{-1} yr^{-1} of Indian Forests (Lal, 2001). Clonal plantations of jortor (*Casuarina equisetifolia*) in southern states, coastal areas and salt affected soils have repeated the success story of eucalypts clones. The three year old *Eucalyptus tereticornis* and *Casuarina equisetifolia* under high density of 40, 000 plants ha^{-1} produced nearly ten times more volume than the conventional density of 2, 500 plants ha^{-1}. Short rotation clonal plantations on 20 mha degraded lands can meet country's current wood energy requirement of approximately 250 million tonnes per year.

Biomass Energy: The majority of world's energy need is supplied through finite source and at the current rate of usage, will exhaust at the short time from now. The fossil fuel use has created an alarming situation of change in climate affecting each and every living being on the earth. Global efforts are going on to save the ecosystem from global warming, and use of renewable resources is an important strategy to mitigate the changing climate. Additionally, the rising cost of fuel oil compelled to search for the alternative fuels. India is mainly dependent on the import, which regulates the price index of commodities including food items. Renewable resources more specifically the biomass has gained importance in the developed world, and developing world including India is also catching the attention on biomass use for energy, which can be used as feedstock for the production of bioenergy/ biofuel, organic acid, animal feed, etc.

Much emphasis has been given on production of ethanol form the agricultural or forestry lingo-cellulosic material but actions in the developing world are bit slow, probably due to low availability of biomass and proper technology for the purpose. There is need to explore the possibility of using the trees outside forests, which are fast growing and catching attention of the farmers to enhance their economics but they need to have diversified uses so that the prices may not dip down. Biomass can be derived from the cultivation of dedicated short rotation energy crops but farmers need multiple option for the disposal of their agroforestry produce otherwise they may not be sure of market for their produce. The conversion of biomass encompasses a wide range of different types and sources of biomass, conversion options, end-uses and infrastructure requirements. With appropriate options, it can help in reducing the impact of energy production and abuse of global environment. Since, the energy demands with increase in population and standard of living are increasing, therefore we have to look for better conservation/management strategies and appropriate conversion processes for use in posterity. There is need to accord high priority for introducing fast growing trees and estimating their potential for bio-energy. Approximately 55-60 per cent of the tree biomass is already being used for fuel but value addition in the form of power generation or alcohol extraction will lead to self reliance on energy with enhanced profit for the farmers. Biomass based energy would be a major player (10 GW by 2022 from current capacity of 4.4 GW) in meeting the country's commitment of 175GW renewable energy by 2022 (Anon., 2015).

Carbon Sequestration: It is not only the short fall in productivity but the atmospheric concentration of greenhouse gases, especially carbon dioxide has also raised the threat of rapid increase of global temperature. Various options have emerged for mitigating the problem of increase in CO_2 concentration & threats associated with climate change. The investment in forestry sector to store carbon in trees and forests is one of the viable option for offsetting the gases released by fossil fuel burning and for mitigating the potential effects of global warming. Perennial vegetation, notably forests have an important role to play in regional, national and international green house gas balances. Moreover, under the Kyoto Protocol recognition has been given to this option but at the global level, approximately 14.6 mha actual forest area is cut annually, which is also adding million of tonnes of carbon to the atmosphere along with other sources of pollution every year. Short rotation forestry including agroforestry can act as a good source of carbon sink. The harvest yield in forest trees is vegetative rather than reproductive and most of the biomass consists of carbon compounds. Short rotation forestry is linked to enhanced photosynthetic fixation of CO_2 per unit land area. In addition, the trees compatible with agricultural crops form unique combination for carbon sequestration. The rapid growth of short rotation woody crop results in high rates of nutrient uptake and large amounts of carbon storage over rotation lengths as short as 5 to 15 years. Net carbon benefits are realized if the wood fiber is used for solid wood products. In some regions, agreements are in place that allow nations or corporations to offset their greenhouse gas emissions by buying credits from farmers who increase their stores of carbon in the soil or in trees. Extensive Indian literature is available on positive role of the plantations in carbon storage in the system (Singh *et al.,* 2000; Bhadwal and Singh, 2002; Dabas and Bhatia, 1996; Sathaye *et al.,* 2006; Swamy and Puri, 2005; Kaul *et al.*, 2010; Jha, 2015; Chauhan *et al.,* 2015). The potential market for these carbon credits could be beneficial to tree growers.

Use of sewage and industrial waste: Waste management is another issue of concern and water scarcity is a major issue in many countries. Good Quality water supplies are not sufficient to meet the rising demands from agricultural, domestic use and industry. The urban and industrial waste water is the major cause of river water pollution, ground water contamination, spread of diseases and environmental degradation in the country.

Treatment of such water is costly, requires lot of energy and man power, which is beyond the capacity of municipal corporations/committees. Many a times, this untreated water is used for higher production of vegetable and fodder crops, however, their unrestricted use without proper treatment aggravates the contamination of food chain system and poses serious threat to soil also. Many techniques like waste water treatment plants, oxidation ponds, fish culture, use of blue green algae, water hyacinth, etc. are used to clean polluted water to make it safer for use in agriculture yet most of these methods are costly. But the use of this water in afforestation programme is an effective alternative, where the chances of pollutants to enter into the food chain are minimum or negligible. The nutrient rich irrigation water can be used for afforestation programme on infertile and inhospitable wastelands and the higher transpiration rate of trees can be exploited to get rid of excess water. Wasted lands along the roads, railway tracts, drains, panchyat/village lands, etc. can be profitably used for direct material benefits besides meeting the ameliorative requirements in the urban and sub-urban areas. Developed countries are also effectively making use of this waste water for the plantation programme.

Keeping in view the economic and environmental benefits of afforestation programme, the efforts of the government agencies (research and development) and other voluntary organizations need to be actively supplemented and complimented by the plantation companies/industrial houses. The non-governmental organizations can play a significant role in the gigantic task of rehabilitation of the degraded lands provided the institutional financing and technological inputs are made available to them. Many forest based companies e.g. Western Indian Match Company Ltd (WIMCO), ITC Bhadrachalam Paper Mills Ltd, West-Coast Paper Mill Ltd, Ballarpur Industries Ltd, TFT New Delhi, etc. have entered into arrangement with farmers to meet their raw material requirements by providing financial and technical assistance for initiating and maintaining plantations on private lands. Use of short rotation intensively managed forestry can be a major help to country striving for more favourable balance of timber trade. No effort could be to large if the national self sufficiency in wood production and environmental stability is achieved in near future through intensive forest farming. It is important to pursue initiatives to promote plantations outside forests but we must not neglect our efforts to conserve, manage and sustainable develop the natural forests.

CONCLUSION

Population pressure forces the people to move into the fragile ecosystems where they destroy the natural resources with disastrous consequences. The biggest challenge today before the production mangers is how to maintain the sustainability in the production system. More than 1.4 billion people worldwide live in poverty with a malnutrition rate higher than 31% and over 340 million people live on less than US $1 per day. The growing human population and its increasing use and misuse of resources is exerting enormous pressure on the "Earth's Life Support Capacity". Every-one including citizens, policy makers, resource managers, leaders of business and industry make decisions related to earth's resources, but such decisions cannot be made effectively without fundamental understanding of the effects of our activities on the Earth's biosphere. We have been interfering with nature since the dawn of civilization. In the name of progress, land has been denuded, water resources poisoned with hazardous chemicals and air polluted with noxious gases resulting in changing ecology. However, the nature retaliates and gives warning signals in the form of drought, floods, changing temperature, earth quake, diseases, etc. The global warming has put the survival of man in danger and pollution has made the air, water and food unfit for human consumption. Protection of land resources and environment is an important agenda for the man today, lest it might become too late. The Indian agriculture will experience lots of ups and downs in the coming years due to natural resource depletion and changing climate events. Farming has to be better adapted to cope with the direct and indirect consequences of these biotic and abiotic stresses. Working Group on Natural Resource Management and Rainfed Farming has strongly emphasized that sustainable and inclusive growth is not possible unless the processes contributing to resource degradation and vulnerability of rainfed agriculture and production systems are squarely addressed and reversed (Anon., 2011). This however, holds good in other ecosystems as well. This paper highlights natural resource depletion and its impact on biology of terrestrial system more importantly agriculture and on-farm forestry.

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Agronomic Management Interventions for Climate Resilient Agriculture

S.K. Pathak, Seema, S.R. Choudhury* and S. Sheraz Mahdi
Department of Agronomy, BAU, Sabour–813210, Bhagalpur, Bihar
*E-mail: *matan.roychoudhury@gmail.com*

Abstract—The changing climatic conditions are expected to increase the atmospheric CO_2 concentration, temperatures and alter the precipitation pattern. Atmospheric CO_2 concentration is predicted to reach 550 ppm by 2050, and probably exceed 700 ppm by the end of this century. These changes are anticipated to affect the production and productivity of agricultural crops and influence the future food security. The impact analysis of climate change on global food production discloses a 0.5% decline by 2020 and 2.3% by 2050. Climate change projections made for India indicate an overall increase in temperature by 1–4°C and precipitation by 9–16% towards 2050s. However, different regions are expected to experience differential change in the amount of rainfall in the coming decades. Another significant aspect of climate change is the increased frequency of occurrence of extreme events such as droughts, floods and cyclones. All these expected changes will have adverse impacts on climate-sensitive sectors such as agriculture, forest and coastal ecosystems, availability of water for different sectors and on human health. The development of climate ready germplasm and management practices intervention to offset these losses is of the upmost importance. The paper aims to discuss likely impacts of climate change on some major agricultural crops and agronomic management interventions to combat the effects climate change for better crop production.

INTRODUCTION

In India, the agriculture sector sustains nearly 70% of the population and it is obvious that any short term climate variability/change events would directly affect agriculture and thus impact on local food production and livelihoods. Observed annual temperature time series show an increasing trend over recent decades. Farming communities are already using several coping strategies to manage climate risks. Climate change is expected to bring additional threats of greater magnitude. Climate change projections forecast that mean annual temperatures will increase by an average of 1.2°C by 2030 and 1.7°C by 2050, compared with the pre-2000 baseline. Regional circulation models project even greater increases in mean annual temperatures: 1.4°C by 2030 and 2.8°C by 2060 and both rises and falls in mean annual precipitation rates, with no clear trends (Ramasamy Selvaraju, 2014).

Climate change projections indicate that the main impacts are likely to include significant warming and uneven and erratic distribution of precipitation, leading to increased frequency of extreme weather and climate events, including floods and droughts. It is likely that new areas will be affected by a variety of different climate-induced threats, exacerbating the negative impacts of climate events. Increasingly frequent and intense hydro-meteorological hazards, high dependency on agriculture with few opportunities for diversifying income sources rapid population growth, shrinking farm size and continued unplanned agriculture in areas prone to climate risks are likely to increase the exposure and loss of livelihoods, unless countermeasures are put in place. High exposure and low adaptive capacity pose a major challenge to the agriculture sector, which is expected to suffer livelihood losses and the reduction of crop and livestock production. Climate change is likely to affect agriculture-dependent livelihoods and ultimately food security. Per capita food availability is declining over the years, because the population continues to increase while the performance of the agriculture sector remains almost stagnant.

According to calculations based on models, the likely impacts of climate change on agricultural production include a 17.3 percent drop in production from a temperature increase of 2.5° C, and these figures do not include the additional negative impacts of extreme climate events (Ramasamy Selvaraju, 2014). Observation of the impacts of recent extreme climate events suggest that clear production declines result from even slight changes in temperature and rainfall regimes. Communities adopt various coping mechanisms to deal with the impacts of climate change. In recent years, seasonal and permanent migration has become more common, leading to increased workloads for family members left behind. The fear of losing crops and agricultural livelihood assets to various risks is causing many rural people to shift from on-to off-farm occupations, with repeated crop failure forcing them to sell their land at low prices and divert to small-scale businesses. There is also evidence that the increasing trend in climatic risks is resulting in conflict over resource sharing between indigenous and migrant populations. The coping practices adopted by communities to reduce these impacts are not enough to address the challenges.

Efforts to respond to climate change should build on local perceptions of climate risks and existing coping strategies. A comprehensive approach should be adopted to address current problems through climate risk management in the short to medium term, slowly switching to adaptation interventions in the medium to long term. Resource conservation is pivotal to promote adaptation and resilience in agriculture. Resource conservation practices include rainwater harvesting and soil moisture conservation; improvement of degraded land; protection from riverbank cutting and inundation; slope stabilization and management; conservation of biodiversity and traditional crops; promotion of conservation agriculture in rice–wheat systems, improved crops and cropping systems, multi-storey cropping and agroforestry systems; sustainable use of forest resources through community forest user groups; and alternative energy sources for households. Farmers need to intelligently adapt to the changing climate in order to sustain crop yields and farm income. Enhancing resilience of agriculture to climate risk is of paramount importance for protecting livelihoods of small and marginal farmers. Traditionally, technology transfer in agriculture has aimed at enhancing farm productivity. However, in the context of climate change and variability, farmers need to adapt quickly to enhance their resilience to increasing threats of climatic variability such as droughts, floods and other extreme climatic events. Over the years, an array of practices and technologies has been developed by researchers towards fostering stability in agricultural production against the onslaught of seasonal variations. Adoption of such resilient practices and technologies by farmers appears to be more a necessity than an option. Therefore, a reorientation in technology transfer approach is necessary. Efficiency in resource-use, environmental and social safeguards, sustainability and long-term development of agriculture assume greater importance. Participatory on-farm demonstration of site-specific technologies will go a long way in enabling farmers cope with current climate variability. Such an approach can ensure adaptation gains and immediate benefits to farmers along with possible reduction in GHG emissions and global warming potential of agriculture.

MANAGEMENT INTERVENTIONS

Various adaptation and mitigation strategies including use of climate resilient crops and cultivars for different regions are most essential for agriculture to successfully cope with climate variability. Improved agricultural practices evolved over time for diverse agro-ecological regions in India have potential to enhance climate change adaptation, if deployed carefully (Venkateswarlu *et al*., 2011). Management practices that improve agricultural production under adverse climatic conditions enhance resilience under variable climate and extreme events. Major strategies of adaptation to climate change include water saving technologies such as in-situ and ex-situ moisture conservation, water harvesting for supplemental irrigation, residue incorporation (to avoid it's burning), growing tolerant varieties, conservation agriculture, site specific nutrient management practices etc. Developing and diffusing crop cultivars with tolerance to climatic stresses such as, drought, heat, submergence is of urgent priority. Indeed, climate resilient crop varieties play a crucial role for coping with climate variability in agriculture. Further, strengthening institutional interventions will go a long way in promoting collective action and build resilience among communities.

Interventions related to soil health, in-situ moisture conservation, water harvesting and recycling for supplemental irrigation, improved drainage in flood prone areas, conservation tillage where appropriate, artificial ground water recharge and water saving irrigation methods etc can be adopted to cope up with climate change. Furthermore, breeding approaches like development of crops and varieties that fit into new cropping systems and seasons, varieties with changed duration, varieties for high temperature, drought, inland salinity and submergence tolerance, crops and varieties that tolerate coastal salinity and sea water inundation and varieties which respond to high CO_2 etc are becoming priority.

MANAGEMENT INTERVENTIONS AGAINST DROUGHT

COMMUNITY PADDY NURSERY AS A CONTINGENCY MEASURE FOR DELAYED PLANTING

Bihar experienced aberrant rainfall situations in 5 out of the previous 10 years impacting adversely rice production and livelihood of farmers. It appears that failure of rain in July is responsible as transplantation of paddy is delayed with resultant adverse effect on productivity and a cascading negative impact on *rabi* crops. Delay intrans planting of paddy affects productivity as over aged seedlings suffer from low tillering ability. Farmers' preference for long duration varieties is overwhelming and often waits for transplanting in lowlands till end of August in anticipation of rains. The existing practice has led to abandoning of nurseries and vast areas remained un-transplanted in several rain fed districts in South Bihar due to deficit rainfall in *kharif* 2013 season. Failure to transplant also creates an additional problem of shortage in fodder in the slack season for livestock which contributes up to 45% of total agricultural income in Bihar. Establishing a staggered community nursery was explored as a local adaptation strategy at the village level to combat the problem experienced by farmers during deficit rainfall seasons in lowlands. The technique involves raising a staggered community nursery under assured irrigation in the village at an interval of 2 weeks. In the anticipation of a two weeks delay in monsoon the first nursery is taken up as acontingency measure by 15 June with the long duration variety (>140 days) in order to transplant 3–4 weeks old seedlings by first fortnight of July. If the monsoon delay extends by 4 weeks, the second nursery is raised with medium duration varieties (125–135 days) by 1stJuly to supply 3–4 weeks old seedlings for transplanting in the 3rd or 4th week of July. In case of anticipation of further delay or deficit rainfall conditions, the 3rd nursery is raised by mid-July with short duration varieties (<110 days) to take up transplanting of 3–4 week seedlings in the first fortnight of August.

Direct Seeded Rice for Promoting Water use Efficiency

Transplanting requires at least 25 ha-cm of water for puddling operation, which creates a dense clay layer in the sub-soil to prevent seepage losses. The crop requires about 130 ± 10 ha-cm of irrigation in addition to adoption of suitable variety and application of recommended dose of fertilizers to realize yield levels of about 6 ± 2 t/ha. Generally, abou 40% of all irrigation water goes to paddy cultivation in the region. It is estimated that floodedrice fields produce about 10% of global methane emissions. Also, injudicious use of nitrogenous fertilizers is a common feature in paddy cultivation which is a source of nitrous oxide emissions. The current practice of excessive exploitation of ground water has led to a decline in the quality of natural resources i.e. land and water. Direct seeding of rice is done with a zero till drill. The quantity of seed required is 20–25 kg/ha compared to transplanted paddy which required 600–80 kg/ha. It endorses water use efficiency in rice. In Bihar, direct seeding of medium duration varieties (125 days) can be done during second fortnight of July in midlands followed by a post-emergence herbicide application. In uplands, direct seeding of rice can be taken up with the onset of monsoon rains.

Drought Tolerant Paddy Cultivars to Tackle Deficit Rainfall Situations

In recent years, deficit rainfall in July is affecting the timely transplanting of paddy in the eastern region in several rainfed districts in Bihar, Jharkhand and Odisha. Long duration (140–150 days) cultivars are preferred by farmers who take up sowing of nursery in June and transplanting in July. However, due to deficit rainfall situation in July, farmers wait for transplanting till August. This result in low productivity and can affect the timely sowing of succeeding *rabi* crop on the same land. The remedy therefore lays in the promotion of stress tolerant paddy varieties of shorter duration that are amenable both for transplanting and direct sowing. Short duration and drought tolerant varieties fit well into contingency plans for all types of farming situations (upland, midlands and lowlands) prevalent in the eastern states. Short duration and drought tolerant varieties that can withstand up to 2 weeks of exposure to dry spells in rainfed areas should be taken. Drought tolerant cultivars demonstrated in farmers' fields of Bihar include: 'Sahbhagidhan' (105–110 days duration in plain areas and 110–115 days in uplands, highly resistant to leaf blast and moderately resistant to brown spot and sheath blight. 'Naveen' (115–120 days duration, released in 2005 for cultivation in Odisha), and 'Anjali' (90 days duration released in 2003 for Jharkhand). Other early maturing varieties that have potential in the eastern states include: 'BirsaVikas Dhan109' (85 days duration), and 'Abhishek' (120 days duration).Average yield in farmer's fields with Sahbhagidhan was 34.6 q/ha with an yield advantage of 26% over traditional long duration variety in seasons that experienced deficit rainfall situation as in 2013 at Jehanabad, Aurangabad, Buxar, Saran and Supaul in Bihar; Koderma, Palamu and Gumla in Jharkhand;

Jharsuguda in Odisha. Average yield of Anjali variety was 41.2 q/ha with a yield advantage of 41% in Gumla and Chatra in Jharkhand. Average yield with Naveen variety was 39 q/ha with a yield advantage of 20% over traditional varieties in East Singhbhum in Jharkhand and Buxar in Bihar. Average yield with Abhishek variety was 35 q/ha with a yield advantage of 31% over traditional variety at Koderma, Jharkhand (Prasad *et al.*, 2014).

Crop Diversification and Intercropping in Scanty Rainfall Areas

In scarce rainfall zones of India, practice of sole cropping is predominant but is risky and often results in low yields or sometimes even in crop failure due to erratic monsoon rainfall and skewed distribution. In such areas intercropping is a feasible option to minimize risk in crop production, ensure reasonable returns at least from the intercrop and also improve soil fertility with a legume intercrop. Cotton, soybean, pigeonpea and millets are the major crops in the scarce rainfall zones. Intercropping of these crops is more profitable and is a key drought coping strategy. Crop diversification including intercropping of rainfed crops is an important risk minimizing strategy for drought proofing in the scarce rainfall zones and paddy growing areas. In contingency situations such as delay in onset of monsoon, adoption of intercropping for delayed plantings can be remunerative instead of sole cropping.

MANAGEMENT INTERVENTIONS AGAINST FLOOD

Flooding is a major challenge for rice production in the country. Heavy and intense rainfall events cause flash floods due to overflow of rivers and canals or sometimes tidal movements in coastal areas. Continuous high rainfall in a short span leading to water logging and heavy rainfall with high speed winds in a short span due to cyclonic storms cause inundation of paddy fields and lodging of the crop at grain filling and maturity stages causing huge losses to the farmer. Floods due to heavy rainfall in upstream areas in Assam, Bihar and Uttar Pradesh often lead to spate of rivers causing flooding of adjacent crop lands. The problem is accentuated due to poor or non-existent drainage and in some cases due to the topography of the land which impedes fast drainage from crop lands. Apart from improving drainage and other preventive measures, farmers can adopt flood tolerant varieties that can withstand inundation for an extended period and reduce the risk from flood damage. Rice varieties Swarna-sub1, MTU-1010, MTU-1001 and MTU-1140 are high yielding with good grain quality apart from possessing submergence tolerance and perform better under flood situation. They cantolerate submergence up to two weeks and can perform significantly better compare to other improved and local cultivars. MTU-1010 is a short duration, dwarf variety resistant to lodging and can withstand moderate wind velocity. This attribute of lodging resistance saves from not only loss in grain but also straw yield which is the main source of dry fodder.

MANAGEMENT INTERVENTION AGAINST HEAT STRESS

The continuous exposure of plants to high temperature or heat stress during crop growth cycle is a major impediment to agricultural production and cause an array of morpho-anatomical, physiological and biochemical changes in plants, which affect plant growth and development eventually reducing economic yield. Heat stress is often defined as the rise in temperature beyond a threshold level for a period of time sufficient to cause irreversible damage to plant growth and development. In general, a transient elevation in temperature, usually 10–15°C above ambient, is considered heat shock or heat stress. Wheat sowing by conventional methods requires multiple tillage operations to prepare a fine seed bed after harvesting of paddy crop. Generally, 2–3 or even more tillage operations are required which cost both time and money for the farmers. Moreover, shortage of time after paddy harvest to sow wheat creates uncertainty and delay in sowings. This sometimes results in moisture stress during the initial stages of crop growth eventually leading to poor yields. Impeded drainage in low lying fields makes it difficult for carrying out normal tillage operations. In such fields, late planting of wheat exposes the crop at critical stages to heat stress leading to decline in productivity. The heat-threshold level that the plant can withstand without adverse effects varies considerably at different developmental stages in different crops. For instance, during seed germination, high temperature may slow down or totally inhibit germination. The adverse effects of heat stress can be mitigated by developing thermo-tolerant crop varieties through genetic improvement and when coupled with various adaptation and mitigation strategies can counter production losses. Heat tolerance is generally defined as the ability of the plant to grow and produce economic yield closest to its genetic potential under high temperatures.

MANAGEMENT INTERVENTIONS AGAINST COLD STRESS

Major food crops, maize (*Zea mays*) and rice (*Oryzasativa*) are very sensitive to low temperature, the growth of these crops are severely affected in terms of their growth and development by temperatures below 10°C resulting in considerable yield loss or even crop failure. When the temperature decreases to less than 5°C for more than three consecutive days it is considered as cold wave/stress in areas where normal temperature remains 10°C or above, while in areas where normal temperature is below 10°C, if temperature goes below 3°C for more than three days it is considered as cold wave (Venkateswarlu *et al*., 2011). Many plants, especially those, which are native to warm habitat, exhibit symptoms of injury when subjected to low non-freezing temperatures. These plants including maize, soybean, cotton, tomato and banana are in particular sensitive to temperatures below10–15°C. Various symptoms in response to cold/chilling stress include reduction of leaf expansion, wilting, chlorosis and necrosis. In chilling stress, primary injury is the initial rapid response that causes a dysfunction in the plant, but is readily reversible if the temperature is raised to non-chilling conditions (Kratsch and Wise 2000).

INTEGRATED FARMING SYSTEM FOR MODERATING CLIMATE CHANGE

Integrated farming system modules minimize risk from a single enterprise in the face of natural calamities and diversified enterprises bring in the much needed year round income to farmers in mono-cropped paddy growing areas and improve their livelihoods and resilience to extreme weather events. Such models can be up-scaled in the north and north eastern states through on going government programmes.

NUTRIENT MANAGEMENT FOR ALLEVIATING CLIMATE CHANGE

Application of fertilizer according to the requirement of crop increases the fertilizer use efficiency due to application of lesser amount of fertilizers. As a consequence, there is less accumulation of nutrients within the crop root zone. This reduces the emission of greenhouse gases particularly nitrous oxide if the nitrogen is added according to the requirement of the crop. Numerous studies have revealed the impact of chemical fertilizers on CH_4 and N_2O emissions which depends on rate, type and mode of fertilizer application. Decrease in CH_4 emission rate with the application of ammonium nitrate due to competitive inhibition of nitrate reduction in favour of methane production. Under field conditions, it has been found that the application of sulphate based fertilizers such as $(NH_4)_2$ SO_4 and $CaSO_4$ have reduced CH_4 emission, while application of K_2HPO_4 enhanced the CH4 emission. It has been reported that application of undecompose organic manure increases the methane flux. It is also important in the mitigation of greenhouse gases. It has been found that the application of urea in plough layers gives less emission of N_2O than band application. Addition of phosphorus and liming materials can also affect nitrous oxide evolution from soil. However, phosphorus induced emissions are higher than those obtained with lime. Plant uptake of fertilizer N can be improved by various methods as deep placement and placing fertilizers in band.

CROP RESIDUE MANAGEMENT TO REDUCE AIR POLLUTION AND IMPROVE SOIL QUALITY

Generally, farmers burn crop residues like stalks of pigeonpea and cotton without recycling them. This is a great loss to the farmer as well to the land, as the land is deprived of biomass, which helps build precious soil organic carbon. This harmful practice is leading to increased CO_2 emissions besides depriving crop residue to the soil. However, farmers resort to burning of the crop residues as removing it involves higher costs for labour to uproot, chop and mix in the soil.

CONCLUSION

The identification of suitable response strategies is key to sustainable agriculture. Agro-ecological zones and farming systems are extremely diverse. Thus interventions need to be targeted to specific contexts. Decision support to match practices and technologies with agro ecological zones is a priority. Proper understanding of climatic conditions and efficient utilization of natural resources are, therefore, of great concern for the improvement and sustainability of agricultural production.

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Future Changes in Rainfall and Temperature under Emission Scenarios over India for Agriculture

Dr. P. Parth Sarthi
Center for Environmental Sciences, Central University of South Bihar, BIT Patna, P.O-B.V. College, Patna–800014, Bihar, India
E-mail: ppsarthi@cub.ac.in/ drpps@hotmail.com

Abstract—Indian Summer Monsoon (IMS) prevails during June-July-August-September (JJAS) and 80% of the annual precipitation is received during JJAS. The spatial and temporal variability of ISMR does influence agriculture and water resources. The fast increase in earth's surface temperature is affecting the patterns of weather and climate and influencing the agriculture. The Coupled Model Intercomparison Project 5 (CMIP5) models output data is generally of higher resolution and include a broader variety of experiments compared to Coupled Model Intercomparison Project 3(CMIP3) and therefore rainfall and surface temperature over India is analyzed under CMIP5.

The Indian Summer Monsoon Rainfall (ISMR) in simulation of BCC-CSM1.1(m), CCSM4, CESM1 (BGC), CESM1 (CAM5), CESM1 (FASTCHEM), CESM1 (WACCM), and MPI-ESM-MR for the period of 2006–2050 under RCPs 4.5 and 8.5 at 99% confidence shows possibility of excess rainfall over homogeneous monsoon regions of NWI, NEI, WCI and PI, while deficit rainfall over NWI, NEI, WCI, CNI and PI. At 99% and95% confidence levels, deficit rainfall is found over CNI, NWI and PI. The CMIP5 model GISS-E2-H, BCC-CSM1.1m and GISS-E2-H-CC for Tmax; GFDL-CM3, MRI-CGM3 and MRI-ESM1 for Tmin; and CESM1 (CAM5) for T under RCPs 4.5 and 8.5 for the period of 2021–2055 shows possible significant warming of 0.5°C–0.7°C at 99% confidence level over homogeneous temperature regions of NC, NW, and WC. The warming of 0.2°C-0.5°C might be possible at other locations.

These future projections may be used in crop simulation models which may assist adaptation to climate change-through changes in farming practices, cropping patterns, and use of new technologies.

INTRODUCTION

The summer monsoon season in India prevails during June-July-August-September (JJAS) (Rao 1976) and 80% of the annual precipitation occurs during JJAS. The Indian Summer Monsoon Rainfall (ISMR) spatial and temporal variability largely influences agriculture and water resources. As well as, rapid increase in earth's surface temperature is affecting the patterns of weather and climate and influencing the agriculture, water sectors and human health.

Under warming conditions, ISMR simulated in different Global and Regional Climate Models have been studied by various researchers; however, uncertainties exist in the regional climate projections due to biasness in the global climate models (Meehl and Washington, 1993; Lal *et al*. 1994, 1995; Rupa Kumar & Ashrit 2001; May, 2004; Kripalani *et al*., 2003; Rupa Kumar *et al*., 2002, 2003). ISMR has great importance over the Gangetic plain for agriculture and water resource purposes, but it is poorly simulated in many modelsover Bay of Bengal (BoB) and adjoining northeast India(Lal *et al*., 2001; Rupa Kumar & Ashrit 2001; Rupa Kumar *et al*. 2003). Using Coupled Model Intercomparison Project phases 3 (CMIP3), Kripalani *et al*. (2007a) suggested significant increase in mean monsoon precipitation of 8% and possible extension of the monsoon period, in doubling of CO_2 experiment of CMIP3. In the same experiment, Kripalani *et al*. (2007b) applied t test and F ratio and found statistical significant changes in future rainfall from −0.6% for CNRM-CM3 to 14% for ECHO-G and UKMO HadCM3 for East Asian monsoon. Menon *et al*. (2013a,b) suggested increase in all-India summer monsoon rainfall (AISMR) per degree change in temperature of about 2.3% K^{-1}, which is similar to the projected increase in global mean precipitation per degree change in temperature in CMIP3. Parth Sarthi *et al*. (2012) suggested that under A2, B1 and A1B experiments of CMIP3, a future-projected change in spatial distribution of ISMR shows deficit and excess of rainfall in Hadley Centre Global Environment Model version 1 (HadGEM1), European Centre Hamburg Model version 5 (ECHAM5), and Model for Interdisciplinary Research on Climate (MIROC) (Hires) over parts of western and eastern coast of India. Multi-model average of CMIP5 simulations does not show improvements in biasness over CMIP3; however, uncertainty in CMIP5 projections is lower than that inCMIP3.

The global mean surface air temperature has been increased by 0.60°C during the 20th century as per the Intergovernmental Panel on Climate Change (IPCC)'s Third Assessment Report (AR3), while as per IPCC's Fourth Assessment Report (AR4), it is estimated to have increased by 0.74°C and could rise up to 1.1°C–6.4°C during 21st century depending on a range of possible scenarios (IPCC 2007). In IPCC's Fifth Assessment Report (AR5), it is stated that enhanced greenhouse gas concentration is the most likely reason behind more than half of this observed increment in temperature and these changes are largely due to anthropogenic emissions (IPCC 2014). In IPCC (2014), increase in global mean surface temperatures for 2081–2100 relative to 1986–2005 is projected to increase in the range of 0.3°C to 1.7°C (RCP2.6), 1.1°C to 2.6°C (RCP4.5), 1.4°C to 3.1°C (RCP6.0), 2.6°C to 4.8°C (RCP8.5) in CMIP5. In the past CMIP3 models have been evaluated for temperature with a future projection. Lal *et al*. (2001), Rupa Kumar *et al*. (2003 & 2013), and Pattnayak *et al*. (2015) haveanalyzed projected surface temperature with various coordinated climate models experiments such as CMIP3 and CMIP5. Lal *et al*. (2001) reported projected mean warming between 1.0°C-1.4°C and 2.2°C–2.8°C by 2020 and 2050, respectively over the Indian subcontinent which is also reported by IPCC (2014). In 21st century, increasing in temperature is particularly conspicuous after the 2040s over India and suggested an increase in Tmin (up to 4°C) all over the country, which might be more in Northeast India (Rupa Kumar *et al*. 2003). Overall increase in surface temperature by 4.8°C, 3.6°C and 2.2°C in A2, A1B, and B1 emission scenarios, may be possible at the end of 21stcentury in CMIP3. Extremes in Tmax and Tmin are also expected to increase over the West-Central India in different scenarios (Rupa Kumar *et al*. 2013). Pattnayak *et al*. (2015) have analyzed the six CMIP5 model's namely GFDL-CM3, GFDL-ESM2M, GFDL-ESM2G, HadGEM2-AO, HadGEM2-CC and HadGEM2-ES in Representative Concentration Pathways (RCPs) 4.5 and 8.5, which are able to capture spatial distribution of temperature with an increasing trend in RCPs 4.5 and 8.5 over most of the regions over India. Chaturvedi *et al*. (2012) worked on multi-model and multiscenario temperature projections over India for the period of 1860–2099 using CMIP5 under RCP6.0 and RCP8.5 scenario, it is found that mean warming in India is likely to be in the range 1.7–2°C by 2030s and 3.3–8 4.8°C by 2080s relative to preindustrial times.

Under World Climate Research Programme (WCRP), Working Group on Coupled Modelling (WGCM), Climate models experiments are carried out for past, present and future climate during the years 2005 and 2006, and this archived data constitutes phase 3 of the Coupled Model Intercomparison Project (CMIP3). The Coupled Model Intercomparison Project 5 (CMIP5) models output data is generally of higher resolution and include a broader variety of experiments compared to CMIP3, therefore it aimed to analyze rainfall and surface temperature over India under CMIP models simulations. Section 1 deals with Introduction and literature survey; data and methodology is in section 2. Results and discussion is placed in section3 while conclusions are in section 4.

DATA AND MODELS

The gridded observed rainfall of India Meteorological Department (IMD) with resolution of 1°×1° during 1961–1999 and of Global Precipitation Climatology Project (GPCP) at resolution of 2.5°×2.5° during 1979–1999 is considered for validating the model's performance. Table 1 and 2 shows list of CMIP5 models considered under Representative Concentration Pathway (RCP) 4.5 and 8.5 experiments for analysis of rainfall and surface temperature T, Tmax and Tmin. RCPs 4.5 and 8.5 experiments are very likely that world will follow these mild and high emission scenarios in future time periods. The simulation of a Historical experiment in CMIP5 is equivalent to 20th-century experiment (20C3M) of CMIP3; models are integrated from 1850 to 2012 with external forcing changing with time. The external forcing includes GHGs, the solar constant, volcanic activity, ozone, and aerosols.

Table 1: List of CMIP5 Models for Rainfall, their Surface Resolution and Available RCP Sexperiment

Sl. No.	Models	Surface Resolution	RCP 4.5	RCP 8.5
1	BCCCSM 1.1(m)	320 × 160	√	√
2	CCSM4	288 × 192	√	√
3	CESM1(CAM5)	288 × 192	√	√
4	CESM1 (BGC)	288 × 192	√	√
5	CESM1 (WACCM)	144 × 96		√
6	MPI-ESM-MR	192 × 96	√	√
7	CESM1 (FASTCHEM)	288 × 192		

Table 2: List of CMIP5 Models for T, Tamx and Tmin, their Surface Resolution and Available RCP Sexperiment

	Models	Surface Resolution	RCP 4.5	RCP 8.5
T	BCCCSM 1.1(m)	320 × 160	√	√
Tmax	GISS-E2-H-CC	144 × 90	√	√
	BCCCSM1.1(m)	320 × 160	√	√
	GISS-E2-H-CC	144 × 90	√	√
Tmin	GFDL-CM3	144 × 90	√	√
	MRI-CGCM3	120 × 120	√	√
	MRI-ESM1	120 × 120	√	

For rainfall, the period of historical experiment is 1961–2005 and for future project is 2006–2050; For surface temperature, the period for historical experiment is 1971–2005 and for future project is 2021–2055.

RESULTS AND DISCUSSIONS

Figure 1 shows homogeneous monsoon regions namely North West India (NWI), Central Northeast India (CNI), North East India (NEI), West Central India (WCI), Peninsular India (PI) and Hilly Regions (HR). Fig. 2 depicts Temperature homogeneous regions namely North East (NE), North West (NW), North Central (NC), East Coast (EC), Peninsula India (IP), Western Himalaya (WH), West Central (WC) of India. To analyze the reduced uncertainty in future projection of rainfall and temperature, students T test at 99% and 95% confidence levels is applied on the projected values.

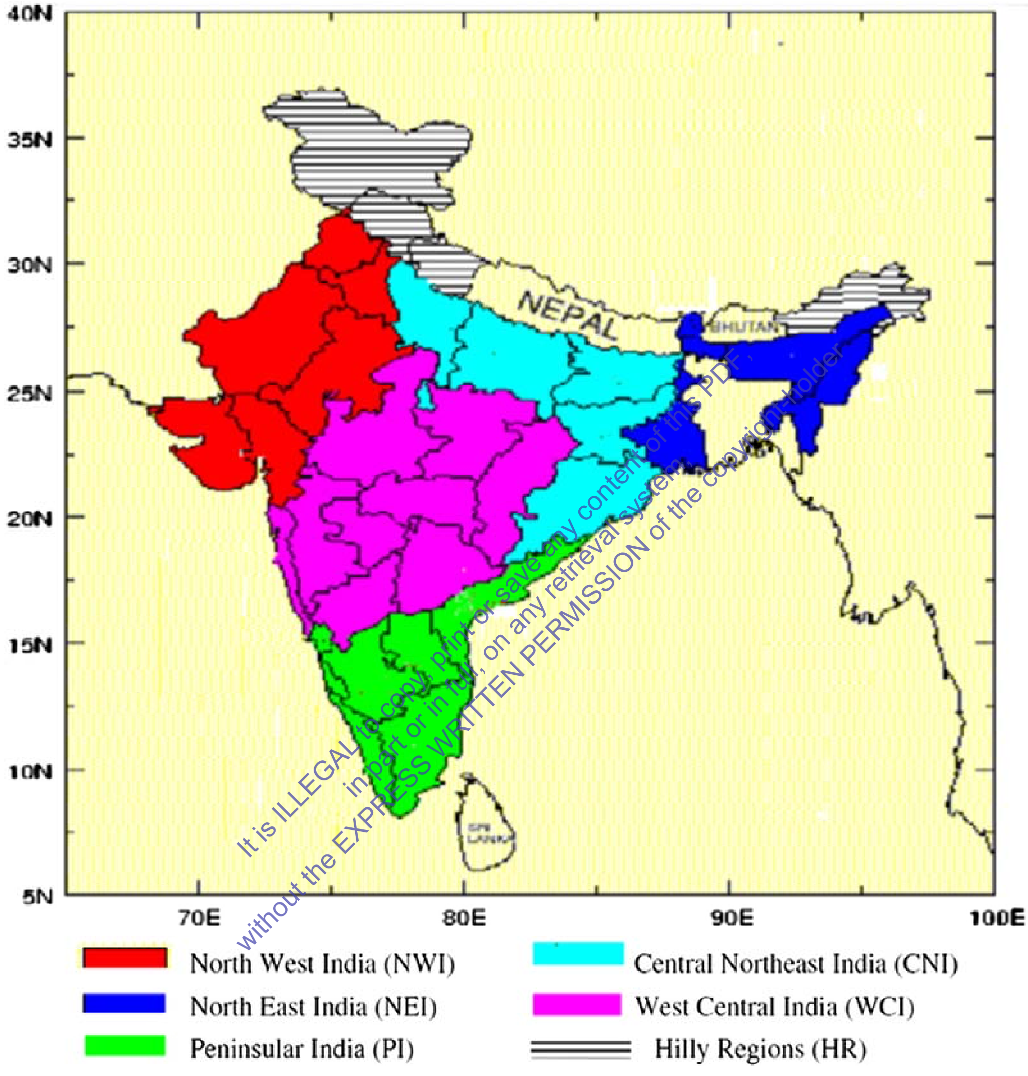
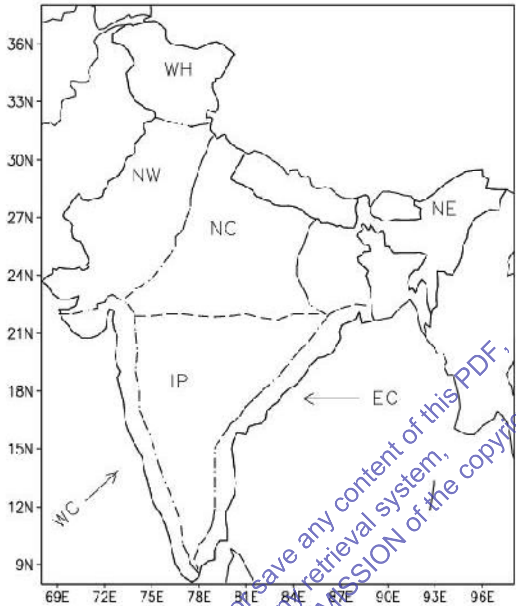


Fig. 1: Homogeneous Monsoon Regions of India

Source: India Institute of Tropical Meteorology, Pune, India



NE–North East NW–North West
NC–North Central EC–East Coast
IP–Peninsula India WH–Western Himalaya WC–West Central

Fig. 2: Temperature Homogeneous Regions of India

Source: IITM, Pune, India

A large number of CMIP5 models under Historical experiment is evaluated with observed rainfall of IMD and GPCP (Fig. not shown) but only BCC-CSM1.1(m), CCSM4, CESM1(BGC), CESM1(CAM5), CESM1(FASTCHEM), CESM1(WACCM), and MPI-ESM-MR performed well and therefore used for analyzing future projections of ISMR in June-July-August-September (JJAS) under RCPs 4.5 and 8.5 emission scenarios. The spatial distribution of future projected percentage changes in JJAS (mm/month) rainfall during 2006–2050 in RCPs of 4.5 and 8.5 of BCC-CSM1.1 (m), CCSM4, CESM1 (BGC), CESM1 (CAM5), CESM1 (WACCM), CESM1 (FASTCHEM) and MPI-ESM-MR with respect to Historical experiment (1961–2005) is shown in Figs. 3a-k at 99% and 95% confidence levels using student t-test. In Figs. 3a-b, an excess of 5–25% rainfall at 99% and 95% confidence levels may be possible over the parts of NWI, Gangetic plain of CNI and PI. Figs. 3c-d shows possibility of 5–15% excess rainfall at 99% and 95% confidence levels over Western Ghat, parts of WCI and Gangetic plain of CNI, in simulations of CCSM4. In CESM1 (CAM5) simulations (Figs. 3e-f), 5–15%

deficit rainfall at 99% and 95% confidence levels may be possible over the Gangetic plain of CNI and 5% deficit rainfall at 95% confidence over PI. Excess rainfall of 5–15% at 99% and 95% confidence levels may be possible over parts of CNI and PI in CESM1 (BGC) (Figs. 3g-h). 5–10% deficit rainfall at 99% confidence level over NWI is simulated in both RCPs. In MPI-ESM-MR simulations (Figs. 3i-j), 10–15% excess rainfall at 99% and 95% confidence levels may be possible over WCI, while 5–10% deficit rainfall over parts of NWI and CNI. In Fig. 3k, CESM1 (WACCM) shows, 10–15% excess rainfall at 99% confidence level over parts of NEI and PI.

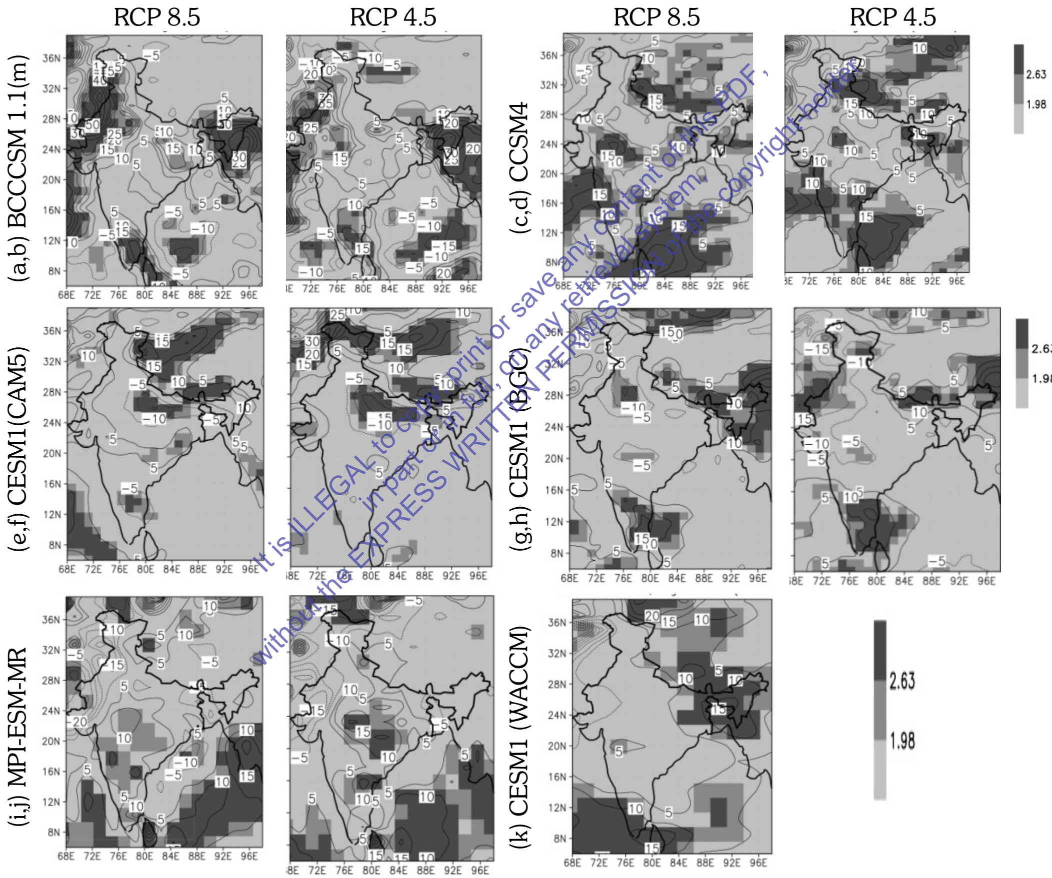


Fig. 3(a-k): Percentage Change in JJAS Rainfall (mm Day-1) for the Period of 2006–2050 under RCP 4.5 and 8.5 with Respect to Historical Experiment for the Period of 1961–2005. 99% Confidence Level in Student T-test is Masked with Dark Blackish Grey Color while 95% Confidence Level is Masked with Light Grey Color

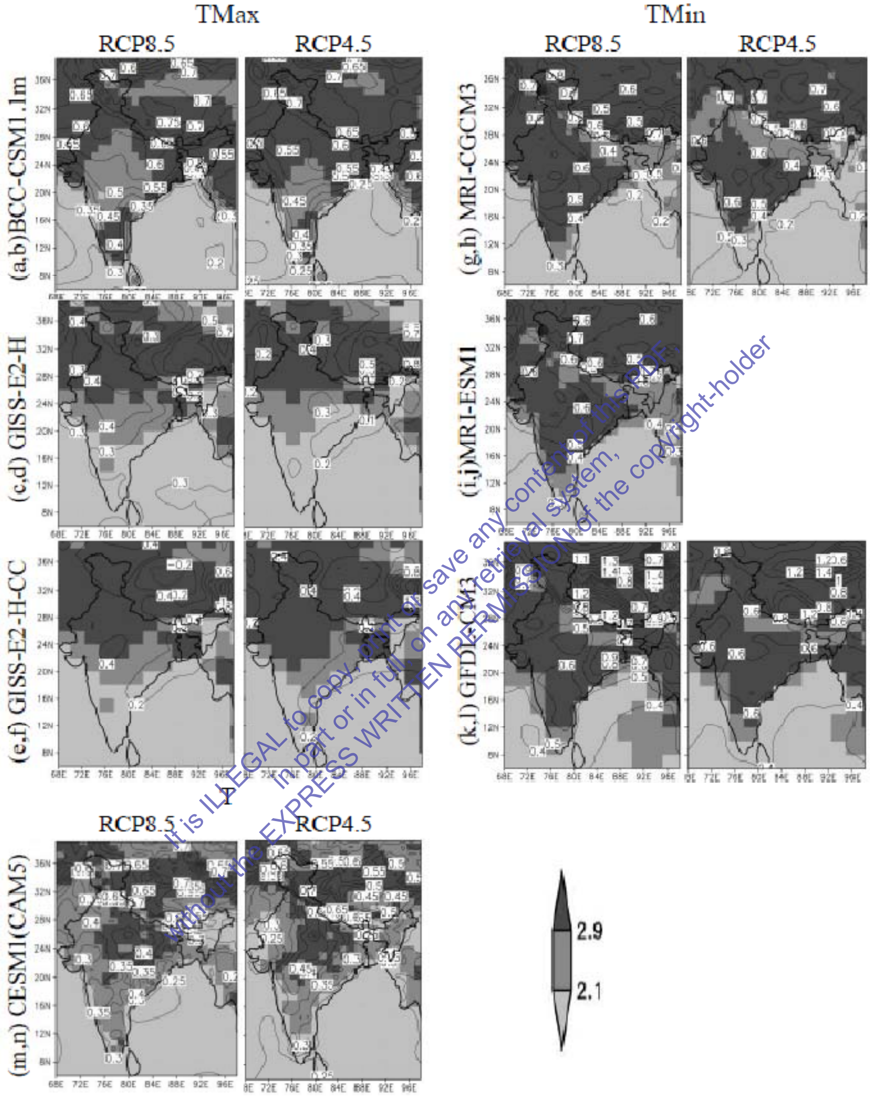


Fig. 4(a-n): Future Projected Changes in Tmax, Tmin, and T (°C) for the Period of 2021–2055 under RCP 4.5 and 8.5 with Respect to Historical Experiment for the Period of 1971–2005. (Regions with statistically Significant at 99% Confidence Level (Masked with Dark Grey Color) and is 95% Confidence Level (Masked with Medium Grey Color) on Two-tailed Student's T-test

In simulating surface temperature, models evaluation shows that model CESM1 (CAM5) for T, GISS-E2-H, BCC-CSM1.1m, and GISS-E2-H-CC for Tmax and GFDL-CM3, MRI-CGCM3, and MRI-ESM1 for Tmin are relatively better performing than other models (Fig. now shown) Fig. 4(a-n) is shows future projected changes in Tmax, Tmin and T during 2021–2055 under RCPs 4.5 and 8.5 with respect to Historical experiment (1971–2005). Student's t-test at 99% and 95% confidence levels is applied to know the significance of future projected changes. In Fig. 4(a-n), 99% and 95% confidence levels are masked with dark gray and medium gray color respectively, while non-significant area is masked with light gray color. GISS-E2-H, GISS-E2-H-CC projected Tmax (Fig. 4(c-f)) shows possibility of 0.3°C–0.4°C warming over NW and NC and 0.6°C–0.7°C over NW and the Gangetic plain under RCPs 4.5 and 8.5. BCC-CSM1.1m (Fig. 4(a–b)) shows possible warming of 0.4°C–0.5°C at 99% confidence level over the entire region of India except over the central west region while 0.25°C–0.45°C over southern India at 99% confidence level. In Fig. 4(g–l), GFDL-CM3, MRI-CGCM3, and MRI-ESM1 simulated Tmin in RCPs 4.5 and 8.5 shows possible warming of 0.3°C–0.7°C over major parts of India, but more warming is seen over northwest and southeast part at 99% confidence level while 0.4°C–0.6°C at 95% confidence level is depicted over whole India. In simulation of CESM1(CAM5), future projected T in RCPs 4.5 and 8.5 (Fig. 4(m–n)) shows a significant warming of 0.4°C–0.5°C over NC and the Gangetic plain at 99% confidence level, and the same magnitude of warming at 95% confidence level may be possible over whole India except WC and EC.

The significantly projected scenarios of rainfall and temperature in CMIP5 models may be used as inputs to Crop simulation models over the Gangetic plain which is more scientific approach to study the impact of climate change on agricultural production. Such study may help in framing adaptation to climate change-through changes in farming practices, cropping patterns, and use of new technologies which may reduce impacts of climate change.

CONCLUSION

These six (6) models namely BCC-CSM1.1(m), CCSM4, CESM1(BGC), CESM1(CAM5), CESM1(FASTCHEM), CESM1(WACCM), and MPI-ESM-MR simulated future projected percentage changes in JJAS rainfall for the period of 2006–2050 under RCPs 4.5 and 8.5 at 99% confidence level is analyzed which shows possibility of excess rainfall over homogeneous monsoon regions of NWI, NEI, WCI and PI, while deficit rainfall over NWI, NEI, WCI, CNI and PI. At 99% and 95% confidence levels, deficit rainfall is found over CNI, NWI and PI. CMIP5 models GISS-E2-H, BCC-CSM1.1m and GISS-E2-H-CC for Tmax; GFDL-CM3, MRI-CGM3 and MRI-ESM1 for Tmin; and CESM1 (CAM5) for T are able to simulate for the period of 1961–2005. In RCPs 4.5 and

8.5 experiments for the period of 2021–2055 with respect to historical experiment for the period of 1961–2005, significant warming of 0.5°C–0.7°C at 99% confidence level may be possible over homogeneous temperature regions of NC, NW, and WC. The changes of 0.2°C–0.5°C might be possible at other locations.

These future projections may be used in crop simulation models which may assist adaptation to climate change-through changes in farming practices, cropping patterns, and use of new technologies.

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Land Economics *vs.* Land Use Planning

B.B. Mishra
Professor, School of Natural Resource Management & Environmental Sciences, Haramaya University, Ethiopia
E-mail: bbmsoil@rediffmail.com

Abstract: Today's lifestyle and high-tech economic race above the ground is challenging to the global sustainability. We need air, water, food and ecosystem for our existence and survival and so we need technologically sound land use planning (LUP) in its broad spectrum in order to insure overall sustainability of the land units and assured profitability of the land uses that we identify at planning stage in a given land unit. The land use or land produce is subject to insure profitability. Thus, the concept of land economics is very relevant to make our land use profitable by applying economic principles within the control of farmers. Importantly, adoption of conservation agriculture based on land evaluation will significantly help in building up not only a healthy soil and producing quality food, but also for sequestering carbon in soil significantly preferably on continued basis. The agri-business techniques including the supply chain process will simultaneously help to alleviate the poverty in a big way. Thus, land economics must be included in course curriculum in Universities across the globe to insure overall sustainability of our land/soil. The Food and Agriculture Organization of UNO may preferably work exhaustively on this line to approve the criteria of how best land economics would be the driving force to streamline the approaches under LUP leading to poverty alleviation, continued carbon sequestration, organic farming and quality food production by restoring the overall soil health. Land economics may be a powerful tool for climate change adaptation-mitigation including poverty alleviation in India.

Keywords: Land Economics, Land Use Planning, Conservation Agriculture, Food Safety, Climate Change Mitigation, Poverty Alleviation

LAND ECONOMICS VS LAND USE PLANNING

Economics works under two broad terms viz. demand and supply. Among many demand forces, population forces, income variation, technology application, market access and transportation facilities are vital for land economics. The accumulated impact of these forces promotes the demand for products or uses of a land. However, a land as being the productive factor does not need an increase in itself as it is fixed, but other productive factors like labour, capital and management are also combined with land and contribute significantly under a set of management. Of course, the area of a land is fixed, but the supply of products and land uses in a given land is variable. This is because:

1. The amount of labour, capital and management combines with land area may be changed to produce more outputs of produce or more products or land uses.
2. If a new technology is introduced, it may change or upgrade the outputs in order to produce a larger amount of products from the fixed area of land.
3. Improved transportation may increase the supply and distribution of produce.
4. Agri-business and entrepreneurship by facilitating a rural based supply chain for produces may sustain the land economics and insure poverty alleviation among the poor resource farmers.
5. Secured land ownership as in India is very positive for land economics, wherein framework for demand and supply for land use or products may be executed freely to achieve the mission.

Land is virtually a physical unit of the environment comprising basically of soil, climate, geology, hydrology, wherein soil as a physical factor of land is only manageable. This is because of which soil is frequently used as synonym to land for all practical purposes. Soil as a natural resource in the landscape is otherwise subject to respond to management in order to cause production to its suitable choice popularly known as land use like crops, vegetation, forest, plantation, pasture, forage, timber etc. Besides, soil cannot be comparable with animal or plant or rocks and minerals particularly for the purpose of any grouping due solely to complex type of its heterogeneity. In brief, soil as a natural resource is in continuum on the landscape, dynamically surrounded by climate, hydrology and soil site characteristics, wherein light radiation and sustainable management are two additional soil forming factors besides Dokucheaev-Jenny postulated known five factors (Mishra 2015).

Since soil is basically a resource intended for management by the farmers, who care for business, there is logistic to shift this business towards insured profitability, since more than 80 percent of Ethiopian population rests on this business. Thus, the importance of land economics is immense. Be sure that the key factor for success in this giant business lies on best agricultural practices in line with land use planning followed by the best business strategies. So, there must be a clear vision to empower the poor farmers with current reliable technological updating in order to compete with the emerging business environment and its processes, because the strength of any business depends on specific business process applied in line with excellence in production. Farmers are made aware to latest knowhow about business management process in order to enable them to adopt such process. In order to mobilize farmer's mindset to incline to business tips, the first and foremost option is to familiarize them with success stories of identical farmers in the adjoining farming areas simply to sensitize for being committed for farm business management. Sushil Kumar, for example, in a village Tulsipur (Naugachia) of Bhagalpur district in Bihar (India) once brought some banana suckers and planted in his farm in the year 1971–72 with agronomic management inputs he learnt in Maharastra. The success story he planted was so reliably acceptable that other farmers not only in his village, but from adjoining villages started following this practice of banana cultivation. The adoption of banana cultivation was so revolutionary that within five years, entire Naugachia, Khagaria, Katihar and Purnea districts in India is known as "*Kelanchal*" i.e. Land of Banana. Importantly, the farmers never receive any encouragement in any way either through the state or central government, but the business zeal among the farming community of the zone left no stone untouched in order to make the profession profitable. Such examples, however, suffers from imbalanced business management process, though the outcome may be profitable, it cannot, however, be stable and sustainable. So, the farmers are made well trained with business process under farming system. In the modern scenario, the business process works in networking, wherein production at one end follows the product being supplied through a well defined supply chain covering the priority area of demand. Hence, the land economics has vast scope to address for soundness of a country. By and large, the concept of land economics lies on the practical framework of the land use planning, a tool based on land and soil evaluation. The land use planning simply means for a systematic assessment of physical, social and economic factors in such a way so as to help the land users to select land-use options that may increase their productivity on sustainable basis. As we know, the land resources are limited and finite. It is projected that if the human population continues to increase at the present rate, there will be almost twice as many people on the globe in the next 50 years. So, the consequences are well understood for coming future, if not alert against ill-effects.

QUICK LOOK TO AGRICULTURAL BASED ECONOMY

India has predominantly an agricultural based economy, wherein food production accounts for 26% of national GDP. Here, agriculture accounts for more than 60% of national employment. In a projected estimate, agriculture is growing only at 3.3% compared to industry that grows at the rate of 7.5% a year. There is tremendous scope in India to transform agriculture into corporate sector. Based on reports (http://www.makeinindia.com/sector/food-processing/), India ranks first in the world (in 2012) in the production of bananas, mangoes, papayas, chickpea, ginger, okra, whole buffalo, goat milk and buffalo meat. India ranks second in the world in the production of sugarcane, rice, potatoes, wheat, garlic, groundnut (with shells), dry onion, green pea, pumpkin, gourds, cauliflower, tea, tomatoes, lentils, wheat and cow milk. Besides, the country's gross cropped area amounts to199 million hectares with a cropping intensity of 140%. The net irrigated area is 89.9 million hectares with a total of 127 agro-climatic zones identified. India's food processing sector ranks fifth in the world in exports, production and consumption. Major parts of the food processing sector are milled grain, sugar, edible oils, beverages and dairy products. It is further to note that India stands second in fruit production after Brazil and similarly second in vegetable production after China. In a general estimate, about 33 million tonnes of fruits and almost 70 million tonnes of vegetables are annually produced in India following a global market share of about 11% and 17.5%, respectively. However, the fruits and vegetables are processed only to an extent hardly of 1 to 2% in India as compared to 70 to 80% in developed countries. Thus, there is a wide gap full of challenges that need opportunities to overcome in almost all sectors of Indian agriculture. The Government of India is, of course, offering incentives in agricultural fields, but there is need of transformation.

As a matter of fact, almost 80% of rural population contributes to the development of agriculture in different directions in India. However, the continued speedy process of urbanization in India has resulted in migration of rural people to the urban areas for non-farming business. Besides, the in-equilibrium between industrial and agricultural wage pattern and structure resulted into unrest and frustration which manifests in the form of violence and sufferings. The aim of this paper lies with the fact that traditional system in agriculture must get transformed for gross rural happiness in livelihood. This could be possible by generating system approach through land economics that works on demand and supply in the framework of land use planning followed by a well knitted supply chain process starting from farmers to consumers through distributors under the supervision of corporate sectors.

WORK CULTURE TO BEGIN WITH LAND EVALUATION

Importantly, the soil is the soul or a building block of infinite lives, because it is foundation for survival and nourishment of such lives. The soil has its origin, its growth and its end. It is natural and takes several years to grow, develop, mature, reform and transform or even erode. Soil cannot be a waste unless it is washed out. It is not renewable and manufactured. As it is a resource, it is subject to production that necessitates site-specific management inputs. It works in critical zone concept (surface-rhizosphere-underground) and influences three basic needs of life viz. ecosystem, food and water besides influencing the climate, biodiversity, energy and livelihood. As a soil system in agriculture, it needs an integrated management skill, but often lacks an acceptable "work culture" within the framework of soil science; for which a global mandate needs to be develop, accepted and practiced in order to attain a balanced soil sustainability, which may be a part of governance in land economics. Soil belongs to an open system in its environment that may be both natural and synthetic or even artificial. So, for any exercise to monitor the soil health and fertility status as often we follow the soil testing of the top soil (0–20 cm), one has to move, prior to this, for a systematic examination of whole soil (pedon) as outlined below.

a. Evaluate the soil (pedon) for deciding its actual and potential productivity/ capability.

b. Identify the associated limitations (correctable/ non-correctable) following the subsequent amelioration, reclamation, mitigation and overall improvement through locally available management and/or technical inputs.

c. Fix suitability of land use choice in a specific set (crop rotation in case of agronomic crops).

d. Decide the fertility level of soil and recommend how much a particular nutrient is applied in the most preferred way i.e. balanced form to enhance the nutrient use efficiencies and so.

This should be made bare mandatory prior to start with crop cultivation or similar land uses. By furnishing above exercise, soil related prescriptions are made available in the form of a written document covering all pedogenic, physical, chemical, microbiological, biochemical, nutritional, pathologic, heavy metal, arsenic and biodiversity issues. Such system approach can safely predict the soil health management of a soil for restoration of total soil health. Soil or even land may be natural, but its management is almost man-made particularly for the purpose of agriculture, wherein the land economics is overall indicator, if approaches are reliably tenable.

A soil with full prescriptions being provided within the above work culture by concerned professionals may then be transferred to Agronomist, Horticulturalist or Farm Manager or farmers, who could simply follow the said prescriptions and management options within the recommended package of practices for given crops or plantation or land use. In fact, the manager on land/soil management takes decision based on some principles and sets certain specifications for choice he can meet. If the manager is novice or irresponsible, he can hardly meet the goal and his business ultimately fails. So, the land economics may be a source of auditing for one's professional endeavour in totality.

Research is merely a means or process of relating a theory to facts or factual relationships. The function of science is to identify and solve the problems. In fact, the essence of science is to test the hypothesis, a process of going from fact to theory. Hypothesis is to predict the facts through verification and so it is a tentative answer or solution. Land research is closely tied with governance, policies and executive decision.

SUPPLY CHAIN OF LAND USES OR PRODUCES

Virtually, the concept of supply chain of land uses or produces is neither fully understood among rural farmers nor accepted, though Food Industries are running around urban areas in different cities. The existing drawbacks need to be addressed on priority basis to flourish corporatization with land uses. Farmers in general are not aware of the merit of supply chain for their produces. So, there is need for visualization of this system among the rural communities through training, demonstration and documentary films. There is need to centralize the planning in supply chain of land uses or produces through distribution into a single management system using IT tools as prevalent in reputed industry. The corporate sectors may also take a lead to implement a planning system to judge the existing land use scenario and make management decisions based upon various situations including storage of raw materials (land uses), processing and finished goods from point-of-origin (farmers) to point-of-consumption (markets) in order to insure the best competitive price to the farmers. Once the farmers get satisfied with economic outcome, they themselves feel eager to stimulate such wonderful approach under land economics for their overall economic promotion. But, further refinement is mandatory by experts in classical economics from across the globe.

POVERTY ALLEVIATION: A KEY ISSUE

As opined earlier, only two major successions could be broadly recognized viz. (i) Agriculture through hunting and (ii) Agriculture through ploughing, sowing or planting and harvesting (Mishra 2014). In the second succession, there have been numerous reforms including reforms during green revolution, mostly technological reforms. Such reforms have definitely solved the food security issues in a big way. But, farmers are by and large poor in terms of livelihood and economic growth. This is of global concern even. However, it is of strong logical understanding to expand the long existing second agricultural succession to its third counterpart (succession), wherein farming (ploughing and harvesting) is made closely tagged with "processing, value addition and marketing at the farmer's door" itself without allowing any role of a middleman. If we accomplish the attainment of the emerging agricultural succession in reality, it will be proved a breakthrough towards alleviation of poverty among farming communities. However, the strategic planning may be developed as below:

a. To enrich the infra-structures as the assumptions for the success towards adoption of the respective management as well as technical training at farmer's doors viz. Secured land ownership, road, water, electricity, banks, self-help groups, internet access/training, transport and market access including location specific processing and other post harvest and value addition plants to be installed.

b. To appreciate some nucleus villages (based on approved standard) for adoption of reliable and proven technologies being approved with assured outcome (produce).

c. To organize frequent trainings on setting-up of agri-based industries as well as food processing and value addition plants for site-specific agri-based products.

d. To set up a market complex for assuring the normal sale procedure for different agricultural products in a way to fetch high price to the farmer without involvement of middlemen.

e. To involve corporate sectors in rural area and get the farmers tagged to begin with new succession of sustainable agricultural production to sustain livelihood and economic growth.

The proposed set rules as qualitatively outlined above may help to develop a framework of agri-business management in a way to assure farmers with maximum profit. Specialized people may sit together to formulate a strategic plan to shift whole traditional farming system into corporate sector within the framework of land use planning (LUP), wherein farmers will be the main actors. That will be the true outcome of the third agricultural succession. As a consequence, farmers will no more remain then poor, if global food security campaign is designed and approved in line with above basic set rules. Accordingly, the farmers will keep adhered to the following responsibilities:

1. Let a farmer sow or plant the seed or seedling following the recommended technology and available inputs (preferably locally) strictly on LUP model.
2. Let him harvest the product under his own control following the improved technology (already existing in most parts).
3. Farmer must have liberty to store his produce or go for post harvest technology/processing or even value addition to fetch a good price. Let farmers be sole responsible in planning and decision process of marketabe produce through some suitable supply chain process offered by corporate sectors.
4. Farmers must be exposed for opportunities in marketing (import/export) and that too under their direct control to fetch the profits with corporate sectors involved.

The above four point programme at farmer's door (direct control) virtually needs encouragement/ approval by the policy makers (Government), agricultural universities, cooperative bodies and extension workers. Every farmer with landed property is legalised to furnish all four steps at his door. Other professions like dairy, goatry, mushroom production, apiary etc are additional to boost up the economics. Once the programme is legalised just by adopting a village as the NUCLEUS VILLAGE, the farmers will get excited towards its adoption and this will be a true success story towards poverty alleviation in India. Obviously, the entire framework lies on how best we manage the land for quality produce following the pillars viz. productivity, safety, profitability and sustainability of land resource and so the land economics, which will shape the real economic picture of a nation.

CONSERVATION AGRICULTURE

The bare truth of conservation agriculture (CA) is to minimize the challenges imposed by climate change through C-sequestration by keeping the land covered with vegetation and/or crop residues round the year with no-till or zero tillage. The CA follows the principles of restoring the biodiversity and pedo-ecosystem. The selection of site-specific crop rotation based on parametric land evaluation followed by land use suitability identification may be the prerequisite for a given field plot. In this particular agriculture, one suitable cover crop is identified between two main crops based on nature and height of main crops already identified and such exercise needs exhaustive experience with indigenous knowledge and this may enable a soil scientist to work together with farmers in an interactive environment. Then, fix the balanced nutrition to the crops in rotation (including cover crops) based on soil fertility evaluation.

Soil covered with vegetation round the year may buffer the diurnal temperature change and minimize the organic matter decay considerably, thus, creating a congenial environment for C-sequestration. As farmers seek to change from chemical-based conventional farming systems to more sustainable kinds of agriculture i.e. organic farming, which may be adopted in conservation agriculture (CA) successfully, wherein one has to be sincere to use accessible organic sources like (i) crop residues comprising of both shoot and root residues (ii) plant debris in suitable sizes (< 2 mm but larger than 0.053 mm) (iii) humus (decomposed materials less than 0.053 mm that are dominated by molecules stuck to soil minerals) and (iv) compost, FYM, vermicompost and others, which are prepared locally (Bowden 2009). In CA, farmers should essentially learn, ahead of managing the organic resources, how to sustain soil moisture by managing organic source itself. The amount of plant available water can be determined by two parameters: (i) the lower limit i.e. the amount of water in the soil that plants cannot extract or utilize and (ii) the upper drained limit i.e. the amount of water that can be held against drainage. The difference between the upper and lower limit does define the potential available water holding capacity (PAWC) of a given soil. If this value can be increased even marginally through CA, it will help to sustain or simply maintain or optimize the potential productivity by allowing the soil to retain more water each time that rains. For any given clay content, as organic carbon increases the upper limit, the PAWC of the soil increases further (Bowden 2009). The amount of carbon in a soil results from the balance between inputs (plant residues or other sources) and losses (microbial decomposition and associated mineralization). Obviously, land economics will cover all these production processes through land use planning leading to adoption of conservation agriculture followed by a smart supply chain within the direct control of farmers.

CONCLUSION

Land economics is a powerful tool to control the process of land use planning through land and soil evaluation following the emerging need for adoption of conservation agriculture and subsequent application of a suitable supply chain system for the land uses or produces at the door of farmers. A success story of this programme will insure a long pending demand of poverty alleviation, climate change mitigation and adaptation and quality food production organically even. However, it requires governance and thus a strong government support across the globe. The FAO must work exhaustively on this line to approve the criteria of how best land economics would be the driving force to streamline the approaches under LUP leading to poverty alleviation, continued carbon sequestration, organic farming and quality food production by restoring the overall soil health. The author has recently developed the Indian system of Soil Classification based on land use options as the ultimate objective (Mishra 2015, 2016) and needs to be linked directly with land economics. However, there is need to develop a common working principle with classical framework of business management over land economics.

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Impact Assessment of Biopriming Mediated Nutrient Use Efficiency for Climate Resilient Agriculture

Amitava Rakshit
Department of Soil Science and Agricultural Chemistry,
Institute of Agricultural Science, Banaras Hindu University,
Banaras–221005, UP, India
E-mail: amitavar@bhu.ac.in

Abstract: Since environmental stress negatively affects crop growth and productivity throughout the world and the energy crisis threatens the *sustainability* of both irrigated and rainfed system, it is becoming increasingly evident that priming techniques can enhance and improve the performance of crops without deteriorating the natural resource base. Among the available options, on-farm seed priming is a simple, proven technology that has been an age old practice, tested, and refined in laboratories, in experimental plots, and by farmers themselves in their fields. It's easy to use with a wide range of crops in many different farming conditions. Farmers in the indo-gangetic plains of Utta Pradesh, India prime rice, wheat, maize and pulse seed before sowing. This simple method is now spreading to other parts of the country as well. Although priming with water or tiny amounts of phosphorus, boron and zinc is common but use of microbes can make a huge difference. Biopriming is becoming a potentially prominent technique to induce profound changes in plant characteristics and to encourage desired attributes in plants growth associated with fungi and bacteria coatings. Biological factors such as fungi and bacteria are used in biopriming which includes: fungi and antagonist bacteria and the most important of all are *Trichoderma, Pesodomonas, Glomus, Bacillus, Agrobacterium* and *Gliocladium*. Therefore, seed priming in combination with low dosage of biocontrol agents has been used to improve the plant performance, stabilize the efficacy of biological agentsin the present set up of agriculture and reducing dependency on chemical inputs.

HUGE ENERGY REQUIREMENT IN AGRICULTURE

Energy has always been essential for the production of food. Prior to the industrial revolution, the primary energy input for agriculture was the sun; photosynthesis enabled plants to grow, and plants served as food for livestock, which provided fertilizer (manure) and muscle power for farming. However, as a result of the industrialization and consolidation of agriculture, food production has become increasingly dependent on energy derived from fossil fuels (Table 1). Today, industrial agriculture consumes fossil fuels for several purposes i.e., fertiliser production, water consumption, farm equipment and processing, packaging and transportation.

Table 1: Input Statistics in Agriculture

Input	**Usage (10^6 Tonnes)**		**Subsidy (Rs. Billion)**		**Size of the Industry (Rs. Billion)**		**Energy Involvement (MJ kg^{-1})**
	India	**Global**	**India**	**Global**	**India**	**Global**	
Fertilizer	24.5	170	750	-	30	5000	78.2(N);17.5(P);13.8(K)
Pesticide	0.85	2.6	-	-	180	2500	215 (Harbicide), 238 (Insecticide) and 92 (Fungicide)
Bio pesticide	0.25	25	-	-	2	200	-
Bio fertilizer	0.28	200	-	-	4	180	0.01(liquid); 0.3(solid)

Source: Rakshit *et al.* (2015)

RISING ENERGY PRICES AFFECT AGRICULTURAL SECTOR

There are three ways by which agriculture sector is influenced by rising energy prices. Farmers have to pay increased prices for energy related inputs such as fuel and fertilizers. This requires more expenditure which, in turn, is reflected in increased cost of production or lower net farm income. Basically rising prices of crude oil or energy add to the general inflation in the country which in turn is fed into the agricultural sector through an increase in prices of all other agricultural inputs. In essence, rising energy prices lead to increased cost of cultivation. The impact of rising prices on agriculture will primarily depend upon the time taken for adjustments. Two time runs may be considered either short term or medium to long term. For farmers, a short term period can be up to one crop growing season or a year. Here, the adjustment time to react to rising energy prices is so short that farmers hardly change their production plans, search for new energy conservation measures, or substitute less energy intensive and relatively cheaper inputs for costlier energy related inputs. In most of the cases, farmers cut back on use of fertilizers to a certain extent. In the medium to long term situation, which could be more than a year or several years, farmers can react in many ways. They can change their production plans, grow less energy intensive crops, adopt energy saving technologies such as low input sustainable agricultural practices, and so on.

NUTRIENT BALANCE SHEET: ANOTHER CONCERN

An assessment of nutrient additions, removals, and balances in the agricultural production system generates useful, practical information on whether the nutrient status of a soil is being maintained, built up, or depleted. Nutrient balance sheets in most soils of India have been deficient and continue to be so. This is primarily because nutrient removals by crops far exceed the nutrient additions through manures and fertilisers. For the past 50 years the gap between removals and additions has been estimated at 8 to 10 M t N+P2O5+K2O per year which is being manifested to the multiplicity of nutrient deficiency problems across the last few decades presented in Figure 1.

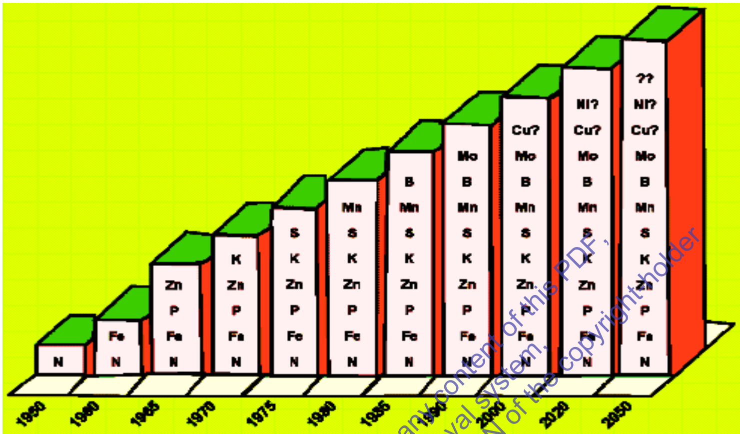

Fig. 1: Nutrient Deficiency Across the Last Few Decades

This has been the case in the past, at present, and this will likely continue into the future. To this extent, the soils are becoming depleted–the situation is akin to mining soils of their nutrient capital, leading to a steady reduction in soil nutrient supplying capacity (Table 2). On top of this deficit are the nutrient losses through various other means. For example, nutrient losses through soil erosion are alarmingly large, but are rarely taken into account.

Again awareness of and interest in improved nutrient use efficiency has never been greater. Driven by a growing public belief that crop nutrients are excessive in the environment and farmer concerns about rising fertilizer prices and stagnant crop prices, the fertilizer industry is under increasing pressure to improve nutrient use efficiency.

Data on N use efficiency for cereal crops from experimental plots reported that single-year fertilizer N recovery efficiencies averaged 65% for corn, 57% for wheat, and 46% for rice. However, experimental plots do not accurately reflect the efficiencies obtainable on-farm. Differences in the scale of farming operations and management practices (i.e. tillage, seeding, weed and pest control, irrigation, harvesting) usually result in lower nutrient use efficiency. Nitrogen recovery in crops grown by farmers rarely exceeds 50% and is often much lower. A review of best available information suggests average N recovery efficiency for fields managed by farmer's ranges from about 20% to 30% under rainfed conditions and 30% to 40% under irrigated conditions.

Table 2: Nutrient Use Efficiency of Major Nutrients

Nutrient	Efficiency
Nitrogen	30–50
Phosphorus	15–20
Potassium	70–80
Sulphur	<5
Zinc	2–5
Iron	1–2
Copper	1–2
Boron	2–3
Molybdenum	2–5

WHAT IS THE WAY OUT?

Given the growing population's food requirements, the world's finite supply of fossil fuels and the adverse environmental impacts of using this nonrenewable resource, the existing relationship between agriculture and energy must be dramatically altered. Among the most obvious solutions is to simply improve the energy efficiency of food production and distribution. This can be accomplished by shifting from energy-intensive industrial agricultural techniques to less intensive methods. Significant yield gaps in different regions that can be exploited through simple interventions such as better seed, nutrients, compatible mixing technologies and water management. However, it is generally necessary to move towards more sophisticated, more knowledge-intensive forms of agriculture–and provide the technologies and incentives that make it viable for farmers to adopt and adapt them. In crop production, agro-ecological intensification primarily implies to implement good agronomic management principles in a local context, including:

- Profitable and sustainable crop rotations
- Choosing quality seed of a well-adapted high-yielding variety or hybrid that also meets market demands
- Planting at the right time to maximize the attainable yield by capturing light, water and nutrients
- Maximize the capture and efficient utilization of available water
- Integrated soil and nutrient management, including conservation agriculture, balanced and more efficient use of fertilizers, as well as utilization of available biological and organic sources

With this back ground priming can be a viable option (Rakshit *et al.*, 2013) which is simple, inexpensive and improves plant acclimatizability under both biotic and abiotic stress.

BIO-PRIMING CAN BE THE ANSWER

Bio-priming is a process of biological seed treatment that refers combination of seed hydration (physiological aspect of disease control) and inoculation (biological aspect of disease control) of seed with beneficial organism to protect seed (Rakshit *et al*., 2014). It is an ecological approach using selected fungal antagonists against the soil and seed-borne pathogens. Biological seed treatments are becoming a safe aid for biotic and abiotic stress management.

SIMPLE TOOL

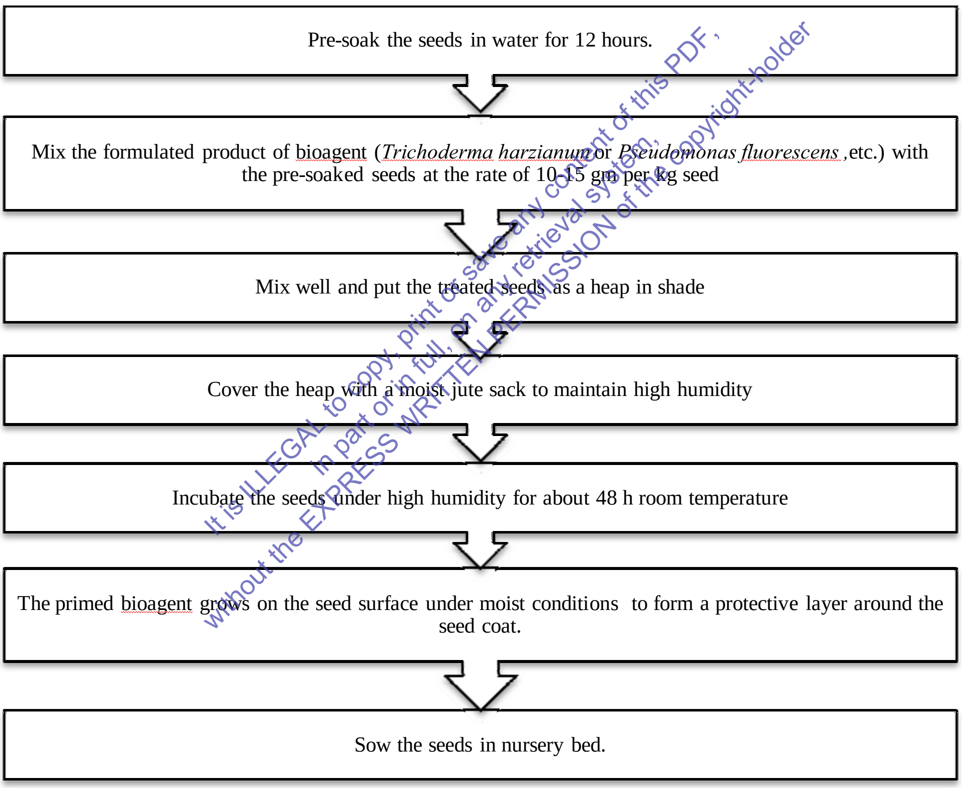

Fig. 1: General Procedure of Seed Biopriming

The methods of introducing biological agents is popular and user friendly (Bisen *et al*., 2015; Fig. 1). Seeds have to be pre-soaked the in water for 12 hours the formulated product of bioagent (*Trichoderma harzianum* and/or *Pseudomonas fluorescens*) have to be mixed with the pre-soaked seeds at the rate of 10 g per kg seed. Biological factors such as fungi and bacteria are used in biopriming which includes: fungi and antagonist bacteria and the most important of all are *Trichoderma, Pesodomonas, Bacillus, Rhizobacteria, Gliocladium* and *Agrobacterium*. Treated seeds are placed as a heap. The heap is to be covered with a moist jute sack to maintain high humidity and incubate the seeds under high humidity for about 48 h at approx. 25 to 32°C. Bioagent adhered to the seed grows on the seed surface under moist condition to form a protective layer all around the seed coat. The seeds have to be sown in nursery bed. The seeds thus bioprimed with the bioagent provide protection against seed and soil borne plant pathogens, improved germination and seedling growth. For seedling treatment suspension have to be prepared by mixing lkg bio-fertilizer culture in 10–15 litres of water. Seedlings required for one acre need to be tied in small bundles of seedlings. Root portion of these seedlings is dipped the in this suspension for 15–30 minutes and transplant immediately. Generally, the ratio of inoculant and water is 1:10 For vegetables like chilly, tomato, cabbage, cauliflower, 250 g of bio-fertilizer is sufficient for 0.1 ha of land.

Many small-scale farmers rely on basic tools, minimal technology to cultivate their crops, which exacerbates their vulnerability to changing energy scenario, weather patterns and other stressors that affect food security.

TREMENDOUS OPPORTUNITIES

Bio-priming provides a simple inexpensive method for improving plant nutrition as well as improving yield of crops. Bio-priming methods have practical advantages of minimal waste material produced compared to others.

- Decrease time between sowing and emergence and to improve seedling vigour.
- Increase nutrient use efficiency.
- Improves WUE of several crop species.
- Increases plant growth and nutrient uptake.
- Competence with weeds.
- Uniform growth of plants.
- Eliminates seed borne pathogens.
- Increases rate of germination.
- Overcome or alleviate phytochrome-induced dormancy in plants.
- Extend the temperature range at which a seed can germinate.

- Application of microbial agents in agriculture has four beneficial effects for plants. First, it can colonize plant root and its rhizosphere, second, control plant pathogens thought parasitism, and antibiosis production, and promote systemic resistance. Third, it improve plant health through increasing plant growth. Ultimately, these microorganisms stimulate root growth and improve plant growth. Studies showed that these group of microorganisms treatment increased fresh weight of root and leaf area index, lateral roots and the nutrient use efficiency in a number of crop species (Table 2).

Table 2: Effect of Bio Priming on Different Crop Species

Biopriming Agent	Crops	Response	Reference
Mycorrhiza	Common bean (*Phaseolus vulgaris),* Kinnow, Rice and Mung bean	Plant Nutrition	Tajini and Drevon 2012, Shamshiri *et al*. 2012, Li *et al*., 2009
	Wheat and Black gram	Resource distribution in plant communities	Shukla *et al*., 2012
	Wheat	Buffering against host plant stress	Gamal *et al*. 2012
	Maize, Green gram, sorghum, millet, mash bean and mung bean	Benefits in the context of agro ecosystems sustainability and role in the stability of ecosystem with climate change	Mobasser and Moradgholi 2012; Ananthi *et al*. 2011, Archana *et al*. 2011, Sharif *et al*. 2011, Amanullah *et al*. 2011
Trichoderma	Soybean, Cucumber, Tomato, Tea, Tomato, Rice	Enhancement of nutrient(macro and micro) use efficiency	Entesari *et al*., 2013, Santiago *et al*., 2012, Molla *et al*., 2012, Moharam and Negim, 2012, Thomas *et al*., 2010, Azarmi *et al*., 2011, Rodrigues *et al*., 2008, Yedidia *et al*., 2001
	Maize, Mustard, Bitter gourd, Betelvine, Muskmelon	Over all performance (above ground and below ground) with reference to yield and buffering against biotic stress	Karthika *et al*. 2013, P Lalitha *et al*., 2012, Lavania *et al*., 2006, Kaveh *et al*. 2011
Pseudomonas	Arabidopsis, Sunflower (*Helianthus annuus* L.), Sweet Corn	Increased growth attributes, nutrient use efficiency	Ryu *et al*., 2005, Moeinzadeh *et al*., 2010, Callan *et al*., 1991, Shaharoona *et al*., 2008
	Broad beans	Phytoremidiation potential	Radwan *et al*., 2005
	Strawberry, Radish	Buffering against biotic stress	Pirlak and Kose, 2009, Kaymak *et al*., 2008
	Wheat, Pea	Buffering against abiotic stress	Egamberdieva, 2008, Zahir *et al*., 2008

Table 2 (Contd.)…

…Table 2 (Contd.)

Bacillus	Rice, Pea, Mungben	Growth promotion under abiotic stress	Palmqvist, 2011, Zahir *et al.*, 2008, Ahmad *et al.*, 2011
	Cotton	Buffering against biotic stress	Flavio *et al.*, 2011
	Mangroves rhizosphere	Bioremidiation potential	Syakti *et al.*, 2013
Agrobacterium	Radish	Buffering against abiotic stress	Kaymak *et al.* (2009)
Gliocladium	Greenhouse cucumber, pepper & tomato	Buffering against biotic stress	Sabaratnam, 2012
PGPR Consortia	Radish (*Raphanus sativus* L.)	Buffering against biotic stress	Çağlar *et al.*, 2009
	Mung bean, Maize, Chickpea, Rajma, Barley	Increased growth attributes	Shaharoona *et al.*, 2006, Karthika & Vanangamudi 2013, Yadav *et al.*, 2013, Mirshekari *et al.*, 2012
	Cucumber, Arabidopsis (*Arabidopsis thaliana*)	Buffering against biotic stress	Ryu *et al.*, 2004, Ryu *et al.*, 2005

BIOPRIMING MEDIATED NITROGEN USE EFFICIENCY

Improving NUE is an important goal to harvest better crop yield on sustained basis. Studies have shown that the growth-promoting ability of microbes may be highly specific to certain plant species, cultivar and genotype (Table 3).

Crop	Bioagent	Nitrogen Use efficiency	Reference
Rice(*Oryza sativa*)	A. amazonense	N (3.5–18.5%)	Rodrigues *et al.* (2008)
Maize (Zea mays)	*T. harzianum*	8.8-9.76% N in root; 3.5% N in shoot	Akladious *et al.* (2012)
Soybean (*Glycine max*)	*Trichoderma harzianum AS 19-2*	N (15.8%)	Entesari *et al.* (2013)
Broccoli(*Brassica oleracea*)	AM fungi	N-102.08%	Tanwar *et al.* (2013)
Cucumber (*Cucumis sativus*)	*T. harzianum 4*	N (13%); P (12%); K (11.7%)	Moharam and Negim (2012)
Melon *(Cucumis melo)*	*T. harzianum*	N (27.03%)	Martínez-Medina *et al.* (2011)
Tea (*Camellia sinensis*)	*Trichoderma harzianum*	N (44%)	Thomas *et al.* (2010)

WHERE DO WE STAND NOW?

Bi-priming technology has been distributed through various channels to improve the livelihoods of resource-poor farmers in marginal environments. In addition detailed advice, research protocols and supporting materials concerning seed priming, have been provided in response to enquiries from individuals and organisations across the length and breadth of the sate who have expressed an interest. The technology has been featured on the radio and on TV on several occasions. Thousands of farmers, researchers and extensionists through RKVY training, farmers training have been exposed to this technology and enough time has elapsed to allow us to follow up and learn from their experiences. In addition, studies on bio-priming technology have been funded directly by ICAR under seed platform. However, more fundamental research will certainly be necessary to understand the nature of the relation between seed priming and integrated resource management.

CONCLUSION

Rising concern among scientists and general public regarding serious health hazards on human health associated with use of chemical in food supplies have propelled research for ecofriendly alternative approaches for integrated crop management for overall growth promotion and performance. Seed biopriming using biological control agents and growth promoter may be an appropriate alternate choice as biopriming with different beneficial microbes may not only enhance seed quality but also boost seedling vigor and ability to withstand abiotic and biotic stresses, and thus offer an innovative crop protection tool for the sustainable improvement of crop yield.

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Decreasing the Vulnerability to Climate Change in Less Favoured Areas of Bihar: Smart Options in Agriculture

Anshuman Kohli[1]*, Sudhanshu Singh[2], Sheetal Sharma[2], S.K. Gupta[3], Mainak Ghosh[3], Y.K. Singh[1], B.K. Vimal[1], Vinay Kumar[1] and Sanjay Kumar Mandal[4]

[1]Department of Soil Science and Agricultural Chemistry, [3]Department of Agronomy
[4]Krishi Vigyan Kendra, Jagatpur, Banka, Bihar Agricultural University, Sabour, Bhagalpur–813210, Bihar
[2]International Rice Research Institute (IRRI), NASC Complex, Pusa, New Delhi–110012
*E-mail: *anshuman_kohli@hotmail.com*

Keywords: Climate Change, *Ahar-pyne* System, Biochar

INTRODUCTION

Climate change is the global environmental and humanitarian concern and with increasing awareness and scientific efforts to monitor and combat climate change, the threat of changing climate appears more real. Agriculture is the precursor for economic growth and more vulnerable sector than others because of its inherent larger dependence on weather and climate. The challenge and threat from climate change in agriculture has been thought to be manageable with a host of adaptive and mitigating options. The mitigation options can be exercised by all consumers and producers; however, adaptive role is largely limited to the stakeholders such as the primary cultivators and others engaged in primary occupations. The adaptation has to be in proportion with their vulnerability or their stake.

POSSIBLE INDICATORS OF GLOBAL CLIMATE CHANGE

There is a general consensus among the scientific community that the threat of climate change is real on a global scale. There are indicators include a generalised global warming characterised by a gradual increase in the mean temperature, increased atmospheric concentration of green house gases, seal level rise, erratic weather patterns, and the increased frequency of extreme weather events. Though the climate of the globe has never been constant on a geological scale, the scientific data available has confirmed beyond doubt that the climate of the globe is changing on scales far shorter than the geological scale, largely because of anthropogenic activities.

VULNERABILITY OF THE LESS FAVOURED AREAS

Communities living in the less favoured areas are more vulnerable because they have lesser access to resources. They need to adapt to a greater degree in order to decrease their vulnerability to the effects of climate change. The flood prone areas on the banks of Ganges, Kosi, Gandak, Budhi Gandak, Mahananda and their tributaries; the rainfed ecosystems of south Bihar; the *tal* and *diara* lands; *chaur* lands; and the areas fed by the *ahar pyne* systems, have characteristics as the less favoured areas in Bihar. Despite their potential to produce under designated management, these areas have not received attention in terms of development initiatives, largely because these are not the ideal choice of the development professionals. Development professionals usually prefer more remunerative postings and even the private sector enterprises do not give an equitable share to these areas. This could partially be because of the lack of infrastructure facilities and partly also due to the tendency to concentrate in the comfort zone.

Another conviction in asserting that the communities in the less favoured areas are more vulnerable to climate change is that the less favoured areas are so largely because of their agro-climatic locations or agro-ecological setting. These areas are less favoured simply because of the harsh agro-climatic conditions that make the agricultural enterprises in these conditions more risky than in the competing areas. Although the communities have adapted to the harsh agro-climate of these areas and there are technologies (both traditional as well as modern) for sustained productivity from these locations, this call for an extra effort and a greater risk; which weans the stakeholders from these ecologies at the very first opportunity in the comfort zone. To illustrate the vulnerability of communities in the less favoured areas to climate change, let us consider the behaviour of irrigation production function in the scenario of climate change (Figure 1). If suppose the climate change scenario involves the shift from a normal to a drier regime, though the irrigation production function would show a southward shift meaning a decrease in the yield of all crops at the similar level irrigation, the maximum decrement in relative terms would be observed in case of rainfed crops. Contrastingly, if the change involves the shift from an existing to a wetter regime, the irrigation production function would show a northward shift meaning an increase in the yield of all crops at the same level of irrigation with a maximum increment in case of rainfed crops. In the first scenario, obviously the most vulnerable communities would be those inhabiting the rainfed areas. In the second scenario, the vulnerability of the rainfed communities would be no less because they are likely to encounter an extreme of the precipitation events which would call for a greater adaptation given their original adaptation for the water scarce environments. Another community at the receiving end in a scenario of shift to a wetter regime would be those inhabiting the flood prone areas which have the increased risk of flooding. These areas, having fewer and poorer infrastructure facilities, have the danger of facing greater losses with the advent of similar inclement weather conditions.

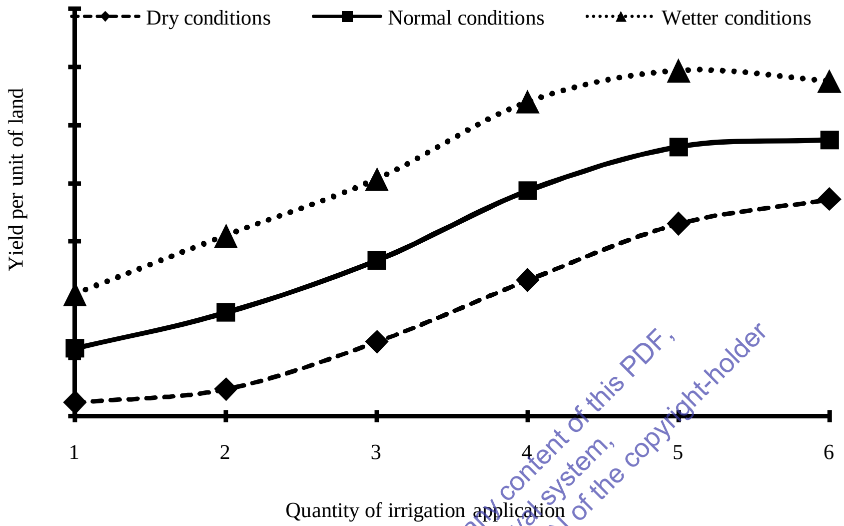

Fig. 1: Production Function for Irrigation under Climate Change

MANAGEMENT ADAPTATIONS FOR MITIGATING CLIMATE CHANGE

Amongst the various possible indicators of global climate change discussed above, the indicator that is likely to respond directly to management adaptations in agriculture is the concentration of green house gases in the atmosphere. The management adaptations that can contribute to decreasing the emission of greenhouse gases from the agricultural soils are primarily reducing or eliminating tillage along with a host of management decisions that can increase crop intensification and plant production efficiency. To illustrate, let us consider a hypothetical case where there is a certain level of greenhouse gas emission under a traditional management regime. These emissions will usually be far greater than those under a fallow system but fall short of those under an intensified production system. This is the scenario when we consider the emissions per unit of land area per se. With a consideration that there is a need to grow more food for the increasing demand due to increasing population as well as to meet the requirements of improved lifestyles, there is no alternative to intensification. Fallowing cannot be allowed when taking decision based on economic sense. Hence, in our analysis, if we just try to focus on emission per unit land area per unit of output or production, we can see that the emissions scenario will be the best for an intensified system followed by that of a traditional cultivation system or a fallow, which could vary with the season. So this means that the whole set of practices that characterise a system as intensive can contribute to a decreased overall load of greenhouse gases in the environment.

SUBTLE CLIMATE SMART TECHNOLOGIES

Climate smart technologies are simple production techniques or apart from the techniques that can potentially reduce the vulnerability to climate change. One of them is preferring cultivation of resilient crops. One example of such resilient crops is millets in rainfed environments during the *kharif* season. Another is *lathyrus* during the *rabi* season. Such resilient crops are least dependent on external inputs and have a lower incidence of pests and diseases. Traditionally these crops have been grown with broadcasting the traditional seeds and can compete with the native weeds in the rainfed environments. They are generally capable of completing their life cycle from seed to seed solely on the soil moisture residual from the previous crop. The root system is robust to capture the soil moisture from the lower soil layers even when the upper soil layers become too dry to allow any vegetation. When roots transgress the lower layers of the profile for moisture, they inadvertently access the nutrients held up in these soil layers and also enrich those layers with the root exudates and associated organic carbon. During broadcasting of seeds, the traditional practice is to use slightly higher seed rates which takes care of the lower germination under rainfed environments. In case of a rainfall event during the initial stages there is an increased plant population which also gets an extra bout of nutrients from the upper profile till the time it has sufficient moisture. Research into sustainable intensification of these practices under such resilient systems has provided resilient cultivars of various crops that can compete with the water limited environments. This has been made possible by breeding of varieties that have a more robust and extensive root system, those which can be cultivated in a bigger planting window that makes them resilient across cropping systems as well as vagaries of weather. This is just another expression of a cultivar resilient to climate change. An example that is coming out of research initiatives in eastern India is that Planting of medium to short duration rice varieties such as *Sahbhagi dhan* make it possible to use residual soil moisture for establishment of the subsequent dry season crop (Figure 2).

Fig. 2: Drought Resistant Rice Cultivar Sahbhagi Dhan Cultivated in Rainfed Tracts of Banka Amidst Traditional Rice Cultivars Depict a Distinct Advantage in Terms of the Availability of an Early Window for Planting Rabi Season Crops that Can Utilize Soil Moisture Residual in the Rice Fields for Crop Establishment and a Substantial Portion of the Early Growth

Scientific research has demonstrated such practices as zero or minimum tillage to be more resilient in the unfavourable environments than the conventional practices. The traditional crop establishment practices such as *bhokha* (direct drilling) or *paira* (relay cropping) have an advantage over the conventional tillage in terms of an early crop establishment that enables the crop to complete a portion of its life cycle on the residual soil moisture. Lack of tillage further reduces the soil moisture loss during the subsequent stages of the crop. This is akin to resilience against climate change. The improved resilient crop establishment practices employ the same principles involving an early establishment of the crop and minimizing tillage so as to retain as much residual soil moisture as possible. Another subtle technology is showing respect to and following the time tested traditions. For instance, the *ahar-pyne* systems prevalent in the plains of south Bihar, present a lively example of a tradition so suited for a fragile ecosystem. An *ahaar* is a traditional water harvesting structure which is a common sight in the rainfed lowland tracts of several districts in south Bihar. Structurally, an *ahaar* is a catchment basin embanked on three sides and the fourth side consisting of a natural gradient of the topography. Substantial areas along the highways can be seen in Gaya that have evolved such systems with a thorough understanding of the local topography and agro-climatic conditions. The lifeline of *ahaars* are the *pynes* which simply are the channels leading water to or from an *ahaar*. The crops being cultivated on the pyne bed include chickpea/ lentil, vegetable peas and wheat. The conventional practice is to broadcast the seeds and then till the soil with a bullock driven plough to cover the seeds. The seedbed is usually very cloddy in case of vegetable peas and chick pea, which are being grown in the area without any supplemental irrigation; however the seed bed for wheat is comparatively smoother. Probably the indigenous communities recognize the presence of water in the profile and so the existing practice is of tilling the soil leaving a cloddy surface with much surface roughness and breaking the capillaries to restrict the movement of profile soil moisture to the surface soil. These indigenous practices are an essential part of the rainfed cultivation of rabi season crops in the ecology. The *ahaar* bed is usually flooded during the *Kharif* season and so there is limited scope of cultivation. However, the advent of the *rabi* season enables cropping in phases as visible in distinct bands as the water level in the *ahaar* recedes (Figure 3). The *Ahaars* can be seen very densely scattered in the area as identified in the archived post monsoon LANDSAT-TM imagery (Figure 4).

Fig. 3: Rabi Cultivation in an Ahaar of Khizarsarai Block of Gaya District Shows a Distinct Gradient in the Time of Planting of Rabi Season Crops Based on Drying of the Ahaar Bed Starting from the Highest Point in the Watershed to the Lower Points

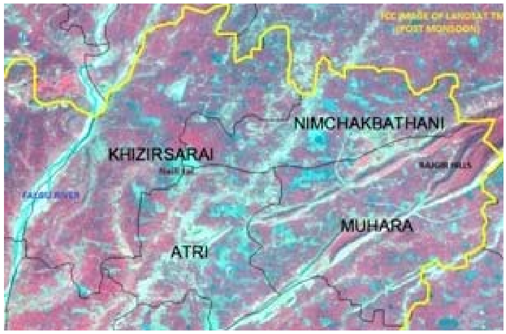

Fig. 4: Based on Visual Interpretation Key, the Ahaar-Pyne Systems Can be Seen Densely Existing in the Rainfed Tracts of Gaya District

DIVERSIFICATION AND INTENSIFICATION OF RAINFED SYSTEMS REDUCES VULNERABILITY TO CLIMATE CHANGE

Drought is a widespread abiotic stress and drastically reduces rice yield. Technologies that reduce the production risk caused by drought will favor input use and have a major impact on system productivity in good and bad years. In addition, improved technologies that reduce labor and land requirements for crops are needed to allow these resources to be released for other income-generating activities. Several varieties of rice have been evaluated for tolerances to abiotic stresses such as drought and submergence. Drought affects rice at morphological, physiological, biochemical and molecular levels and thereby affects its yield. Good opportunities for diversification through post-rice crops are provided by the development of new drought-tolerant short-duration rice varieties/lines such as Sahbhagi dhan and Susk Samrat. Most farmers practice limited or no cropping during the Rabi season in drought-prone areas of Bihar, thus failing to realize the full production potential of their land. New area specific systems need to be developed to improve the post-rice production. Timely and appropriate planting techniques allow earlier-maturing crops, maximizing the use of residual water for post-rice *rabi* crops. New, improved varieties of *rabi* season crops, notably pulses, allow for a greater range of options for *rabi* season cropping and land productivity. Broadcasting of seeds of pulses like lentil or lathyrus into the standing rice crop before harvest is practiced in these areas if sufficient moisture is available. There is a strong need of managing midterm and terminal droughts of 2–3 weeks to have a capacity for intensifying cropping in hitherto single crop situations; more so because of the prevailing low cropping intensity in these areas (e.g. the cropping intensity of Bihar is just 146 per cent). Besides weather, soil moisture availability in a situation also depends on land use practices. There is a need to identify agricultural practices that maximize precipitation utilization and minimize evaporation. Reduced tillage, raising the height of farm bunds, rational residue retention and reducing the time of fallow between crops can allow better utilization of precipitation. Soil incorporation of biochar like substances can improve the water holding capacity, infiltration rate, microbial ecology and nutrient relations. System diversity can be increased by introducing interventions such growing short to medium duration legumes like chickpea, green gram, grass pea, vegetable peas and lentils or short duration oilseeds like linseed. A host of practices that aim to increase the infiltration opportunity time, minimize evaporation, decrease soil bulk density and erosion susceptibility, increase the access of the rainfed crops to the stored water and nutrient resources in the lower layers, staggered planting in conjunction with diverse crop rotations, weed management, controlling grazing and human interference and avoidance of terminal heat stress can contribute towards obtaining greater yields from rainfed agriculture on a sustainable basis. However, the effects of each of management option needs to be quantified on a uniform scale for the effects to be additive and comparable.

TARGETING PRECISION NUTRIENT MANAGEMENT USING IT ENABLED TOOLS FOR SMALLHOLDERS IN LESS FAVOURED AREAS FOR MITIGATING CLIMATE CHANGE

Precision nutrient management aims at satisfying the total mineral nutrient requirements of the crop by filling the deficit between the total needs to the crop and the soils' indigenous supply by first ensuring the effective use of the indigenous nutrients and then assessing the crops additional needs based on an attainable yield target. The benefits towards mitigating climate change by adopting precision nutrient management are expected in terms of the savings in fertilizers and increased fertilizer use efficiencies that can reduce the emissions of green house gases. The conventional approach for implementing a precision nutrient management programme is through soil testing based management. There is no doubt about the validity of this approach, but still it is a fact that despite the best efforts of government agencies, agricultural universities and others, the soil testing programme has had little visibility. This is obvious considering the high cost of analysis and difficulty in availability of timely results of analysis. Of late, several organizations have made concerted efforts to develop IT enabled tools to recommend a balanced fertilizer dose for various crops considering the system as a whole. Use of SSNM-based fertilizer recommendations for rice were shown to increase yields, increase net income of farmers, and provide positive impacts on the environment when compared to existing fertilizer practices. Field experiments were conducted at Bihar Agricultural University, Sabour with tools such as Nutrient Expert™ for Hybrid Maize, Nutrient Expert™ for Rice, Rice Wheat Crop Manager, Rice Crop Manager for stressed conditions (drought) and with Crop manager for rice based systems, all of which have shown a potential for considerable fertilizer saving, improving yields and profitability.

SUSTAINABLE BIOCHAR TECHNOLOGY FOR MITIGATING CLIMATE CHANGE IN LESS FAVOURED AREAS

Scientific literature is multiplying exponentially with new benefits and applications of biochar as a soil conditioner and as a carbon negative technology. No other technology has a potential to trap atmospheric carbon dioxide in the soil for a time scale greater than that offered by biochars, whose mean residence time in the soil is of the order of thousands of years. During biochar production, up to a large fraction of the carbon in the original organic residue is retained in the crystalline biochar structure. Simultaneously, there is production of energy in the process. Thus our organic residues/ wastes can be used for energy production using vessels which allow pyrolysis. The byproduct of these energy production systems can be a useful material known as biochar. Biochar production can be achieved during energy production systems at household to industrial scale. For instance, electricity co-generation in several rice mills is achieved by pyrolysis of rice husk, and this simultaneously produces rice husk biochar. The communities in the less favoured areas are dependent on fuel wood or other agricultural waste biomass for cooking activities with traditional stoves. At a household scale, there are top lit up draft (TLUD) stoves that can be used for cooking with any organic residue as feedstock and result in generation of clean energy for cooking and simultaneously producing biochar as a byproduct. TLUD technology needs to be promoted as a low external input technology which can be used easily in the far flung areas and hinterlands as against the current impetus of the governments on taking LPG connections to each household. Use of biochar in soils not only increases crop productivity, but also improves soil tilth, fertility, water holding capacity, reduces risk of soil erosion and the need for fertilizer inputs.

Tackling Climate Change: A Breeder's Perspective

P.K. Singh

Professor & Chairman and R.S. Singh
Department of Plant Breeding and Genetics
Bihar Agricultural University, Sabour

Abstract—The threat of climate change is well evident by the fact of increasing temperature and more frequent severe drought and floods in recent times, and higher incidence of insects-pest and diseases impacting agriculture and food production. This situation has aggravated the scarcity of food and hunger around the world. To mitigate the ill effects of climate change, developing climate resilient varieties for heat, cold, drought and flood stresses is one of the options, where breeders can play major role. Several Institutions in the world are engaged in developing viable strategies. This will require a much better understanding of our genetic resources, the underlying mechanism of gene interactions and pyramiding multi-stress related genes for developing new variety or improving the already cultivated variety. The most suited approaches should involve conventional breeding as well as new emerging technologies like doubled haploidy, marker-assisted selection, high throughput phenotyping and bioinformatics to hasten the crop improvement. For breeders, ample opportunity lies in developing climate resilient high-yielding varieties, resistant/ tolerant to biotic and abiotic stresses that help increasing food production and productivity, thus ease the cultivation under climate change regime. In this direction, several international institutes have initiated work on developing climate resilient crops, for example, the International Rice Research Institute (IRRI) has released 44 varieties of rice that are resilient to the effects of climate change and work is underway on a tripartite rice variation to cope with stresses like droughts, floods and saltiness. Even, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) identified 40 germplasm lines of chickpea with resistance to extreme weather conditions such as drought, high temperature and salinity. In India, various ICAR institutes and state agricultural universities, under National Innovations on Climate Resilient Agriculture (NICRA) programme, made the concerted efforts to develop different high yielding cultivars with enhanced tolerance to heat, drought, flooding, chilling and salinity stresses for different agro-climatic zones. Thus, effect of climate change can be withstand to a greater extent with a suitable genetic blue print in our cultivars and that need more focussed research and development from breeder's side.

Keywords: Climate Change, Plant Breeding, Genetic Resources, Climate Resilient Varieties

INTRODUCTION

Climate change is very obvious now, we see increasing temperature, increasing CO_2 concentration, melting of glacier and rising global average sea level. The threat of climate change is well evident also by the fact of more frequent and severe drought and floods in recent times, and higher incidence of insects-pest and diseases impacting agriculture and food production. For breeders, ample opportunity lies in developing eco-friendly and high-yielding varieties, resistant to pests and diseases that could increase food productivity and production, thus ease the cultivation under climate change regime. Modern breeding methods enable faster and more efficient breeding of crops adapted to specific regions. Breeding a particular variety for a specific situation gets further boost with the help of genomics-based approaches.

The International Rice Research Institute (IRRI) has released 44 varieties of rice that are resilient to the effects of climate change and work is underway on a tripartite rice variation to cope with stresses like droughts, floods and saltiness. Even, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) identified 40 germplasm lines of chickpea with resistance to extreme weather conditions such as drought, high temperature and salinity. Similarly, International Centre for Agricultural Research in the Dry Areas (ICARDA) has started evolutionary participatory programmes for barley and durum wheat. In our country, various ICAR institutes and state agricultural universities, under National Innovations on Climate Resilient Agriculture (NICRA) programme, made the concerted efforts to develop different high yielding cultivars with enhanced tolerance to heat, drought, flooding, chilling and salinity stresses for different agro-climatic zones. Thus, effect of climate change can be withstand to greater extent with a suitable genetic blue print in our cultivars and that need more focussed research and development from breeder's side.

CLIMATE CHANGE IMPACT ON AGRICULTURE

Increased intensity and frequency of storms, drought and flooding, altered hydrological cycles and precipitation variance have implications for future food availability. The potential impacts on rainfed agriculture *vis-à-vis* irrigated systems are still not well understood. The developing world already contends with chronic food problems. Climate change presents yet another significant challenge to be met. While overall food production may not be threatened, those least able to cope will likely bear additional adverse impacts (WRI, 2005). In developing countries, 11 percent of arable land could be affected by climate change, including a reduction of cereal production in up to 65 countries and about 16 percent of agricultural GDP (FAO, Committee on Food Security Report, 2005).

Enhanced frequency and duration of extreme weather events such as flood, drought, cyclone, cold and heat wave as a result of climate change may adversely affect agricultural productivity. This is projected to reduce the crop yield in India, like in irrigated rice by ~4% in 2025 and rainfed rice yield by 6%; wheat by 6 to 23%; mustard by 2%; potato by ~2.5 %, rainfed sorghum by 2.5%; maize yield in Kharif season by 18% (www.nicra.iari.res.in).

The growing concentration of CO_2 in the atmosphere, global warming and a higher frequency of extreme weather events mean increasing fluctuations in yields from agricultural crops and growing yield losses. The initial effects of the shift in climatic zones, vegetation zones and habitats are already visible: Pest and disease pressure on crops is growing. Global population is increasing while arable land area reducing day-by-day due to industrialization and human encroachment, and at the same time water shortages like situation, decreases the efficiency of agricultural production. In the short to medium term, agriculture can adapt by means of agronomical measures, such as tilling, crop rotation and optimized fertilization methods, and plant protection measures to safeguard the plants.

Each and every sphere of agriculture get affected by climate change be it crops, pasture, forests and livestock, land, soil and water resources, weed and pest, besides socio-economic impacts. The increased temperature (2–4°C) by 2100, rise in CO_2 concentration, droughts and floods might be frequent events of future therefore, emphasis needs to be on climate smart agriculture with the aim of reduction of greenhouse gas emissions enhanced resilience and reduced wastes with the increase in the productivity of small and large scale farmers (Mukhtar *et al.*, 2013).

How Can Plant Breeding Help

Increasing frequency of biotic stress is also highly probable. Plant breeding has addressed both abiotic and biotic stresses for a long time. Strategies in the face of climate changes may be based more on plant architectural changes to plant nutrient use efficiency, photoperiod and temperature responsiveness, with different maturity period to escape or avoid the unfavourable situation crop life cycles. Development of new more climate-resilient crop varieties will always be critical. All the cereals, oilseed, pulses, vegetables, flowers and fruits that is part of our day today life come from varieties developed by plant breeders and grown by farmers across the world. Now, with the intervention of modern genomics and biotechnology tool, the development of new adapted varieties has become a more precise and rapid process that contributes in feeding the world and tackling Climate Change at the same time. In the present scenario, the most suited approaches should involve conventional breeding as well as new emerging technologies like doubled haploidy, marker-assisted selection, high throughput phenotyping and bioinformatics to hasten the crop improvement.

For long time, plant breeders have been applying mutagenesis to induce genetic variation for increasing crop yield and improving the adaptability of crop plants. In the beginning, the X-ray radiation and gamma-ray radiation were used to induce point mutations and chromosomal mutations (Muller, 1927, Devreux and Scarascia Mugnozza, 1964). Designing crop breeding system suited for climate change with the help of superior combinations of genes into new varieties for new cropping systems and new environments. Environmentally friendly varieties such as improved varieties resistant to pests require fewer pesticides. Increase food production per unit area and alleviate pressure to add more arable land to production systems. The new improved varieties should be environmentally friendly, ensuring food security, while conserving the environment. Designing the crop breeding systems (1) to study the useful traits in response to various climatic factors such high CO_2 and high temperature, (2) a non-invasive phenotyping methods for specific traits, and (3) simulation of phenotypes will be helpful in plant breeding programs.

EXPLORING PLANT GENETIC RESOURCES

Utilizing our plant genetic resources as source of traits/genes for resilience to changing environmental conditions and stresses could be a good option. Biodiversity itself is capable of providing genetic resources resilience to changing environmental conditions and stresses. The concerted effort on their bio-prospection is needed. The variability is the essence of plant breeding and the exploitation of plant ecosystems has resulted in loss of many valuable genetic resources. Plant breeders in recent time can take the advantage of genetics and genomics in characterizing the genetic resources so that enhanced breeding materials could be developed. The institution like National Bureau of Plant Genetic Resources (ICAR-NBPGR) does the task of several jobs related to plant genetic resources from introduction, exploration and collection, documentation, quarantine, maintenance and sharing. The gene bank maintained at NBPGR is good resource for exploring the genetic resources for traits suitable for high temperature, drought, and flooding, high salt content in soil, pest and disease resistance have been harnessed for new crop varieties by national and International programmes.

Developing genetic responses to climate change is incumbent on effective evaluation and exploitation of the existing genetic variability. Use of molecular markers to predict adaptive variability is rather ineffective because little correlation exists between molecular genetic diversity and quantitative genetic variation (Gilligan *et al*. 2005). Genomics possesses the potential to increase the diversity of alleles available to breeders through mining the gene pools of crop wild relatives. Genomics tools also enable rapid identification and selection of novel beneficial genes and their controlled incorporation into novel germplasm. In the genomics era, this technology will be used to safeguard the future through improved food security. Taken together, the application of genomics for crop germplasm enhancement offers the greatest potential to increase food production in the coming decades. With continued rapid advances in genome technologies, the application of genomics to identify and transfer valuable agronomic genes from allied gene pools and crop relatives to elite crops will increase in pace and assist in meeting the challenge of global food security.

CONVENTIONAL BREEDING APPROACHES

One of the strategies for introgressing traits to mitigate the effect of climate change on plants performance for sustainable food production is identifying and incorporating suitable alleles by means of conventional breeding approaches. For this purpose, crop relatives have been used for decades for breeding, in particular to transfer genes of resistance or tolerance to pests, diseases or abiotic stress to the cultivated species (Hajjar and Hodkin 2007; Honnay *et al*., 2012). In case of non-availability or no known source of suitable alleles, mutation breeding is one of the choice upon which breeder's can rely. By exposing seeds to mutagenic chemicals or radiation the mutants are generated with desirable traits to be bred with other cultivars. In radiation-based approaches, FAO/IAEA reported in 2014 that over 1,000 mutant varietals of major staple crops were being grown worldwide.

In India, Bhabha Atomic Research Centre (BARC) has contributed a lot by induced mutation (mostly using gamma rays)-based varietal development programme in different crops for example, groundnut, mungbean, blackgram, soybean, redgram, cowpea, mustard, rice and jute.

Mutation breeding using radiation technology for crop improvement is an active area of research at the Bhabha Atomic Research Centre (BARC), Trombay, Mumbai. (http://dae.nic.in). Using radiation induced mutation and cross-breeding, 39 new crop varieties (Trombay varieties) developed at BARC have been released. These include 20 in oil seeds (14-groundnut, 3-mustard, 2 soybean, 1 sunflower), 17 in pulses (8-greengram, 4-blackgram, 4-pigeonpea, 1-cowpea) and one each in rice and jute for high yield, some with additional desirable characters like disease resistance, early maturity, suitability to rice fallows, improved quality parameters etc. (Table 1).

Table 1: Varieties Developed by Mutation Breeding for Various Stresses

Crop	Recommended for States	Features (Including Stress Tolerance)
Groundnut		
TG 26	Gujarat North Maharashtra Madhya Pradesh	Earliness, high harvest index, 20 days seed dormancy, smooth pods, salinity tolerance, high harvest index
TG 37A	Haryana, Rajasthan, Punjab, Uttar Pradesh, Gujarat, Orissa, West Bengal, Assam, North Eastern states	High yield, smooth pods, wider adaptability, collar rot and drought tolerance
Sunflower		
TAS-82	Maharashtra	Black seed coat, tolerant to drought
Pigeonpea		
TJT-501	Madhya Pradesh, Gujarat, Maharashtra, Chhattisgarh	High yielding, early maturing, tolerant to Phytophthora blight
Mungbean (Green gram)		
TJM-3	Madhya Pradesh	Resistant to powdery mildew, yellow mosaic virus and Rhizoctonia root–rot diseases.
TM 2000-2	Chhattisgarh	Suitable for rice fallows and resistant to powdery mildew
TMB-37	Eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal, Assam	Tolerant to yellow mosaic virus
Urdbean (Black gram)		
TU 94-2	Andhra Pradesh, Karnataka, Kerala, Tamil Nadu	Resistant to yellow mosaic virus

Source: http://dae.nic.in

ICAR-National Rice Research Institute, Cuttack, has development blast tolerant mutants of rice (CRM 49, CRM 51 and CRM 53) from IR 50 (a blast susceptible variety) through mutation breeding (chemical-based mutagenesis). CRM 49 and CRM 51 were isolated from sodium azide-treated populations, while CRM 53 from ethyl methane sulfonate (EMS)-treated populations. These mutants possessed semi-dwarf stature, long slender grains and with a yield potential of 5 t/ha.

In mutational programme, the work on calmodulin-binding protein gene family involved in abiotic stress responses in rice is going on at BAU, Sabour. More than 1,50,000 M_3 mutant rice (Gamma irradiated) plants of Rajendra Mahsuri-1 and Rajendra Kasturi were grown and screened for drought stress in field condition. Rice mutants (R. Mahsuri-1) were showing different phenotypes like early flowering, increased L/B ration and any marked visual changes were selected.

BREEDING STRATEGIES FOR MAJOR CLIMATE CHANGE EFFECT

The breeding strategies to tackle the adverse climate change effect on crops should encompass the development of stress tolerant genotypes together with sustainable crop and natural resources management along with sound implementation of policies. Meanwhile, development of resistance genotypes to biotic/abiotic stresses, choice of crops, change in the cropping patterns, rotation, time of planting and avoidance, nutrient use efficiency and the approaches like wide hybridization, mutagenesis, genomics-assisted breeding and transgenic will be very helpful to achieve the goal of yield sustainability.

Under "National Inovation in Climate Resilient Agriculture" (NICRA), IARI has developed a new crop varieties with higher yield potential and resistant to multiple stresses (heat, drought, flood, salinity) that will be the key to maintain yield stability. Two germplasm, Nerica L44 and N22 were identified as novel sources of heat tolerance in rice by the Institute. Further, in an effort to map the QTLs governing heat tolerance recombinant inbred line mapping populations are being generated involving heat tolerant genotypes namely L44 and N22, which are in F4 generation. Marker assisted backcross breeding was carried out using molecular marker linked to the QTL governing drought tolerance, q DTY1.1 into Pusa Basmati 1 and q DTY3.1 into Pusa 44 and 41 (in Pusa Basmati 1 background), 36 (in Pusa 44 background). Similarly, in wheat the standardized physiological trait-based phenotyping protocol for screening for heat and drought tolerance in wheat and also, maize genotypes tolerant to low and high temperature tolerance were identified.

Table 2: List of Varieties Released by ICAR-IARI for Various Stresses

Crops	Variety	Stress
Maize	Pusa Composite 3, Pusa Composite 4	Moisture stress
Karan rai	Pusa Swarnim (IGC01), Pusa Aditya (NPC9)	
Pearl millet	Pusa Composite 383, Pusa Composite 443, Pusa Composite 612	
Pigeonpea	Pusa 991	Salinity
Indian mustard	Pusa Vijay (NPJ93)	
Wheat	Kaushambi (HW 2045), Pusa Gold (WR544), Pusa Basant (HD2985), Pusa Wheat111, (HD2932), Harshita (HI1531)	High temperature tolerance
Chickpea	Pusa 547	
Mungbean	Pusa 9531	
Indian mustard	Pusa Agrani (SEJ2), Pusa Mahak (JD6), Pusa Vijay (NPJ93), Pusa Tarak (EJ13), Pusa Mustard25, (NPJ112), Pusa Mustard26, (NPJ113), Pusa Mustard27 (EJ17)	
Mungbean	Pusa 0672	Cold tolerance
Maize	AH421 (PEHM5)	Water logging
Cotton	PSS2 (Arvinda)	Hot and humid conditions
Wheat	VSM (HD 2733), Kaushambi (HW 2045)	Diseases-pest
Chickpea	Pusa 1088 (Kabuli)	

Source: http://www.iari.res.in

Maize inbred lines were also screened for multiple disease resistance. In tomato, two wild species i.e., *L. peruvianum* and *L. pimpinellifoium* crossable to cultivated tomato have been identified for temperature stress tolerance. Among cultivated genotypes (Pusa Sadabahar and TH-348) and hybrids (DTH-9 and DTH-10) were identified for heat stress tolerance.

Under Cereal Systems Initiative for South Asia (CSISA) programme, at BAU Sabour, with rigorous effort of scientists, Rajendra Mansuri has been identified as suitable for direct seeded rice (DSR) cultivar that would save labour and water. This variety can be recommended for water deficit region and would help in climate change regime.

Plant breeding programmes at ICAR-IARI has led to release of several varieties in different crops for stress tolerance (Table 2).

Flood and Salinity Tolerant

Climate induced weather extremes, such as flooding, submergence and salinity impacts crops adversely. About 20 million hectares of rice land is prone to flooding in Asia, which is major rice growing continent. Of this, India and Bangladesh share more than 5 million hectares of rice field, flooded during most of the planting seasons (http://irri.org/). Progressive salt accumulation due to excessive irrigation with poor water quality coupled with poor or improper drainage results in high salt levels (Ismail *et al*., 2007). Excess water in the soil reduces oxygen availability to the plant (Kozlowski, 1984). The extended deep submersion can cause plant death because of a lack of oxygen required to sustain plant growth and an accumulation of toxic substances, such as organic acids, NO^{2-}, Mn^{2+}, Fe^{2+}, and H_2S (Kozlowski, 1984; Janiesch, 1991).

Generally, the traits like the vigorous roots and less evapo-transpiration could be developed in plants that can help maintaining water balance up to some extent. The past decade has witnessed an increase in studies related to detection of quantitative trait loci (QTL) for drought-related traits, and the first encouraging results in QTL cloning have been reported (Salvi and Tuberosa, 2005). Thus, development of more flood-tolerant cultivars is critical for enhancing sustainable production of crops. For example, rice dies within 5-6 days of complete submergence, resulting in total crop loss. These losses affect rice farmers in rainfed and flood-affected areas where alternative livelihoods are limited. After the gene called Sub1 gene was found, it was infused into popularly grown rice varieties in rice-growing countries in Asia ((http://irri.org/)). IRRI has developed a rice variety using Sub1 gene through marker-assisted backcrossing, Swarna-sub1 in 2005 that can withstand being submerged under water for two weeks.

Soil salinity is a major cause of concerns in rice growing areas. In India nearly 6.72 million ha of total land are salt affected out of which 2.95 million ha are saline (including coastal) and 3.77 million ha are alkaline (IAB, 2000). In Bangladesh's coastal areas, salinity affects about one million hectares of land that can otherwise be used for rice farming. Rice productivity in salt-affected areas is very low less than 1.5 tons per hectare. But this can potentially increase by at least two tons per hectare with improved varieties that can withstand soil salinity.

IRRI scientists have identified a major region of the rice genome called Saltol that gives the rice plant tolerance to salinity. Saltol is being used to develop varieties that can cope with exposure to salt during the seedling and reproductive stages of the plant. Recent work at IRRI has shown that the SUB1 gene and Saltol can be combined in the same variety of rice, increasing the rice plant's tolerance to salinity and submergence. Plant breeders have incorporated Saltol in popular rice varieties such as the BRRI Dhan 11, 28, 29 varieties released in Bangladesh. To date, IRRI, with the help of its national partners, has developed more than 100 salinity-tolerant elite lines. These elite lines possess superior traits such as high yield, good eating quality, resistance to pests and diseases, and tolerance of stresses, and are ready for testing in farmer's fields.

Central Soil Salinity Research Institute, Karnal, India (CSSRI) has identified several promising salt-tolerant crops such as salt-tolerant varieties of rice, for example, CSR 10, CSR 11, CSR 13, CSR 27 for inland situations and CST 7-1, CSR 4 and CSR 6 for coastal areas. Likewise, salt-tolerant varieties for wheat, KRL 1-4 and mustard, CS-52, CS-330 have been developed and released (Dagar, 2005).

COLD, HEAT AND DROUGHT TOLERANCE

Tolerance to freezing temperatures is the most important component for winter survival, but also of considerable importance is the capability to withstand combinations of stresses due to desiccation, wind, ice-encasement, low light, snow cover, winter pathogens, and fluctuating temperatures. Resistance to desiccation through the maintenance of cell membrane integrity and retention of cellular water is essential, and it is unsurprising that the same genetic response to the onset of freezing temperatures is often observed with drought or salinity stress (Yue *et al*., 2006). Indeed, cold acclimation can frequently improve adaptation to a mild drought stress and vice versa (Seki *et al*., 2002). Higher temperatures are speculated to reduce rice grain yields through two main pathways: (i) high maximum temperatures that in combination with high humidity cause spikelet sterility, and (ii) increased night time temperatures, which may reduce assimilate accumulation (Wassmann and Jagadish, 2009).

Cold tolerance is a complex trait controlled by many genes. IRRI scientists have identified three regions of the rice genome that have a direct link to cold tolerance at the plant's reproductive stage. Cold stress at critical times of reproduction hinders the formation of fertile pollen that is crucial for fertilization and consequently the rice plant may fail to produce grains. In pigeonpea at BAU, Sabour, it was found that the pigeonpea lines starts dropping flowers and newly developed pod when temperature goes below 10°C. In this context, 120 pigeonpea genotypes planted in augmented design with four checks. Genotypes categorized into cold escape, cold tolerant and susceptible. It has been found that the early group of pigeonpea genotypes which completed their reproductive cycle before temperature down below 10°C was not affected by temperature considered cold escape such as, ICP-13359, ICP-11627, ICP-11059, ICP-11477. Other long to medium duration genotypes ICP-15382, ICP-7076, ICP-7076 and ICP-14229, i.e., also developed pods normally since temperatures were not critically low during winter season. Hence conclusion cannot be made this year due to normal winter season.

IRRI scientists are looking for rice that can tolerant high temperatures by screening improved and traditional rice varieties. These donors are used in a crossing program to incorporate tolerance of high temperature into elite rice lines that are then tested for heat tolerance in 'hot and dry' and 'hot and humid' countries. Some of the development that can help fight against climate change, for example, discovery of a cold-tolerant breeding line called IR66160-121-4-4-2 that inherited cold tolerance genes from Indonesia's tropical japonica variety Jimbrug and northern China's temperate japonica variety, Shen-Nung89-366 by IRRI's and South Korea's Rural Development Administration.

Drought is the most widespread and damaging of all environmental stresses, affecting 23 million hectares of rainfed rice in South and Southeast Asia. In some states in India, severe drought can cause as much as 40% yield loss, amounting to $800 million. In all cases, the emphasis will be on identifying and using sources of genetic variation for tolerance/ resistance to a higher level of abiotic stresses. The two most obvious sources of novel genetic variation are the gene banks (ICARDA has one of the largest gene banks with more than 120 000 accessions of several species including important food and feed crops such as barley, wheat, lentil, chickpea, vetch, etc.) and/or the farmers' fields. Currently, there are several international projects aiming at the identification of genes associated with superior adaptation to higher temperatures and drought. At ICARDA, as elsewhere, it has been found that landraces and, when available, wild relatives harbour a large amount of genetic variation some of which is of immediate use in breeding for drought and high temperature resistance (Ceccarelli *et al*. 1991; Grando *et al*. 2001).

Sabour Ardhajal, a drought tolerant variety of rice developed at BAU, Sabour under Stress-Tolerant Rice for Africa and South Asia (STRASA) programme, which contains QTL for reproductive stage drought tolerance would be important climate change scenario. Further, under the same project at BAU Sabour, several multi-environmental trials (MET) underway on aspect of breeding for drought, heat and cold tolerance, in H-MET total 14 entries were evaluated including local check R. Mahsuri-1. Yield differences were found to be significant and varied from 2827 kg/ha (CGZR-1) to 4971 kg/ha (IR 91953-141-2-1-2(R-119). Two entries IR 91953-141-2-1-2(R-119) and IR 92937-178-2-2(R-155) recorded yield significantly superior to R. Mahsuri-1 (3752 kg/ha). While in MET-2 (Loc-1), total seven entries were evaluated including local check Prabhat. Yield differences were found to be significant and varied from 2183 kg/ha (Prabhat) to 3638 kg/ha (MTU1010). Entry R-RHZ-7 recorded yield significantly superior to Prabhat (2183 kg/ha). In MET-2 (Loc-3), total seven entries were evaluated including local check Prabhat. Yield differences were found to be significant and varied from 2123 kg/ha (Prabhat) to 3437 kg/ha (MTU1010). Entry R-RHZ-7 recorded yield significantly superior to Prabhat (2123 kg/ha). In Swarna Sub-1+ drought (control), total 16 entries were evaluated including two checks namely S. Sub-1 and Swarna. Yield differences were found to be varied from 6696 kg/ha (IR 96321-315-294-B-1-1-1) to 9494 kg/ha (IR 96321-558-563-B-2-1-3). However, none of the entry could statistically surpass the best check Swarna (9063 kg/ha). In Swarna Sub-1+ drought (Drought), total 16 entries were evaluated including two checks namely S. Sub-1 and Swarna. To identify suitable drought donors, a total 24 entries were evaluated including checks. Yield differences were found to be varied from 949 kg/ha (Koi Murali) to 4348 kg/ha (Binuhangin). Top three yielder donors were Binuhangin, Dular and Uri. Donors were crossed with the locally adapted varieties.

Under Heat stress Tolerant Maize (HTMA) for Asia project at BAU, Sabour, 20 entries (in AMDWTC-17" trial) were tested and significant differences were observed among the entries for grain yield. Grain yield ranged from 2400-6930 kg/ha but none of the entry showed significantly higher yield than the best check "PIO3396" (6930 kg/ha).

In another programme on improvement of pigeonpea for plant type, early maturity, pod borer resistance and moisture stress tolerance at BAU, Sabour, 250 pigeonpea germplasm received from NBPGR were planted with four checks (Asha, Patam, Pusa 9 and Bahar) to screen genotype against pod borer at flowering and podding. For this experiment was left without chemical treatment (insecticide/ pesticide). Plants (5/row) were tagged to monitor damage by pod borer. Before harvest pods were plucked from individual plant and counted. The damage pods were counted separately and percent infestation were recorded on plant basis. It has been found that out of 250 entries 23 genotypes showed less infestation (< 30%) with minimum 7%. However, maximum infestation went up to 90 %.

In chickpea programme at BAU, Sabour, the evaluation of advanced generation chickpea genotypes for yield and abiotic/ biotic stress tolerance (Desi) were done involving nine chickpea advanced breeding lines including PG 186 as check were evaluated in RCBD (Timely sown condition). Varietal difference with respect to grain yield was found significantly superior which ranged from 1555 kg/h to 2043.2 kg/ha. Highest grain yield (2043.2 kg/ha) was recorded by cross no 14 (ICCV 10 x ICCV 97105) which was 15% superior to check PG 186, while two entries were at par with check. The trials were planted under normal moisture condition; however disease and insects infestation was less than 10 %. Also characterization and evaluation of eighty chickpea genotypes (Desi) including four checks for heat tolerance (late sown and normal sown condition) is underway. The varietal difference with respect to grain yield was found significantly superior which ranged from 300 kg/h to 1905.2 kg/ha. Highest grain yield was recorded by ICCV 4958 followed by IPC 10-59, JG 14, PG 186, JG 18 under late sown condition.

The work on understanding heat and drought tolerance mechanism in lentil and its improvement by over-expression of antioxidant genes is also being carried out keeping in view climate change at BAU, Sabour. Under *in vitro* condition shoot cultures of four genotypes viz. Noori, HUL 57, Arun and SBO Local were established. Shoot regeneration for Noori and HUL 57 have been standardized from embryonal axis. Pot experiments were conducted using 14 contrast genotypes under heat and drought stress condition.

The evaluation of linseed germplasm under utera (sowing in standing paddy crop) condition is being carried out that may help climate resilience by early harvest of linseed. One hundred eight entries were evaluated along with two checks (T-397 & R-552), twenty five entries were found promising as they recorded more yield than the best check, T-397 (825 kg/ha). The top ranker five entries were BRLS-112-2 (1497 kg/ha), BRLS-113 (1454 kg/ha), BRLS-110-2 (1453 kg/ha), BRLS-109-2 (1428 kg/ha), BRLS-111-2 (1312 kg/ha). One of the variety released recently Linseed variety "Sabour Tisi-1" has been released for utera condition.

In rapeseed-mustard breeding programme, to combine traits of interest viz. early and late sowing, bold seed, semi compact canopy, lodging and shattering resistant, TW high, MR to AB & aphid, high yield, profuse branch, semi-apprressed, non-glossy stem and upright branches in popular varieties is being carried out. Also, inter-specific crosses (*Brassica* *juncea* X *Brassica carinata*) for drought tolerance and better growth under late sown condition were done.

In safflower, Brassinosteroid-mediated increase in seed yield and enhanced abiotic stress tolerance Safflower (A1 variety) were transformed with CaMV:DWF4:NOS gene construct by *Agrobacterium* transformation. The presence of transgene in transgenic safflower lines (T1 and T2) were confirmed using PCR analysis. RT-PCR was carried out to confirm the expression of transgene. Sub-cellular localization experiment showed that the expression of DWF4 in cytoplasm.

DISEASES AND PEST

To date, research on the impact of climate change on plant diseases has been limited, with many studies focusing on the effects of a single atmospheric constituent or meteorological variable on the host, pathogen, or the interaction of the two, under controlled conditions. Rising temperature and atmospheric CO_2 are also indirectly affecting crops through their effects on pests and diseases. These interactions are complex, and their full impact on crop yield is yet to be fully appreciated. Impacts of warming or drought on resistance of crops to specific diseases may be through the increased pathogenicity of organisms or by mutations induced by environmental stresses (Gregory *et al*. 2009). The influence of climate change on plant pathogens and their consequent diseases has been reviewed extensively (Coakley and Scherm 1996; Chakraborty 2005). Different individual parameters associated with climate change, such as warming, increased levels of CO_2, decreased rainfall, and erratic pattern of rainfall, have been studied for their influence on different aspects of pathogens and diseases across various crops (Chakraborty 2005).

At BAU, Sabour, the engineered resistance in rice against fungal pathogens is underway. Rice calli of Rajendra Kasturi were transformed using *Dwf1* gene construct using *Agrobacterium* mediated transformation. The presence of transgene in transgenic rice lines (T_1 and T_2) were confirmed using PCR analysis. RT-PCR was carried out to confirm the expression of transgene. While in lentil, for biotic stress the work on identification of donor parents resistant to *Fusarium* wilt is going on. In this, a trial consisting 16 released varieties including check from different states were tested for the performance for its adaptability in different ecological regions of Bihar. HUL 57 (1250 Kg/ha) was the best check, three entries were found significantly superior than the check. Out of 16 entries BRL-3 has yielded out highest (1860 Kg/ha) followed by BRL-1 (1629 Kg/ha) and BRL-2 (1539 Kg/ha), other varieties were at par with the best check HUL 57 (1250 Kg/ha).

In wheat, for biotic tolerance the work on development of spot blotch resistant genotypes of spring wheat for eastern Gangetic plain of India using double haploid (DH) technology was undertaken keeping in view climate change. For this purpose, spot blotch resistant genotypes viz. Chirya 3, Chirya 7, MACS 2496, GW373, HD 3118, RAJ 3765, WH730, BH1146 were procured. Crosses were made involving Spot blotch resistance genotypes and high yielding locally adapted genotypes. Procedures and physical conditions were optimized for pseudo seeds production. Nutrient media and physical conditions were standardized for haploid production

GENOMICS ASSISTED-BREEDING AND BIOTECHNOLOGICAL INTERVENTION FOR CLIMATE CHANGE

Potential of Genomics-assisted Breeding in Producing Climate Resilient Crops Genomics offers tools to address the challenge of increasing food yield, quality and stability of production through advanced breeding techniques. Advances in plant genomics provide further means to improve the understandings of crop diversity at species and gene levels, and offer DNA markers to accelerate the pace of genetic improvement (Muthamilarasan *et al*., 2014). A genomics-led breeding strategy for the development of new cultivars that are "climate change ready" (Varshney *et al*., 2005) commences by defining the stress that will likely affect crop production and productivity under certain climate change scenarios.

The ideotype breeding coupled with DNA fingerprinting, and gene/ quantitative trait loci (QTL) will assist in selecting screening promising accessions against specific stress. Similarly, precise phenotypic assessments and appropriate biometric analysis will assist in identifying unique responses of a set of genotypes in a given physiological stage influenced by variation of weather patterns. This information will be further used in genomics aided breeding approaches such as genome-wide selection of promising germplasm for further use in crop breeding aiming at both population improvement and cultivar release. Genetic mapping and QTL analysis, via bi-parental or association mapping (AM) populations, have accelerated the dissection of genetic control of agricultural traits, potentially allowing MAS, QTL, and AM studies or direct calculation and genomic selection (GS) of high value genotypes to be made in the context of breeding programs (Kulwal *et al*., 2011).

With the advent of next-generation sequencing (NGS) methods has facilitated the development of large numbers of genetic markers, such as single nucleotide polymorphisms (SNP), insertion-deletions (InDels), etc. even in relatively researchneglected crop species. Discovery of novel genes/alleles for any given trait could be then performed through genotyping-by-sequencing (GBS) approaches. Similarly, genome-wide association studies (GWAS) could be used to identify the genomic regions governing traits of interest by performing statistical associations between DNA polymorphisms and trait variations in diverse collection of germplasm that are genotyped and phenotyped for traits of interest.

Compared to radiation methods, chemical mutagens tend to induce SNPs rather than chromosomal mutations. Currently, chemical mutagens, such as Ethyl methanesulfonate (EMS) are being used to induce random mutations into the genome and have become a useful complement to the isolation of nuclear DNA from mutated lines by TILLING (Targeting Induced Local Lesions in Genomes) technology and screening of the M_2 population at the DNA level using advanced molecular techniques.

At BAU, Sabour, the work on architectural modification of Katarni rice through marker assisted selection is underway. The work will bring down the height of Katarni rice resulting in lodging resistance and help the crop stand against storm or high wind and rain. Survey of parental polymorphism between Katarni, IR-64, Rajendra Sweta and BPT 5204 was undertaken through the set of 25 additional SSR markers in rice were conducted. Validation of F_1 plants of Katarni/ BPT5204 through parental polymorphic SSR was done in PCR. Backcrossing of 8 validated Katarni/ BPT5204 F_1s with recurrent parent Katarni was done to obtain the BC_1F_1 seeds. 388 BC_1F_1 plants of Katarni/ R. Sweta// Katarni were raised out of which 107 plants were selected based on the foreground selection using *badh2* gene specific primer (Bradbury, 2005). Out of 107 fragrant allele positive plants, 87 were found to be positive for *sd1* gene through PCR using *sd1* gene specific primer as suggested by Spielmeyer, 2003. On the basis of grain and leaf aroma KOH sensory test, 15 plants were selected out of the 87 positive plants for *sd1* gene. These 15 plants will be evaluated for the presence of aroma, *sd1* gene with early flowering trait in next segregating generation. Out of about 10000 F_2 plants of Katarni/ R. Sweta, 410 plants were selected based on KOH sensory test, plant height and early date of flowering. Out of about 6000 F_2 plants of Katarni/ IR64, 350 plants were selected on the basis of plant height and date of flowering.

For the first time, the germin-like protein multi-gene family in tomato has been identified in our lab at Plant Breeding and Genetics lab, BAU Sabour. Through detailed bioinformatics analysis, a potent candidate gene (annotated in this study as *SlGLPH*) has been identified. The *SlGLPH* transcript has been detected in leaf, stem, flower and fruit tissues of tomato. Relative abundance of the *SlGLPH* transcript has been found to be significantly increased under abiotic stress conditions. The coding DNA sequence of the *SlGLPH* gene has been amplified from tomato (cultivar: Pusa Ruby) genomic DNA and verified through custom sequencing. A genetic construct for over-expression of the *SlGLPH* gene has been prepared, mobilized to *Agrobacterium* and plant transformation (tomato and brinjal) has been initiated.

CONCLUSION

Plant breeders need to focus on traits with the greatest potential to increase yield. Hence, new technologies must be developed to accelerate breeding through improving genotyping and phenotyping methods and by increasing the available genetic diversity in breeding germplasm. Crop improvement through breeding brings immense value relative to investment and offers an effective approach to improving food security. Many new improved varieties are environmentally friendly, ensuring food security, while conserving the environment. The holistic approach in tackling climate change should encompass the climate resilient genotypes coupled with a suitable crop and natural resources management and sound implementation policies that could led to climate-smart agriculture.

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Contingent Crop Planning in flood and Dry Spell of Monsoon in Bihar

Sunil Kumar*, Sanjay Kumar and S. Sheraz Mahdi
Department of Agronomy,
Bihar Agricultural University, Sabour–813210, Bihar
*E-mail: *iitsunil@gmail.com*

Abstract—The increasing frequency of flood and drought in Bihar is really a challenge to make the contingent crop plan in advance for the area concerned. Rainfall analysis for Pusa, Purnia, Sabour and Patna representing North west alluvial plains (Zone I), North East alluvial plains (Zone II), and South Bihar alluvial plains (Zone III A and III B), respectively using annual and weekly rainfall data was carried out for Bihar state. The overall mean annual rainfall was lowest (1031 mm) for zone III B and highest (1466.7 mm) for zone II. But coefficient of variation was highest (30.8%) for Pusa (zone I) and lowest (23.7%) for Patna (zone III B). A long term significant decreasing trend in annual rainfall was observed in Patna (zone III B). At Pusa and Purnea, 25th to 34th SMW are favorable weeks for field preparation/sowing and transplanting of rice crop due to more than 75% probability of rainfall of 10-30 mm. At Sabour, probability of rainfall more than 20 mm is 75% during 25th–33rd week while for Patna; it is during 27th–34th SMW. So, sowing and field operations may be delayed by two weeks in Patna region. The study reveals that crops and varieties could be selected through the analysis of wet spell durations with the onset of monsoon in the given region. In the flood situation, short duration rice varieties can be grown after removal of flood water. When monsoon is late or dry spell is encountered, practice direct seeded rice or intercropping of green gram or black gram. Under stress situations, less water requirement crops like sorghum, ragi, finger millet etc. can be adopted in the region.

INTRODUCTION

The occurrence of drought and flood is increasing due to climate change in Bihar. Nearly 80% of annual rainfall is received in a span of 4 months (June-September) which is quantitatively enough for most of the crop needs. However, the aberration in temporal and spatial distribution makes the crop vulnerable to drought as well as flood. Rainfall is the single most important factor in crop production planning in rainfed ecologies. The information on annual, seasonal and weekly rainfall of a region is useful to design water harvesting structure for agricultural operations, field preparation, sowing, irrigation, fertilizer application and overall in field crop planning (Singh *et al*., 2008). Historically in Bihar, zone I and zone II are receiving too much rainfall to cause flood in the region whereas zone III B is characterized as rainfed region with low, erratic and uncertain rainfall pattern with frequent dry spells during the monsoon season. Hence monsoon cropping is tricky operation in the region as well as sudden crop failures during the *kharif* season is a common phenomenon due to early withdrawal of monsoon. Rainfall probability pattern has been studied by many scientists in India (Suchit *et al*., 2012) and conclude that rainfall occurrence is certain at greater than or equal to 80% probability, while 50% probability is the medium limit of certainty and may involve dry spell risk. Taking into account these climatic and probability factor, the study was conducted for four different locations situated in different agro climatic zones of Bihar for interlinking the rainfall probability with the crop planning pattern inthe region.

Kumar *et al.,* (2008) analyzed weekly rainfall data of Bihar for the period 1955 to 2012 i.e. 58 years pertaining to Pusa, Purnia, Sabour and Patna representing North west alluvial plains (Zone I), North East alluvial plains (Zone II) and South Bihar alluvial plains (Zone III A and III B) of Bihar respectively as per availability was used for analysis. Weekly, annual and seasonal rainfall distribution patterns were critically examined and analyzed. Trends were examined by Mann-Kendall rank statistics as described by Sneyers (1990). This test was used by several researchers to detect trends in hydrological time series data (Luo *et al*. 2008). An initial and conditional probability of weekly rainfall at different threshold limits (10, 20 and 30 mm) were computed using first order Markov chain process (Robertson, 1976). Expected amount of rainfall at a given probability level was computed for 24–39 SMW during monsoon season using Weibull's distribution (Chow 1964).

VARIABILITY IN ANNUAL AND SEASONAL RAINFALL

The average annual rainfall of Pusa (zone I) is 1246.9 mm with coefficient of variation (CV) of 30.8% (Table 1) (Kumar *et al.,* 2014). About 83.8% of annual rainfall is received from south west monsoon. The winter, pre monsoon and post monsoon season rainfall contribute 2.4, 7.9 and 5.9 percent rainfall to the annual rainfall respectively. For Purnia (zone II), the average annual rainfall is 1466.7 mm with CV 25.8%. The contribution of monsoon, post monsoon, winter and pre monsoon season rainfall to the annual rainfall is 80.1, 6.5, 1.4 and 12 percent respectively. The average annual rainfall of Sabour (zone III A) is 1231.4 mm with CV of 24.5% and monsoon season rainfall contribution is 78.7 percent. The winter, pre monsoon and post monsoon rainfall contribution is 2.8, 10.4 and 8.1 percent respectively. The average annual rainfall of Patna (zone III B) is 1031.0 mm with CV of 23.7% and monsoon season rainfall contribution is

85.9 percent. The winter, pre monsoon and post monsoon rainfall contribution is 3.3, 4.5 and 6.3 percent respectively.

TREND ANALYSIS

The long-term annual rainfall of Patna (zone III B) shows significant decreasing trend (Table 1) (Kumar *et al.,* 2014). In Pusa (zone I), it also shows decreasing trend but statistically non-significant. In Purnea (zone II) and Sabour (zone III A), there is increasing trend but statistically not significant. There is a decreasing trend of winter rainfall in all the zones though it is statistically not significant. There is significant increasing trend of pre monsoon rainfall in Patna (zone III B). In pre monsoon season, there is increasing trend of rainfall for all the zones except zone II, though it is statistically not significant. But there is decreasing trend of monsoon and post monsoon rainfall, in Pusa (zone I) and Patna (zone III B) though it is statistically not significant.

Table 1: Variation, Percentage Contribution (% C) and Long Term Trends of Seasonal and Annual Rainfall in four Districts Representing Different Zones of Bihar

Season	Pusa (Zone I)				Purnia (Zone II)			
	Rainfall (mm)	CV (%)	% C	Trend (mm/Year)	Rainfall (mm)	CV (%)	% C	Trend (mm/Year)
Annual	1246.9	30.8	-	-1.57	1466.7	25.8	-	0.81
Winter	30.3	75.8	2.4	-0.48	20.6	97.5	1.4	-0.10
Pre-monsoon	98.6	59.3	7.9	1.10	175.5	54.4	12.0	-0.14
Monsoon	1044.7	34.3	83.8	-1.20	1175.3	28.3	80.1	2.26
Post-monsoon	73.3	93.5	5.9	-0.99	95.4	99.0	6.5	-1.20
	Sabour (Zone III A)				Patna (Zone III B)			
	Rainfall (mm)	CV (%)	% C	Trend (mm/Year)	Rainfall (mm)	CV (%)	% C	Trend (mm/Year)
Annual	1231.4	24.5	-	2.08	1031.0	23.7	-	-7.04*
Winter	34.8	89.3	2.8	-0.39	34.0	79.2	3.3	-0.51
Pre-monsoon	127.8	66.3	10.4	0.54	46.4	68.2	4.5	0.43*
Monsoon	969.7	25.0	78.7	2.39	886.1	25.1	85.9	-5.74
Post-monsoon	99.1	91.2	8.1	-0.46	64.5	94.5	6.3	-1.23

*Significant at 5 % (Source: Kumar *et al*., 2014)

EXPECTED RAINFALL AMOUNT AND CROP PLANNING

As discussed above, rainfall at 75% and 90% probability is assured rainfall and at 50% probability is the median limit for taking risk. At Pusa, the probability of more than 30 mm rainfall from SMW 25th is above 50 %, but there is some risk (Kumar *et al.,* 2014). From 27th SMW, there is probability of more than 75% of getting rainfall of more than 15 mm and farmers can initiate their field preparation operations and from 28th week expected rain becomes more than 20 mm, 27th and 28th week are an ideal time for sowing/transplanting of *kharif* crop and also for the crop fertilization based upon the rainfall pattern and intensity. In Purnia, the probability of more than 20 mm rainfall from SMW 25th is above 75 % and more than 10 mm rainfall is above 90% (Table 2). From SMW 25th, sowing of *kharif* crop can be initiated in the region. In 28th and 29thweek probability of receiving more than 30 mm rainfall is more than 75% which is sufficient amount of rainfall for transplanting of rice in the region. In Sabour and Patna region, the probability of more than 10 mm rainfall is above 75 % from 25th and 26th SMW respectively (Table 3). The probability of receiving more than 20 mm rainfall in the regions are from 28th and 29th week respectively in which transplanting of rice can be completed.

Table 2: Expected Weekly Rainfall (mm) at Different Probability Level (%) in Pusa and Purnia

SMW	Pusa				Purnia			
	50 %	**75 %**	**90%**	**Total**	**50 %**	**75 %**	**90 %**	**Total**
24	18.4	5.4	1.2	32.3	32	9.6	2.2	56.5
25	34.4	10.8	2.7	58.9	47.5	24.2	11.6	59.5
26	32	9.3	2.1	57.4	53.8	24.8	10.4	71.6
27	42.9	16.1	5.1	65.2	52.8	21.8	7.9	75.4
28	56.2	22.6	7.9	81.8	85.4	41.3	18.5	111.1
29	50.9	20.3	7.1	74.2	82.6	39.8	17.8	107.5
30	46.5	19.8	7.5	65	50.6	25.7	12.2	63.6
31	42.2	17.8	6.6	59.3	53.5	23	8.8	74.5
32	49.7	21	7.8	70	37.7	17.3	7.2	50.1
33	47.5	19.1	6.7	69	42.1	14.4	4.1	67.8
34	47.2	19.1	6.8	68.3	45.2	20.9	8.8	60
35	33.3	12.6	4	50	34.9	13	4.1	53.3
36	38.8	16	5.8	55.3	48.1	24.1	11.3	60.8
37	39.4	15.4	5.2	58.2	51.2	22.6	9	69.9
38	23.8	8.1	2.2	38.1	29.8	11.5	3.8	43.9
39	26.1	6.5	1.2	51.9	46.7	17	5.2	72.4

Source: Kumar *et al*., 2014

Table 3: Expected Weekly Rainfall (mm) at Different Probability Level (%) in Sabour and Patna

SMW	Sabour				Patna			
	50 %	**75 %**	**90 %**	**Total**	**50 %**	**75 %**	**90 %**	**Total**
24	22.6	7	1.7	38.4	14.7	3.6	0.6	29.6
25	31.5	12.8	4.6	45.1	24	8.2	2.3	38.3
26	39.9	16.8	6.2	56.2	31.2	10.3	2.8	51.2
27	34.9	12.8	4	53.6	50.3	20.8	7.6	71.8
28	54.2	22.3	8	77.7	47.6	17.6	5.5	73.1
29	45.8	19.1	7	64.9	72.3	33.4	14.1	96.5
30	33.1	12.5	4	49.7	49.5	18.2	5.6	76.2
31	40.4	16.1	5.6	58.8	47.1	22.5	9.9	61.3
32	35.9	13.1	4	55.3	49.6	22.8	9.6	66

Table 3 (Contd.)…

…Table 3 (Contd.)

33	42.9	15.6	4.8	66.4	40.6	15.7	5.2	60.5
34	26.8	8.8	2.3	44.1	55.3	26.2	11.4	72.5
35	23.4	7.8	2.1	38	33.7	13.8	5	48
36	25.4	8	2	43.2	36.9	15.8	6	51.3
37	23.4	8.5	2.6	36	44.6	17.7	6.1	65.2
38	20.4	5	0.9	41.4	16	5.5	1.5	25.3
39	24	5.3	0.8	52.1	25.6	7.7	1.8	44.9

Source: Kumar *et al*., 2014

CONTINGENT PLAN FOR FLOOD AFFECTED AREA

If there is total loss of rice seedlings due to flood, short duration rice var. like Prabhat, Turanta, Saket-4, Dhanlaxmi, Richhariya, Rajendra bhagawati etc. can be sown for new seedling. By dapog method seedlings can be make ready within 10–12 days. Already germinated seeds can be sown in the field. After flood, 50–60 days old seedlings of rice can be transplanted and at a time 6–8 plants should be transplanted. The dose of nitrogenous fertilizer can be increased.

CONTINGENT PLAN FOR DROUGHT AFFECTED AREA

DROUGHT PREVENTIVE MEASURES

Among the different *kharif* crops the upland rice is most affected by drought. Therefore, diversified land use with low duty non-paddy crops is the best option in these lands. In real sense the technology available to mitigate drought are mostly preventive in nature and requires early planning. The age-old adage "Prevention is better than cure" thus holds good in drought management. Therefore it is imperative to have a long term policy and planning at the beginning of the season for judicious use of water, land and crops in a particular locality for best results. The major thrust in drought mitigation in rainfed areas should be on rain water management through *in-situ* conservation and water harvesting through on-farm reservoirs/ capturing runoff from local catchments/ flash flood water from local streams to recycle at the time of need. Some of the important preventive measures that can be adopted early in the season to mitigate the impact of drought and augment sustainable crop production are elaborated below.

UPLAND

Select efficient crops and cropping systems matching the length of growing season. Some of the promising non-rice crops for rainfed uplands are maize, cowpea, arhar, black-gram, ragi, sesame, pumpkin and sweet potato. Choose short duration varieties which possess faster rate of growth, deep and penetrating root system and ability to escape drought. Store rain water to use as lifesaving irrigation. On-farm water harvesting structures lined with 6:1 soil: cement mortar of 6 cm thickness in 10% land area helps to harvest the rainwater for providing protective irrigation. Perform off season ploughing to conserve moisture, reduce pest and weed problem and to facilitate early sowing. Follow partial mechanization to ensure timeliness and precise of operations (desired depth and tilth) to utilize land, rainfall and other natural resources effectively. Adopt intercropping/ mixed cropping system in recurrent drought prone areas as mentioned below:

The area where rainfall is between 625-850 mm and there is medium to deep soil and water capacity is 200-300 mm, following intercropping system will be helpful.

Jowar + Arahar (2:1)

Maize + Soybean (1:2)

Arahar + Soybean (1:2)

Maize + Groundnut (1:3)

The area where average rainfall is more than 900 mm and water holding capacity of soil is 300 mm and there is deep soil, following intercropping can be suitable.

Maize + Gram/Safflower

Soybean-Safflower

Maize-Soybean/Safflower/Gram

In situ soil and water conservation measures like cover cropping, ridge and furrow method of planting can be done. Manage water ways through check dams, stone structures, and brushwood structures on natural streams/ nallahs to store water. Water harvesting (digging ponds and lining) in 10–12% area. Utilize harvested water through micro-irrigation methods (drip/sprinkler). Moisture conservation through mulching can be increased. Gully plugging through stacking of locally available pebbles filled in empty cement bags across water ways. Growing of grasses in water ways is also helpful in reducing soil erosion. Construct a series of percolation tanks in light textured soils to recharge the profile and for supplemental irrigation. Strengthen village institutions to enable people's participation. Apply a portion of FYM in the seed furrows at the time of sowing to conserve moisture to prevent seedling mortality from early drought. Grow short duration rice varieties such as Prabhat, Turanta, Saket-4, Dhanlaxmi, Richhariya, Rajendra bhagwati, etc. Sow non-paddy crops like ragi, maize, arhar, green-gram, black-gram, cowpea, sesame, groundnut, castor in place of rice. Vegetables come up well in drought/low rainfall years. Utilize the ponds, reservoirs and water bodies for growing tomato, cauliflower, radish, brinjal, runner bean, cowpea, lady's finger and chilli.

MEDIUM/ LOW LAND

Rainwater management in medium and low lands is crucial for mitigation of drought and improvement in production. A technology for storing excess rain water in medium/ low land has been standardized by devoting 10% of the cultivable area. The objective is to minimize runoff by encouraging its entry into the soil (*in-situ* water conservation) and capturing that which cannot get into the soil. In the first step, the field bund is strengthened by raising the dyke height to 45 cm with provision of weir at 20 cm height for spilling over excess water to runoff collection tank (refuge). The refuge is constructed at the lower reach of the plot with top width3.0m, bottom width 2.0m and depth 1.8m. The length of the refuge is equal to the width of the plot. This technology is based on the principle that out of total annual rainfall nearly 50% of the rainfall comes from a few intense showers resulting in higher runoff. On the other hand, in certain years there is a break in rainfall at a stretch for 10–12 days during crop growth period. This long stretch of dry period affects the rice crop adversely. The excess runoff discharged over the weir height during intense showers in the early season if collected in the refuge can provide protective irrigation to mitigate the intermittent drought in rice crop.

DROUGHT AMELIORATIVE MEASURES

It is difficult to define the exact crop and weather scenario during an anticipated drought or dry spell. Hence, it is really a difficult task to delineate rigid contingent measures well in advance of the cropping season applicable to all situations. However, there are three distinct periods of *kharif* season relating to crop growth stage and associated farm practices. Depending on the rainfall onset and pattern of distribution, seven types of scenarios have been projected and required contingent measures have been suggested below.

EARLY SEASON DROUGHT (JUNE 10 TO JULY 31)

SCENARIO 1: EARLY ONSET AND SUDDEN STOPPAGE OF MONSOON

Under such a situation there is more likelihood of mortality of sprouts and seedlings and difficulties in sowing.

UPLAND

When there is more than 50% mortality, re-sow the crop up to July after receipt of sufficient rain water. It is always wise to raise low water requiring non-paddy crops like ragi, greengram, blackgram, cowpea, sesame and castor. If mortality is less than 50%, the crops may be gap filled. Cultivate vegetables-cowpea, radish, okra, cauliflower, brinjal, tomato wherever possible.

MEDIUM AND LOW LAND

If rice population is less than 50%, re-sow the crop. Select medium duration varieties. Sprouted seeds may be direct seeded or fresh seedlings of short duration varieties may be raised for transplanting. The sprouted seeds can be sown in the lines by seed drill. If the rice population is more than 50% carry out weeding and adjust the plant population by *Khelua* (removing and redistributing the hills) and clonal propagation. Raise community nursery of rice for transplanting at a reliable water source to save time for further delay. In saline soil use FYM/ green leaf manure, sow sprouted seeds, gap fill the crop by clonal propagation.

SCENARIO 2: LATE ONSET OF MONSOON

Sow drought tolerant non-paddy crops like ragi, green-gram, black-gram, cowpea, guar, sesame, castor in place of rice. Cowpea maybe grown in the first week of August to meet the fodder crisis. Grow sweet potato in the ridges and allow the furrows to conserve rain water. Grow vegetables like tomato, cauliflower, radish, brinjal, and cowpea, lady's finger and chilli. Apply full P, K and 30% N of the recommended dose as basal along with well decomposed organic manure for early seedling vigor. Major emphasis should be given on *in-situ* rain water conservation, harvesting excess run-off for its recycling to make provision for life saving irrigation.

MID-SEASON DROUGHT (AUGUST 1 TO SEPTEMBER 15)

SCENARIO 3: NON-PADDY CROPS AFFECTED

Complete hoeing and weeding in non-paddy crop fields to provide dust mulch. Spray 2% KCl + 0.1 ppm boron to black-gram to overcome drought situations. Foliar application of 2% urea at pre-flowering and flowering stage of green-gram is helpful to mitigate drought. Spray 1% urea in brinjal. Take up spraying measures against mealy bug and mite which are more prevalent in dry weather. Top dress the crops after receipt of rain. Spray 2% urea in late planted jute to encourage growth. Top dress nitrogen to ginger and turmeric @ 60 and 30 kg/ha, respectively after receipt of rainfall followed by mulching. Practice mulching with organics to extend the period of moisture availability. Thin out to the extent of 25% and use the removed plants as feed/ mulch. Close the drainage holes and check the seepage loss in direct sown medium land rice regularly.

SCENARIO 4: *BEUSHANING* OF RICE DELAYED

Do not practice *beushaning* (blind cultivation) in rice, if the crop is more than 45 days old. Weed out the field without waiting for rainfall. Go for gap filling using seedling of same age or clonal tillers to have a uniform distribution of plant. Strengthen the field bunds and close the holes to check seepage loss. Withhold N fertilizer application up to receipt of rainfall.

SCENARIO 5: TRANSPLANTING OF RICE DELAYED

Generally in this case rice seedlings are over aged. Seedlings up to 45 and 60–70 days old can be transplanted in case of medium and late duration rice varieties, respectively without much reduction in yield. Remove the weeds and follow plant protection measures against blast in the nursery. Pulverize the main rice field in dry conditions, if it is not ploughed earlier to save time in final pudding. Use tractor/ power tiller/tractor mounted rotavator for speedy land preparation/ puddling to cover more area with less time. Follow close transplanting using 5–7 seedlings/ hill. Apply 50% recommended nitrogen at the time of transplanting. Apply lifesaving irrigation to maintain the nursery seedlings in good health. Do not top dress nitrogen in nursery.

SCENARIO 6: TRANSPLANTED RICE AFFECTED AT EARLY VEGETATIVE STAGE

Provide protective irrigation through recycling of harvested rain water. Remove the weeds and follow plant protection measures against blast in the nursery if existing. Withhold N fertilizer application up to receipt of rainfall. Apply Potassic fertilizers wherever soil moisture allows or wait up to receipt of rainfall. Strengthen the field bunds and close the holes to check seepage loss.

LATE SEASON DROUGHT (SEPTEMBER 16 TO OCTOBER 31)

SCENARIO 7: MEDIUM AND LOW LAND RICE AFFECTED AT VEGETATIVE/ REPRODUCTIVE STAGE

It occurs as a result of early cessation of monsoon rains. In this situation provide protective irrigation through recycling of harvested rain water. Provide irrigation at critical stages such as flowering, grain filling, etc. in alternate furrows in wide spaced crops. Crops like cowpea, greengram may be harvested for fodder purpose to avoid their failure as grain crops. Under situation of complete failure of *kharif* crop dismantle it. In such situation or where land is remaining fallow, sow (dibble) the pre-*rabi* crops. The ideal pre-rabi crops with residual moisture condition are horse gram, castor, niger, blackgram and sesame in uplands and well drained medium lands.Pre-position inputs, particularly seeds for the rabi crop.

Major crop of the region is rice, which is highly dependent on monsoon rainfall for nursery bed preparation, transplanting and maintenance of water in the field. Analysis indicates the need for selection of crops according to the probability of getting wet weeks preceded by wet weeks with the onset of southwest monsoon in the region. Timely monsoon will favour selection of long duration and high water requiring crops like rice. Late monsoon will lead to selection of crops with medium duration and moisture stress tolerant crops like ragi, finger millet and sorghum, in the moderate rainfall districts, where erratic monsoon behavior is observed. Pulses like green gram and black gram, need to be selected often as intercropping based on varied rainfall situation. Direct seeded rice can be adopted in that situation. Analysis reveals that past rainfall record may be handy tool for future rainfall probability projections.

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Climate Change and its Impact on Agriculture and Allied Sectors

Feza Ahmad* and Samik Sengupta
Department of Horticulture, (Fruit & Fruit Technology), Bihar Agricultural University, Sabour, Bhagalpur, Bihar
*E-mail: *feza@rediffmail.com*

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INTRODUCTION

Climate and weather play an important role in the economic success or failure of fruit crops. Air temperature and rainfall influence vegetative and pheological phases in plants and their impact are profound in higher plants. For determining suitability of an area for fruit production, climate and rainfall play an important part. In the last few decades there has been extensive research on potential and observed vulnerability to climate change on all kinds of fruit and allied crops. Thus, a clear description of the vulnerable situation is an important first step for avoiding misunderstandings around vulnerability. The assessment of vulnerability in the context of extreme climate events and historical climate variability is an important avenue for engaging the policy community. A focus on climate variability automatically brings to the fore the way in which socio-economic systems becomes vulnerable to climate hazards. At the same time, this analysis provides insights that are relevant immediately to deal with extreme climate events well before the full range of consequences of mean changes in the climate state become apparent. Therefore, improved understanding of vulnerability and adaptive capacity is essential for identifying and realizing the full benefits of developmental projects, and in ensuring that such projects, particularly infrastructure projects, do not lead to mal-adaptation with regard to future climate change.

The last two decades have witnessed extensive research on potential and observed vulnerability to climate change on all kinds of fruit crops. Vulnerability depends critically on context, and the factors that make a system vulnerable to a hazard will depend on the nature of the system and the type of hazard in question.

IDENTIFYING KEY FACTORS AFFECTING VULNERABILITY

Vulnerability depends critically on context, and the factors that make a system vulnerable to a hazard will depend on the nature of the system and the type of hazard in question. There are certain factors that are likely to influence vulnerability to a wide variety of hazards in different geographical and socio-political contexts. These are developmental factors including poverty, health status, economic inequality and elements of governance, to name a few. These may be referred to as generic determinants of vulnerability, as opposed to specific determinants relevant to a particular context and hazard type, such as the price of a particular food crop, the number of storm shelters available for the use of a coastal community, or the existence of regulations concerning the robustness of buildings.

CLIMATE CHANGE AND ITS IMPACT ON FRUIT CROPS

Climate-related changes have already brought widespread changes in flowering and fruiting patterns of different fruits. In some places with the rising in temperature in areas previously too cold for a particular fruit production are making them more suitable for its production. For instance, an increase in temperature during coldest month has made mango cultivation possible in the valley areas of Himachal Pradesh and Uttarakhand. In several parts of the globe increasing temperature will offer opportunities for mango production in new areas. In case of litchi, relatively cool temperature is the only factor known to induce flowering, but does not ensure floral initiation will occur because there are important interactions with vegetative growth (Menzel and Simpson, 1995). In USA it has been observed that in fruit crops like apple and grape there is a steady advance in blooming time suggesting a slightly more rapid advance in spring bloom (Fig. 1), about 2 days per decade (Wake, 2005). The implications of earlier bloom for horticultural crops will depend on many factors. In some cases, it may translate in a straightforward fashion to earlier yields. This will benefit farmers who receive higher prices for earlier production, but could have a negative effect if there is increased competition from farmers in other regions earlier in the season. Earlier bloom could potentially reduce yields if spring temperatures become more variable as the climate changes and an early bloom increases the risk of frost damage to flowers and developing fruit.

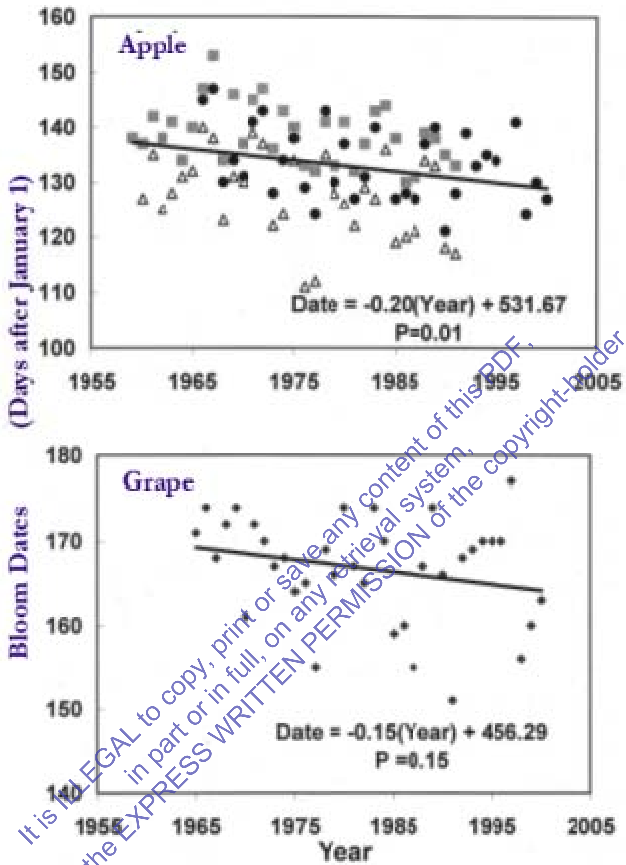

Fig. 1: Trends in Apple and Grape Bloom Dates Indicated by the Inclined Lines

Source: Wake C 2005

IMPACT ON AGRICULTURAL SYSTEMS

The agriculture sector in India is already threatened by existing factors such as land use changes, scarcity of water resources, increasing air pollution and loss of biodiversity. In a tropical country such as India, even minimal warming will lead to loss in crop yields (Parry *et al.*, 2007). Further studies conducted by the Indian Agricultural Research Institute (IARI) indicate the possibility of loss of 4-5 million tons in wheat production with every rise of 1°C temperature throughout the growing period even after considering carbon fertilization. Losses for other crops are still uncertain but are expected to be smaller, especially for kharif crops (Aggarwal, 2008). Research also suggests that erratic monsoons will have serious effects on rain-fed agriculture with projected decreases in the productivity of crops including rice, maize and sorghum (especially in the Western Ghats, Coastal region and North eastern regions), apples (in the Himalayan region) (Kumar *et al*, 2011). Studies indicate that increased droughts and floods are likely to increase production variability and lead to considerable effects on microbes, pathogens, and insects needed for the upkeep of healthy agricultural systems. The UNFCC (2007) have indicated that increasing sea and river water temperatures are likely to affect fish breeding, migration, and harvests. Increasing glacier melt in Himalayas could affect availability of irrigation especially in the Indo-Gangetic plains, which, in turn, would have consequences on food production. Aggarwal *et al.* (2009) estimated the impact of climate change on livestock and conclude that animal distress could lead to effects on reproduction and subsequently loss of 1.5 million tons of milk by 2020. Tripathi (2013) assessed the vulnerability to climate change of farmers in Uttar Pradesh (UP). He used 17 environmental and socioeconomic factors to see which districts of UP are the most vulnerable to climate change, and attempts to identify the factors on a set of explanatory variables. The study finds that infrastructurally and economically developed districts are less vulnerable to climate change; in other words, vulnerability to climate change and variability is linked with social and economic development. This observation is corroborated by the findings of relational analysis. In relational analysis, livestock, forestry, consumption of fertiliser, per capita income, and infant mortality rate are observed to be important correlates of farmers' vulnerability to climate change; these should be focussed on. Also, farmers' awareness and adaptive capacity to climate change needs to be strengthened, for which policy options such as crop insurance and early warning systems would help.

IMPACT ON FORESTS AND BIODIVERSITY

Chaturvedi *et al.* (2011) developed a vulnerability map and projected the impact of climate change on Indian forests and conclude that 39% and 35% of the forests grids in India will likely undergo change under the A2 and B2 scenarios respectively. The vulnerability map suggests that the concentration of vulnerable forest grid is higher in the upper Himalayan stretches, parts of central India, northern Western Ghats and Eastern Ghats. The upper Himalayan stretches and parts of central India currently have low development indicators, so that they will struggle to cope with any impacts they might be faced with. The forests of northeast, southern Western Ghats and eastern parts of India are projected to be least vulnerable. This is on account of their high biodiversity, low fragmentation, high tree density as well as low rates of vegetation change (as these regions experience lower levels of temperature increase and gain substantially in terms of precipitation). They also suggested that low vegetation vulnerability in North-eastern India means these regions are suitable especially for forest conservation projects.

IMPACT ON INFRASTRUCTURE SYSTEMS

In India, investments worth US$ 120 billion have been planned for infrastructure asset creation during 2011-2012 (Naswa and Garg, 2011) Climate change induced natural disasters could put serious pressure on these investments. The critical climate parameters of temperature, precipitation, sea-level rise and extreme events pose direct and indirect threats to India's infrastructure assets. Enhanced landslides, vegetation cover, excessive siltation in rivers, and soil erosion could be direct impacts. Groundwater table depletion, energy demand changes, and migratory traffic could be the possible indirect impacts. The risks could be physical, technological, supply-chain or regulatory in nature (Naswa and Garg, 2011). A study on the adverse impact of climate change on the Konkan Railways (a 760 kilometre line connecting Maharashtra, Goa and Karnataka – a region of criss-crossing rivers, deep valleys and mountains) leading to both direct and indirect risks in the railway sector has indicated key impacts such as infrastructure damages, disruption to services, repair and reconstruction costs, changes in both agricultural freight traffic and passenger traffic are a result of climate change. The study identified that 20% of repair and maintenance expenses on tracks, tunnels and bridges were due to climatic reasons (Gacuhi *et al.*, 2011).

POLICY IMPLICATIONS

Many of the strategies and activities designed to achieve adaptation to climate change overlap with and will be integrated into those taken to achieve national development goals, poverty alleviation, disaster risk reduction and other dimensions of sustainable development and resilience (e.g., the green economy, green jobs and green growth). Simultaneously, efforts to mitigate climate change are gathering momentum and are generating changes within human society as well (Klein *et al.* 2007).

Richardson *et al.* (2009) emphasized on equity issues and societal transformation to mitigate and adapt to climate change and bring long-term benefits. This is the climate change science and policy arena that faces the adaptation community: while scientific research findings are painting an increasingly challenging picture, the policy community and industry have yet to develop an effective response. Taken together, these warning signs add urgency to calls to reduce greenhouse gas emissions, while at the same time planning for the challenges and potential opportunities linked to the changing climate. Extreme weather events exert a huge cost on economies and societies. Innovative design can invoke and illuminate new visions of possible futures and inspire further creativity and optimism. The role of innovative design in adaptation, mitigation and sustainability paradigms should be investigated as well.

There is a major role for both the arts and the humanities in such planning and design. Changes in engineering standards, coastal and flood zone planning and management, requirements for private and public sector climate hazard disclosure and in public and private insurance and reinsurance markets could also lead to a "new normal' that catalyzes large-scale changes in mitigation, sustainable development and adaptation potential (Dawson, 2007). The key questions include how to minimize impacts of transition on the most vulnerable communities, the extent to which transitional costs (e.g., shoreline retreat) should be borne by those exposed to the hazard or society as a whole and how to ensure that all stakeholders are included in long-term decision-making (Smit and Pilifosova, 2003). Integrated research is needed across private and public entities on how to minimize the risk of perverse incentives, including those that can be associated with price distortions in insurance markets, the resilience of our society, financial and the natural economy, data and projections in support of adaptation, mitigation and sustainable development, the effectiveness of planning and design for climate change responses in urban areas, their surrounding infrastructure and resource-sheds and rural areas are extremely required (Betts *et al.*, 2011).

CONCLUSION

In view of these problems, horticulturists and allied scientists will have to play a significant role in the climate change scenario and proper strategies have to be envisaged for saving horticulture and allied sectors. The most effective way is to adopt conservation agriculture, using renewable energy, forest and water conservation, reforestation etc. to sustain the productivity modification. Development of new cultivars of horticultural crops tolerant to high temperature, resistant to pests and diseases, short duration and producing good yield under stress conditions, as well as adoption of hi–tech horticulture and judicious management of land use resources will be the main strategies to meet these challenge.

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New Approach for Light Manipulation in Litchi Trees for Quality Production

Sushil Kumar Purbey*, Sanjay Kumar Singh and Alemwati Pongener

ICAR-NRC on Litchi, Muzaffarpur–842002, Bihar

*E-mail: *skpurbey_nrcl@yahoo.com*

INTRODUCTION

Efficient management of limited environmental resources in horticulture can be considered one of the most important tasks for sustainable, high quality fruit production. Each plant has certain environmental requirements. To attain the highest potential yields a crop must be grown in an environment that meets these requirements. Producing quality fruit requires appropriate plant management. Under the changing climatic condition as a whole and particularly during litchi reproductive phase is becoming a limiting factor nowadays. Light limits the photosynthetic productivity of all crops and is the most important variable affecting productivity and quality. The transpiration rate of any crop is the function of three variables; ambient temperature, humidity and light. Of these three, it is light which is usually out of our control as it is received from the sun. Supplementary lighting does offer opportunity to increase yield during low light periods, but is generally considered commercially unprofitable. The other means for manipulating light are limited to screening or shading and are employed when light intensities are too high. However, there are also general strategies to help maximize the crop's access to the available light. Fruit plants respond to light quantity, quality, direction, and periodicity. There are numerous photoreceptors in plants, including chlorophylls, phtyochromes, cryptochromes, phototropins, and ones that react to green light. Light, along with other environmental cues, enables plants to adapt to environmental conditions. Efforts to manipulate plant morphology and physiology using photoselective filters have been ongoing for decades, especially in greenhouse environments.

LIGHT INTERCEPTION AND DISTRIBUTION

Global climate change may force variation in timing, duration and synchronization of phenological events in fruit crops. Fruit trees in general are expected to respond variously to changes in light interception, rainfall and temperature because they differ widely with respect to adaptations to seasonal drought and cues for bud break of vegetative and flower buds. Now evidences are available to show that significant variation (advanced or delayed) in onset dates of flowering and fruiting responses do exist in different fruit trees as a result of climatic change. Light is an important factor in production of fruit. It has a role in flower induction as well as in fruit development through carbohydrate synthesis. While increased assimilates in the shoots is a pre-requisite for flowering in mango and other fruits generally, high yield of quality fruits are attributed to high light interception and distribution in the tree canopy. The fruit yield is related to light interception, whereas fruit quality is a function of light distribution. Light interception is influenced by plant density, canopy shape, canopy leaf area index and can be raised by increasing the density of foliage in the canopy, the height of the tree and number of tress per hectare. Light intensity decreases, within the tree canopy as the outer portion shades the inner canopy. Light exposure influences flower bud differentiation, fruit set, fruit colour and quality. Approximately 30 per cent of full sunlight is required to maximize photosynthesis and initiate flower buds. The fruit quality attributes like fruit size, firmness, soluble solids (sweetness) are increased under high light conditions and are decreased in deeply shaded areas of the tree canopy. At least 50-60 per cent of full sun light is required for fruits to develop and acquiring maximum red colour particularly for tropical and sub tropical fruit crops. In case of litchi, during reproductive phase, mostly the value of PAR is >700 and westerly wind during this period is causing maximum fruit drop, sun burning and cracking due to desiccation.

THE LIGHT USE EFFICIENCY OF PLANTS

Plants use the light in the 400 to 700 nm range for photosynthesis, but they make better use of some wavelengths than others. All plants show a peak of light use in the red region, approximately 650 nm and a smaller peak in the blue region at approximately 450 nm. Plants are relatively inefficient at using light and are only able to use about a maximum of 22% of the light absorbed in the 400 to 700 nm region. Light use efficiency by plants depends not only on the photosynthetic efficiency of plants, but also on the efficiency of the interception of light. Light exposure is a factor that varies with the position within the canopy of the fruit-bearing branch and of the fruit itself. The effect of light on photosynthesis includes both a direct effect of the photosynthetic photon flux on the rate of electron flow and an indirect effect of light on leaf photosynthetic capacity, since plants allocate nitrogen resources within the canopy to enhance photosynthetic capacity in portions of the tree receiving high irradiances.

Perennial fruit orchards do offer great potential for modification of light and temperature environments within canopies by pruning, tree training, tree size, row spacing and row orientation. More recently, there are some tools/ practices which can manipulate the light quality specifically for plant development and growth as well as quality production. These are: use of reflective films improves UV and Red light properties, colour shed net (black, blue, green, red, white) and bagging of fruit bunches. The concepts involved in the optimization of environment for quality production is to maximize the photosynthetic process in the plant. Therefore, on-going modifications are made to harness the maximum available natural resources to match the maximum rate of photosynthesis so that we can get more quality production. This implies that growers can direct the results of photosynthesis, the production of assimilates, sugars and starches, towards both vegetative and generative in a balance.

USE OF REFLECTIVE FILMS

Reflective mulches are able to change major environmental parameters, specifically the light-environment at the tree canopy level. Changes in the light micro-environment induced by reflective mulches are likely to be responsible for the increased accumulation of specific classes of compounds in the fruit. Experiments conducted with high density polyethylene mulch, characterized by having a reflective metalized surface, on peach cultivars selected for their poor red colouration, showed significant increases in red colour, especially on fruit from the lower part of the canopy. Reflective mulch (Extenday Europe Ltd., Egham, UK) was laid down on both sides of the inter-row of half of the trees (Fig. above). Fig. 1.

Fig. 1

COLOUR SHED NET

Shed net can provide physical protection (birds, hail, insects, excessive radiation), affect environmental modification (humidity, shade, temperature), and increase the relative proportion of diffuse (scattered) light as well as absorb various spectral bands, thereby affecting light quality. These effects can influence crops as well as the organisms associated with them.

RADIATION

Nettings, regardless of color, reduce radiation reaching crops underneath. Obviously, the higher the shade factor, the more radiation will be blocked. Reductions in radiation resulting from netting will affect temperatures (air, plant, soil) and relative humidities. Besides affecting the amount of radiation, nettings can influence the radiation direction.

RADIATION SCATTERING

Diffuse light has been shown to increase radiation use efficiency, yields (both at the plant and ecosystem level), and even be a factor affecting plant flowering (timing and amounts) Any shade netting can scatter radiation, especially ultraviolet because netting is usually made using ultraviolet-resistant plastic. Shade netting that increases light scattering but does not affect the light spectrum has been shown to increase branching, plant compactness, and the number of flowers per plant. Colored shade nets can also increase light scattering by 50% or more (Fig. 2) and this alone may influence plant development and growth.

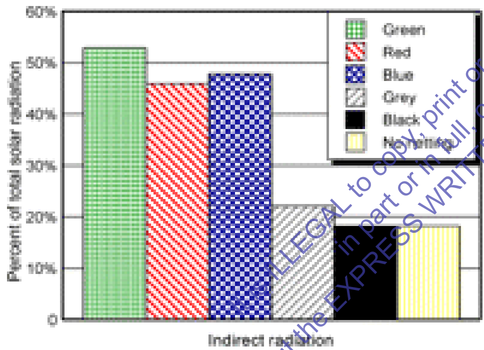

Fig. 2: Light Scattering under Colored Shade Nets Compared with no net (Oren-Shamir *et al.*, 2001

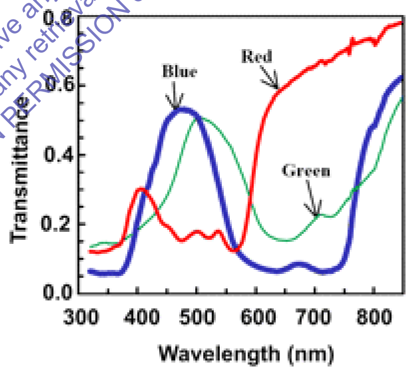

Fig. 3: Spectra of Transmittance for Three Colored Shade Nets (Oren-Shamir *et al.*, 2001)

PHOTOSELECTIVITY

Colored shade nets are being intensively tested primarily because of their ability to manipulate the spectra of radiation reaching the crops below (Fig. 3). They can be used to change red to far-red light ratios that are detected by phytochromes, the amounts of radiation available to activate the blue/ultraviolet-A photoreceptors, blue light involved in phototropic responses mediated by phototropins, and radiation at other wavelengths that can influence plant growth and development.

AIR MOVEMENT

Nettings also reduce wind speeds and wind run, which can affect temperatures, relative humidities, and gas concentrations resulting from reductions in air mixing. These changes can affect transpiration, photosynthesis, respiration, and other processes. The effects on air movement depend on the porosity and physical location of the netting in relation to the plants and can be affected by time of day, season, and other factors.

A study conducted at ICAR-NRC on Litchi, Muzaffarpur, where the litchi trees were covered 20 to 25 days after fruit set with shade net (white and green) and two shading percentages (30 and 50 %) and an uncovered control comprising of 9 treatment combinations in total. The results showed that irrespective of colour and percent shading, shade nets had a significant effect on increase in fruit weight, percentage of Class I fruits, less discarded fruits and extending the harvesting period in comparison to control (uncovered). Shade net treatments had about 50% higher fruit retention and almost 40% less sunburned and cracked fruits and extended the harvesting period by almost 7 to 12 days compared to open trees. Shahak *et al.* (2004) found that a red/white shade net treatment that reduced PAR by 18% increased fruit set of apple cultivar Smoothee Golden Delicious (SGD) compared with the no-net control. It was further observed that all the shade nets except white improved the midseason red coloration (coverage and intensity) of Topred delecious. Berry and cluster weights of cultivar Superior were increased most under 30% yellow nets, but 30% gray reduced yields compared with the no-net control. Yields were also increased under 30% black, 30% red, and 22% white nets. In other trials using Red Globe as the cultivar, the authors reported increased berry size under the 30% yellow compared with five other colored nets and increased berry weight under black, red, and white netting compared with no net. Colored netting was also shown to affect the rate of fruit maturation with lightscattering nets (pearl, white) increasing the rate of maturation of a number of cultivars and black and red nets delaying the maturation of 'Red Globe'. With blue netting, maturation was advanced for Superior but delayed for Perlette (Shahak *et al*., 2008). Similarly in pear, kiwi fruit, pepper, mango etc the effects of different shed net are varied and plant responses may differ even among cultivars of the same plant. Therefore, much additional research is needed to demonstrate and elucidate the effects of colored shade nets. Because colored netting has numerous effects besides photoselective ones and even photo selectivity can change over time. Radiation quality and quantity values and microclimate parameters should be measured and reported to aid in the determination of which factors might be causing any reported results.

BAGGING OF FRUIT BUNCHES

The fruit bagging technique is widely adopted in the production of apple, pear, grapefruit, litchi, longan and other fruits, for improving fruit quality and reducing pesticide residues effectively, preventing from rust, decreasing rates of insect or disease damaged fruit and cracking fruit. The effects of bagging were different from fruit trees. It is a physical protection technique commonly applied to many fruits, which not only improves fruit visual quality by promoting fruit coloration but also enhances internal fruit quality. Pre-harvest bagging of fruits has been conventionally practiced for fruit growing in Japan, Australia and China as well as in peach, apple, pear, grape and loquat cultivation in order to optimize fruit quality through reduced physiological and pathological disorders and for improving fruit coloration to increase their market value leading to improved appearance (Table 1).

Table 1: Bagging Practices in Various Fruit Crops

Fruit	Bagging
Apple	Yellow colour non woven PP bags at 45-60 days before harvesting
Banana	Blue polyethylene (0.5mm thick) sleeves at 15 days prior to harvesting
Custard apple	White/ yellow plastic bags at early stage of fruit development
Guava	Waxed paper bag/ plastic bag 1 month before harvesting
Litchi	White colour non woven PP bags/ butter paper bags at 20-30 days before harvesting

Several authors have reported contradictory results for the effects of pre-harvest bagging on fruit size, maturity, peel color, flesh mineral content and fruit quality, which may be due to differences in the type of bag used, the stage of fruit development when it was bagged, duration of fruit exposure to natural light after bag removal (before harvesting), and/ or fruit-and cultivar-specific responses. Bagged fruits are capable of synthesizing anthocyanin when they were exposed to light for few days before 55 the actual date of harvest. It is believed that bagging increases light sensitivity of fruit and stimulates more anthocyanin synthesis when fruits are kept in WBPB and MCB (59.16 and 61.38 % photo-permeability respectively) than fruit kept in BPB (3.90 % photo-permeability) during maturation, which indicates medium light intensity could be imperative for anthocyanin synthesis. Table 2: bagging practices in various fruit crops Fruit Bagging Apple Yellow colour non woven PP bags at 45-60 days before harvesting Banana Blue polyethylene (0.5mm thick) sleeves at 15 days prior to harvesting Custard apple W hite/ yellow plastic bags at early stage of fruit development Guava Waxed paper bag/ plastic bag 1 month before harvesting Litchi White colour non woven PP bags/ butter paper bags at 20-30 days before harvesting A study conducted at ICAR-NRC on Litchi, Muzaffarpur showed that litchi fruit bunches when bagged 25-30 days before expected harvesting with non-woven PP bag (White) there was 25–30% less damaged fruits due to sun burning and cracking in comparison to control. It was also found that fruits were

80-90 percent less borer infested as compare to unbagged fruits. Bagged fruits produced comparatively heavy and big size fruits with 9-19 % more weight over unbagged fruits with more bright red color. Management of tree canopy and structure for efficient adoption of bagging technique is essentially required.

CONCLUSION

Environmental factors are one of the main sources of variation of fruit quality, as has been described in various studies and reviewed in this paper. These preharvest factors affect both fruit growth during its development by changing the accumulation of water and dry matter, including biochemical and mineral compounds, and fruit behaviour during its storage. Having knowledge of and then being able to control changes in fruit quality in response to environmental conditions may be essential for adopting cultural practices that will provide high quality fruits. A way to improve final fruit quality traits such as size, colour, taste, nutritional value and flavour through an integrated approach of canopy management along with practices/ designs to manipulate the environmental factors especially light, which influences the various components of fruit quality.

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Impact of Livestock on Global Warming and its Mitigation Strategy

Kaushalendra Kumar[1] and Sachidanand Samantaray[2]

[1]*Assistant Professor, Department of Animal Nutrition,*
[2]*Dean, Bihar Veterinary College, Patna*
Bihar Veterinary College, Patna–800014, India
E-mail: [1]drkaushalivri@gmail.com

Abstract: Recently, climate change is a major concern globally which affects livestock both directly and indirectly. Air temperature, humidity, wind speed and other climate factors directly influence animal performance including growth, production, health and reproduction. Higher temperatures along with altered precipitation are likely to result in the problem of heat stress in livestock in climate change sensitive regions leading to decreased production and increased susceptibility to diseases. Growth of livestock has great significance regarding food and nutritional security of India. In India, the livestock production is based on low input-low output economy. Our country produces largest volume of milk and animal protein from this production system. With farmer centric policies, government and private sector investment in agriculture and allied sectors, it would be possible to meet the challenges of climate change with the needs of improving productivity of agriculture and livestock and improve the food and nutritional security for human populations of country.

INTRODUCTION

Climate change represents one of the greatest environmental, social, ecological and economic threats facing the planet now a day. Global warming is a slow and steady process and global temperature, carbon dioxide and methane level increases in the atmosphere, all these parameters did not change rapidly before the industrial revolution, about 250 years ago. During the last 100 years, there has been a rise of 0.8°C in temperature, which in absolute term does not appears to be very high, but it is a continuous phenomenon and the rate of further rise in climatic temperature might be much higher and faster than that was observed in the last century. Increasing temperatures and shifting rain patterns reduce access to food and create effects that impact regions, farming systems, households, and individuals in varying ways. Formulating adaptation strategies is an important part of ensuring that countries are well prepared to deal with any negative impacts that may occur as a result of climate change.

Adapting to climate change and reducing GHG emissions may require significant changes in production technology and farming systems that could affect productivity. Developing alternative strategies tending to reduce CH_4 emissions from ruminants are big concern even more if strategies improve feed efficiency and increases profitability (Reyes *et al*. 2011). To be considered viable, these emissions reduction strategies must be consistent with the continued economic viability of the producer, and must accommodate cultural factors that affect livestock ownership and management system.

PROSPECTS OF GREEN HOUSE GASES

Intergovernmental Panel on Climate Change (IPCC) included six gases under the head of GHG such as carbon dioxide (CO_2), Methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perflurocarbons (PFCs), and sulphur hexafluoride (SF_6). The first three gases are present in the atmosphere and are produced as a result of agricultural and livestock activities performed by human being. The global warming potential (GWP) of these gases in comparison to carbon dioxide is several times higher like methane and nitrous oxide have 23 and 296 times higher potential for global warming, respectively. Therefore, it is essential that their levels in the atmosphere are kept within safe limit. During the last two century the level of two important gases (methane and nitrous oxide) have risen by 115% and 15%, respectively which is not a good indication for the environment. India is exempted from the Kyoto Protocol in August, 2002. Indian Prime Minister in G8 meeting pointed out that the per capita emission rates of the developing countries are a tiny fraction of those in the developed world. Therefore, India maintains that the major responsibilities of cubing emission rest with the developed countries, which have accumulated emission over a long period of time. But the developed countries like US and European countries assert that India, along with Brazil and China, will account for most of the emission in the coming decades, owing to their rapid industrialization and economic growth. Due to this reason, many a times developed countries wish that India, Brazil and China should also contribute equally for the control of these GHG, irrespective of the previous emission levels.

The emission of CO_2 (by animals, industries, human) in 2006 was the highest in China (6110 million metric tons) followed by US, European Union, Russia and India, but share in global total emissions were 17, 16, 12, 4.6 and 3.6%, respectively. But the per capita CO_2 emission was the highest in US (19.2 tones/head) followed by Australia (18.9), Canada (17.4), Saudi Arabia (13.4), Russia (11.5), Taiwan (11.4) and India (1.1 tone/head) at 20^{th} position in the world.

LIVESTOCK AND GLOBAL WARMING

The majority of feed consumed by the ruminants is composed of lingo-cellulosic crop residues and their digestibility depends upon the micro-biota present in the rumen, which converts this non utilizable form into a utilizable form of energy (volatile fatty acids) and the microbial protein which is used as a source of amino acids by the animals. During feed degradation, hydrogen is generated in the form of reduced co-factors (NADH and NADPH) which are oxidized by reduction of carbon dioxide to methane. The oxidation of cofactors in the rumen is essential for the fermentation of feed in continuation. Therefore, an adult cow produces more than 200 litre of methane every day and most of it is belched out and only a small fraction which is synthesized in large intestine is passed out through anal route. As far as the production of methane in India is concerned, 105 Tg methane is generated by the agricultural activities of the farmers out of which about 60% is produced by enteric fermentation of livestock. Out of a total contribution of livestock in methane emission, 92% is produced only by cattle and buffaloes and the rest 8% methane is generated by all other herbivores animals like sheep, goat, yak, mithun, horse, elephants etc. Therefore, all the strategies aimed at mitigation of methane generation are limited to cattle and buffaloes.

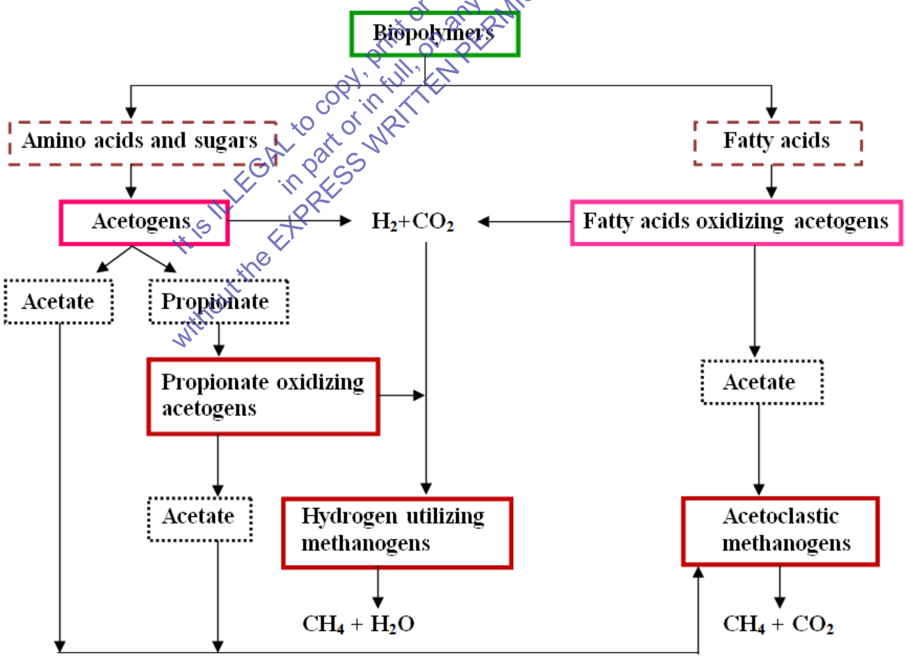

Fig. 1: Flow Chart of Methane Production

It is not important which country is producing how much methane, carbon dioxide, nitrous oxide or any of the green house gases, but all these gases affect the climate adversely and all the countries have to suffer, irrespective of the pollution, they have created in the past. Therefore, it appears to be logical if the under developing or developing countries like India, China and Brazil demand a compensation from those developed countries which are really responsible for creating pollution and harming the climate in the past. A lot of research has been conducted and is still going on to find out strategies by which lower the emission of green house gases and global warming effect, if not completely stopped. Some of these techniques are listed below which appears to have some potential of reducing the production of these gases and their release into the climate.

ADAPTATION STRATEGIES FOR SUSTAINING LIVESTOCK PRODUCTION DURING CLIMATE CHANGE

There are different adaptation strategies for sustaining livestock production during climate change such as feed production technologies, diversification of livestock species, breeding locally adapted livestock species, adopting livestock production as an adaptation strategy, resource management practices, pastoral livestock mobility, diversification of livelihood activities, understanding the constraints to adaptation, social innovation, technological innovations, management innovations, developing niche markets to preserve indigenous breeds, information technology, new energy supplies, climate forecasting capacity, developing financial services etc.

IMPLICATIONS OF DIFFERENT STRATEGIES FOR REDUCING METHANE EMISSION

Decreasing Low Producing or Non-producing Ruminants Population: Because of these animals methane production per kg livestock product is higher in India and the country is criticized for this activity throughout the world, but elimination of such animals is not possible due to a ban of cow slaughter in many states of India. This can be done strategically during a long duration to slowly decrease the numbers of low producing or non-producing livestock with improved indigenous and cross-bred animals.

Enhancing the Efficiency of Livestock Production: Improving the efficiency of ruminant animal performance will generally lead to a reduction of methane emitted per unit of animal product. There are two aspects such as; genetic improvement of the animals themselves to achieve more product per unit of feed intake (for example pigs and poultry, and nutritional manipulation via increased feed intake and appropriate feed composition.

Increasing Dry Matter Intake: Increasing feed intake, decreases the methane emission per unit of feed intake. By feeding animals ad libitum it is possible to both maximise efficiency and reduce methane emission per unit of product. By improving animal production efficiency, emissions per unit product can be reduced by 25 to 75 percent depending on animal management practices. In addition, improved productivity can allow managers to reduce the size of the herd to produce a certain quantity of product.

Selection of Low Methane Producing Animals: Proportion of such animals might be low and the character might not be genetically inherited, but do exist a few animals, which are low methane producers (reason not known). Further research is needed to find out probable reasons why a few of them produce lower methane than the others and this trait can be commercially exploited to produce livestock on large scale with low methane production.

Identification of Low Methane Producing Diets (Roughage Source and Oil Cakes): There are certain feeds which produce lower methane than the others, almost similar in chemical composition and energy content. If these feeds are included in the diet of animals, methane production can be reduced by at least 10-15%. But, in Indian conditions, the farmers do not have sufficient choice of feeds to be fed their animals and economically it is not feasible for the poor farmers to purchase a desired feed from the market.

Probiotics Feeding: There is very little information on the effects of probiotics on CH_4 production in dairy cattle. The effects of the most widely used microbial feed additives, *Saccharomyces cerevisiae* and *Aspergillus oryzae*, on rumen fermentation were earlier studied in vitro (Mutsvangwa *et al*., 1992). *Aspergillus oryzae* was shown to reduce CH_4 by 50% as a result of a reduction in the protozoal population (Frumholtz *et al*., 1989). Probiotics also provide nutrients, including metabolic intermediates and vitamins that stimulate the growth of ruminal bacteria, resulting in increased bacterial population. However, the specific mode of action is still unknown.

Another theory indicates that probiotics stimulate lactic acid utilizing bacteria, resulting in a reduction of lactic acid which provides more stable ruminal environment. Eun *et al*. (2003) reported that brewer's yeast culture enhanced the activity of bacteria that convert H_2 to acetate and decreased CH_4 output by 25% in a continuous culture of ruminal microorganisms. Although microbial preparations are commercially available as ruminant feed additives, but there is a need for further research to establish the potential of probiotics for reducing CH_4 production *in vivo*. There is a need to identify the dietary and management situations in which probiotics can give consistent production benefits as well as the added effect of reducing CH_4 emissions (Moss *et al*., 2000).

Use of Methane Oxidizers: Methane oxidizing bacteria have been isolated from different environments, including the rumen. *In vitro* studies with stable carbon isotopes suggest that the extent of CH_4 oxidation to CO_2 is quantitatively minor (0.3 to 8%) in the rumen (Kajikawa and Newbold, 2000). Valdez *et al*. (1996) isolated a CH_4 oxidizing bacterium from the gut of young pigs, which decreased CH_4 accumulation when added to rumen fluid *in vitro*. However, this approach has not been validated *in vivo*. In long-term, CH_4 oxidizers from gut sources could be screened for their activity in the rumen to reduce the proportion of ruminal gas in the form of CH_4.

Improving the Feed Quality: An improvement in diet (increased digestibility of roughages) decreases methane emission and improves livestock productivity. Increasing grain in di*et al*so has a similar effect. But improving digestibility of poor quality feeds is and inclusion of grain in diet has its own limitations like cost involved and availability in the market. Therefore, this can be exploited commercially, if there is a change in policy of the government and feed grade grain is allowed to be imported for incorporation in the ration of ruminants.

Application of Production Enhancing Substances: Production enhancing agents are available for use to increase production efficiency in ruminants. Bovine somatotropin (bST) for dairy cows is a naturally occurring growth hormone produced by the pituitary gland. Recombinant bST, an identical molecule, is produced biotechnologically and has been shown to increase milk production in dairy cows. In general, the use of bST leads to increase in milk production of 10-20 percent and therefore, animal numbers can be reduced to lower total enteric emissions (Clemens and Ahlgrimm, 2001). Johnson *et al*. (1996) estimated that the use of bST to improve dairy cattle productivity could result in decreased CH_4 emissions by about 9 percent.

Supplementation of Oils and Fatty Acids: Most of the oils and fatty acids that reduce methanogenesis reduce ruminal level of protozoa that are known to be co-symbionts of methanogens as mentioned in the section on ionophores. Therefore, a reduction in protozoan numbers is partly responsible for the decreased methane production induced by oils and fatty acids.

Nutritional Improvement: Forage rich diet results in acetate type fermentation, with an increase of methane production compared to propionate type fermentation which is stimulated by concentrate feed (Kingeston-Smith *et al*., 2010). Methane production was reduced (7% and 40%) by increasing DMI and the proportion of concentrate in the diet. The proportion of concentrate within the diet has been reported to be negatively correlated with methane emissions. The use of more digestible forage (less mature and processed forage) resulted in a reduction of methane production (-15% and-21%). Grinding or pelleting of forages to improve the utilization by ruminants has been shown to decrease methane losses per unit of feed intake by 20-40% when fed at high intakes (Johnson *et al*. 1996). At lowered fibre digestibility, decreased ruminally available organic matter and faster rate of passage associated with ground or pelleted forages can explain the decline in methane production. In summary, there are several promising strategies to reduce methane emissions through forage selection, but these need further investigation on a whole farm level.

Use of Plants Secondary Metabolites and their Extracts: Many feed additives originating from plant materials have been screened for their potential ability to reduce rumen methanogenesis. Although the inhibitory effect of saponin and sar-saponin on methanogenesis varies with the plant source, inhibition ranging from approximately 5-60%, accompanied by enhanced propionate. Rumen protozoa are particularly sensitive to saponins which reduce their level in the rumen, resulting in the depression of methanogens associated with protozoa as exo and endo-symbionts could be the main mechanism by which saponin feeding reduces methanogenesis. Essential oils also have a good potential for reducing methanogenesis in the rumen. Their antibacterial properties are relatively broad and their mechanism of action involves interaction of the antibacterial compound with the bacterial cell membrane which destabilizes the membrane and depressive effect on rumen proteolysis. Recent research indicates that plant containing secondary metabolites or their combinations improve animal performance without adversely affecting feed utilization. The incorporation of tannins in diet (1.5-2.5%) appears to be very effective in reducing methane production, which checks growth of intestinal parasites; lower nitrous oxide emission from faeces, improves animal performance and reduces methane emission by the ruminants.

Application of Archaeal Viruses: Another possible method of biological control of methanogens is the use of archaeal viruses (bacteriophage). Bacteriophages are obligate pathogens that can infect and lyses bacteria and methanogens. They are highly host specific. Although the presence of bacteriophages in the rumen is well known but knowledge of archaeal viruses is still limited. So, it is a considerable need to increase knowledge of the genetic diversity and viral susceptibility of methanogens and the host range of archaeal viruses, without which it is difficult to assess the potential of archaeal viruses as a biological control agent.

Inorganic Compound as Terminal Electron Acceptor: Nitrate can be a good methane inhibitor, but use of nitrate reducing bacteria as probiotic is must, which inhibits methane emission and improves feed conversion efficiency when nitrate reducing bacteria are used as a probiotic.

Selective Removal of Ciliate Protozoa from the Rumen: Scientifically feasible as some methanogens have ecto-symbiotic relationship with ciliate protozoa and their removal from the rumen results in 20-30% lower methane production, but it is difficult to maintain a protozoa free herd of animals.

Stimulation of Reductive Acetogenesis in the Rumen: Reductive acetogens (acetate producer, from carbon dioxide and hydrogen) compete with methanogens for hydrogen, but thermo-dynamically methanogenesis is preferred over acetogenesis. Therefore, inhibition of methanogenesis (by any techniques) is must for stimulation of acetogenesis in the rumen.

Use of Ionophores and other Antibiotics: Its application in diet result into lower methane emission, improved livestock productivity, but resistance of microbes to antibiotics and their ban in use as a stimulator are the major hurdles for practical application. Ionophore antibiotics, represented by monensin, have been widely used all over the world as feed additives for ruminant livestock and are considered as a growth promoter due to its favourable effects on rumen fermentation including methane reduction, propionate enhancement and ammonia reduction. Monensin is inhibitory for protozoa, gram-positive bacteria but not for gram negative bacteria, and therefore produce more propionate and less acetate, butyrate, formate and hydrogen which contributes to methane reduction (4-31%).

By Improving Grassland Management: Increasing the digestibility of cell walls in forages has been suggested as a means to lower methane losses, but in fresh grass and grass silage the scope of this approach appears to be rather limited. Shifting the animals from grass to legumes plant species tend to decrease the enteric emission due to lower proportion structural carbohydrates and faster rate of passage which shift the fermentation pattern towards higher propionate production (Johnson and Johnson, 1995) and altering the dietary cation anion balance of a roughage diet could decrease ruminal methane production without altering other aspects of rumen fermentation.

Immunization: A unique attempt to reduce rumen methane production is ongoing in Australia. This approach does not involve dietary manipulation by the inclusion of additives but involves vaccination of the animal against methanogenic bacteria in the rumen. Wright *et al*. (2004) reported that a significant 7.7% reduction in rumen methane production, corrected for dry matter intake level, was achieved by immunization strategy. They estimated that less than 20% of the methanogens were targeted by the vaccine that was prepared using 3 *Methanobrevibacter* strains. A vaccine of broader range is being developed to induce a greater extent of methane reduction (targeting >52% of different species/strains of methanogens that were tested based on a survey of sheep prior to vaccination) and a much more broad spectrum approach together with a more comprehensive understanding of the rumen methanogen population is surely required for the vaccination approach to be successful.

POSSIBLE RECOMMENDATIONS FOR LIVESTOCK RESEARCH AND DEVELOPMENT

- Promote breed development which is relevant to local environmental conditions
- Strengthen the understanding of appropriate pasture management
- Increase participatory research into the roles of women in the livestock sector
- Strengthen access to appropriate veterinary services to rural areas
- Develop relevant fodder production and conservation technologies
- Identify ecologically and socially sound options for improving water availability
- Strengthen natural resource and governance
- Explore the options and benefits for mitigation strategies in the livestock sector

CONCLUSION

The reduction of enteric methane emissions from livestock by selecting more feed efficient animals based on their estimated breeding value offers a novel way of reducing the methane production in livestock species without compromising the growth rate. Improved knowledge of quantitative nutrition provides powerful tools to develop concepts to undertake a wide range of problem oriented research with the goal of curtailing methane production by livestock farms. Interpretation of rumen microbial diversity and its interrelationships is much essential for the successful manipulation of rumen fermentation towards a significant reduction in methane emission from ruminant. The above techniques practically might give synergistic effect on livestock productivity and methane inhibition.

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Nanotechnology in the Arena of Changing Climate

Nintu Mandal*[1], Rajiv Rakshit[1],
Samar Chandra Datta[2] and Ajoy Kumar Singh[3]
[1]*Department of Soil Science and Agricultural Chemistry,*
Bihar Agricultural University, Sabour, Bhagalpur
[2] *Emeritus Scientist, Division of Soil Science and Agricultural Chemistry,*
Indian Agricultural Research Institute, New Delhi–110012
[3]*Vice-chancellor, Bihar Agricultural University, Sabour, Bhagalpur*
*E-mail: *nintumandal@gmail.com*

INTRODUCTION

Climatic aberrations are increasing day by day causing adverse impact on essential ecosystem functions. Spatial and temporal shifting of amount and frequency of rainfall is affecting agricultural operations in a massive way. Climatic extremities (Heat wave, cold wave *etc*) are affecting agricultural production system in a bigger way.

Surface temperature is projected to rise over the 21st century under all assessed emission Scenarios (IPCC, 2014). It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise (IPCC, 2014). There are multiple mitigation pathways that are likely to limit warming to below 2°C relative to pre-industrial levels (IPCC, 2014). These pathways would require substantial emissions reductions over the next few decades and near zero emissions of CO_2 and other long-lived greenhouse gases by the end of the century. Implementing such reductions poses substantial technological, economic, social and institutional challenges, which increase with delays in additional mitigation and if key technologies are not available. Limiting warming to lower or higher levels involves similar challenges but on different timescales (IPCC, 2014).

Technolological interventions in the changing climatic conditions seem to be imperative in formulating adaptation and mitigation strategies. Nanoscience is the study of matter at atomic or nano (1 nm=10^{-9} m) scale. Nanotechnology deals with fabrication of materials at nanoscale. Nanomaterials are materials having at least one dimension in 1-100 nm scale as per USEPA (United State Environment Protection Agency). Nanotechnological interventions in increasing input use efficiency, effective pest control and draught management in agriculture are of utmost importance in present day agriculture and in future also.

INTELLIGENT DELIVERY OF AGROCHEMICALS RHIZOSPHERE CONTROLLED RELEASE NUTRIENT FORMULATIONS MAJOR NUTRIENT FORMULATION

Montmorlonitic nanoclay separated from Vertisol was employed for controlled release N, P formulation by Sarkar *et al*., 2013. They prepared series of nanoclay polymer composites (NCPCs) by using various clay minerals *viz*. Kaolinite (Alfisol), Smectite (Vertisol) and Mica (Inseptisol) and concluded that smectitic type of clays were most suitable for NCPC preparation owing to its higher specific surface area and high aspect ratio. The types of composites were exfoliated types were confirmed by disappearance of typical bentonitic peak within polymer matrixes (Fig 1).

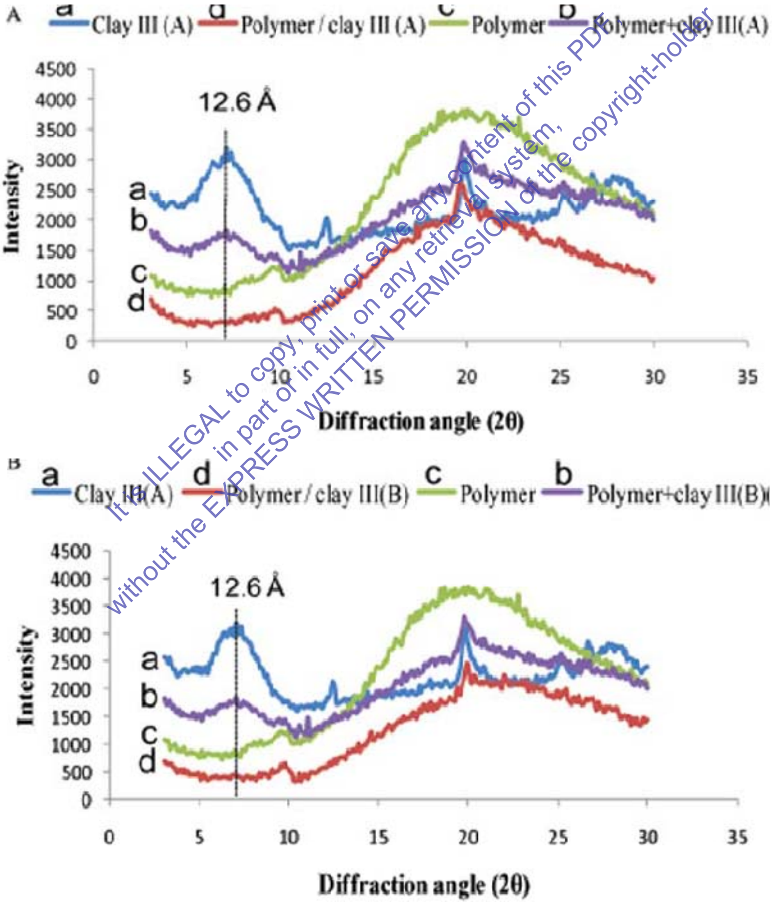

Fig. 1: Randomly Oriented Powder XRD Patterns of the Clay, Polymer/ Clay Composite, Polymer, and Polymer 1 Clay Physical Mixture for (A) Clay III(A) and (B) Clay III(B)

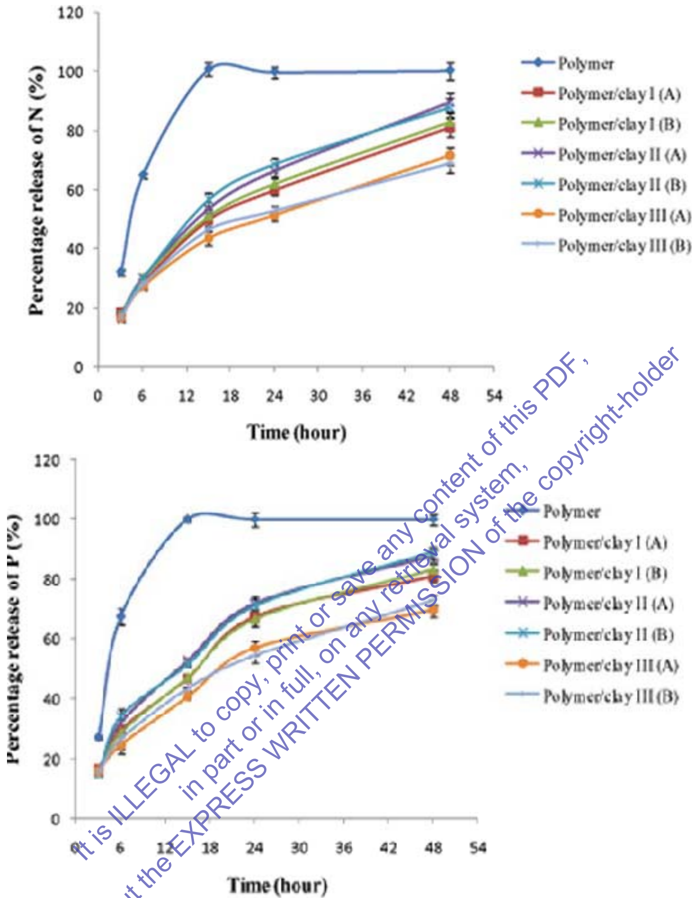

Fig. 2: Release of N and P from the DAP-Loaded NCPCs Incorporated with different Kinds of Clay (10 wt %) in Distilled Water. I, II and III Represents Clay Separated from Alfisol, Inseptisol and Vertisol Respectively. A and B Indicates with and without Aluminosilicates Respectively

In case of the NCPC incorporated with clay I (the kaolinite dominated clay) and clay II (the mica-dominated clay), the reaction occurred on the surface of the clays. However, the polymer layer penetrated into silicate layers, and the clay was exfoliated when clay III (the smectite-dominated clay) was introduced. The equilibrium water absorbency and nutrient release rate decreased with the incorporation of clay into the polymer matrix because of the increase in crosslinking points and the decrease in the mesh size of the NCPCs as compared to those in the pure polymer.

MICRONUTRIENT FORMULATIONS ZINCATED NANOCLAY POLYMER COMPOSITES (ZNCPCS)

NCPC based micronutrient formulation was reported by Mandal *et al*., 2015. Bentonitic nanoclay were separated through ultracentrifugation and used as a diffusion barrier in the acrylic acid (AA) and acrylamide (Am) copolymer masteries using ammonium persulphate (APS) as initiator and N, N, Methylene Bis acryalmaide (NNMBA) as crosslinker. Zn was loaded as Zn-citrate. Laboratory release study revealed thatnanoclay were more effective as compared to clay in slow release behaviour (Fig. 3). Olsen-P content in soil also increased in ZNCPC treatments owing to citrate Solubilization of native soil P (Fig. 4).

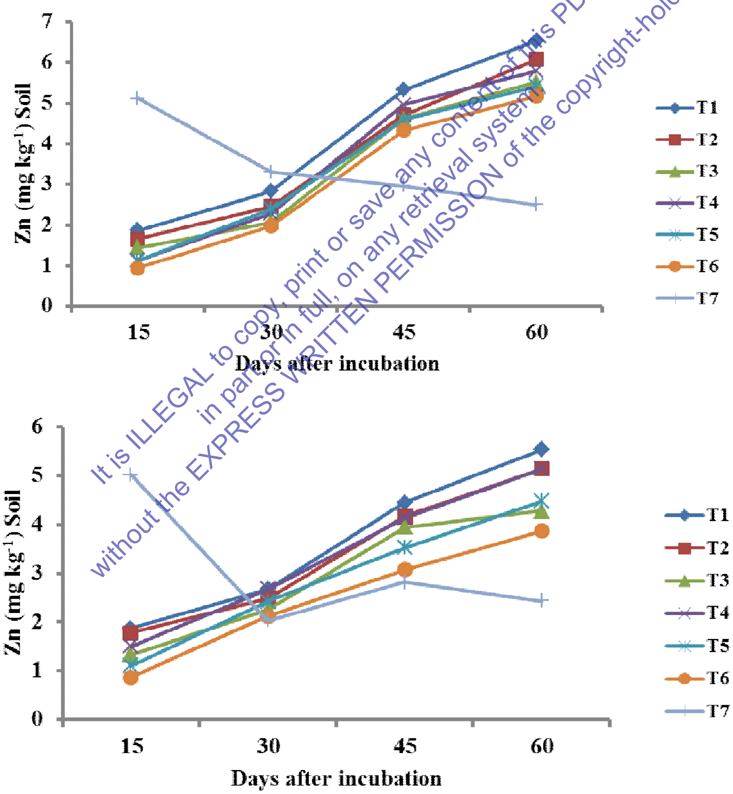

Fig. 3: Release of DTPA Extractable Zn in Soils during Incubation Experiment T1: 8% Clay; T2: 10% Clay; T3: 12 % Clay ; T4: 8% Nanoclay; T5: 10% Nanoclay; T6: 12% Nanoclay and T7: $ZnSO_4$. 7 H_2O

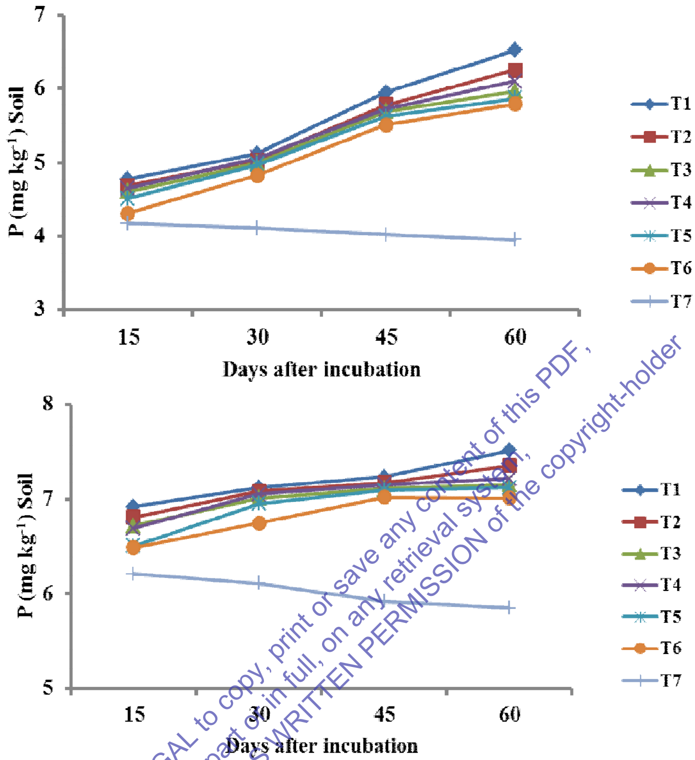

Fig. 4: Release of Olsen-P in Soils during Incubation Experiment T1: 8% Clay; T2: 10% Clay; T3: 12% Clay ; T4: 8% Nanoclay ; T5: 10% Nanoclay; T6: 12% Nanoclay and T7: $ZnSO_4 . 7 H_2O$

SUPERABSORBENT NANOCOMPOSITES FOR SOIL MOISTURE CONDITIONER

NOVEL SUPERABSORBENT NANOCOMPOSITES: IMPROVEMENT IN MOISTURE RETENTION AND AVAILABLE MOISTURE CONTENT IN SOIL

Novel superabsorbent nanocomposites are recently being reported as promising materials in improving moisture retention characteristics in soil. Singh *et al.*, 2011 prepared a novel nanosuperabsorbent composite (NSAPC) by in situ grafting polymerization and cross-linking on to a novel biopolymer of plant origin (complex heteropoly saccharide in nature) in the presence of a clay mineral using a green chemistry technique. The inorganic clay mineral acted as additional network point, resulting in increase in crosslinking with increase in clay content, manifested in decreased water absorbency.

Addition of test hydrogels to soil and soil-less media significantly increased the availability of water to plant compared with control (Fig. 5). In case of soil-less medium, the lower rate of application (0.5%) was as effective as higher rate (0.75%) for both the gels. This observation was substantiated by the values of onset wilting point in amended and unamended plant growth media (Fig. 11). As is clear, because of more availability of water in gel amended treatments, the permanent wilting point approached in the amended soil in 4.7–6.3 days compared with 2.4 days in control. Delay by 1.4–3.6 days was observed in soil-less media.

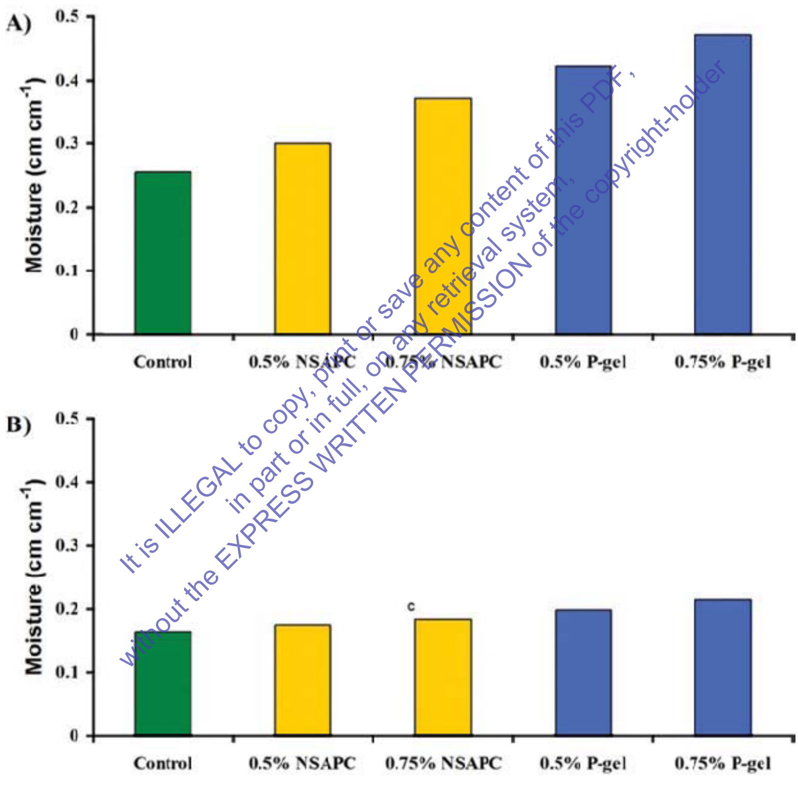

Fig. 5: Effect of Gel Addition on Available Water from Soil (A) and Soil-less Media (B)

Effect of NSAPC on water absorption and retention characteristics (Fig. 6) of sandy loam soil and soil-less medium was also studied as a function of temperature and tensions. Addition of NSAPC significantly improved the moisture characteristics of plant growth media (both soil and soil-less), showing that it has tremendous potential for diverse applications in moisture stress agriculture.

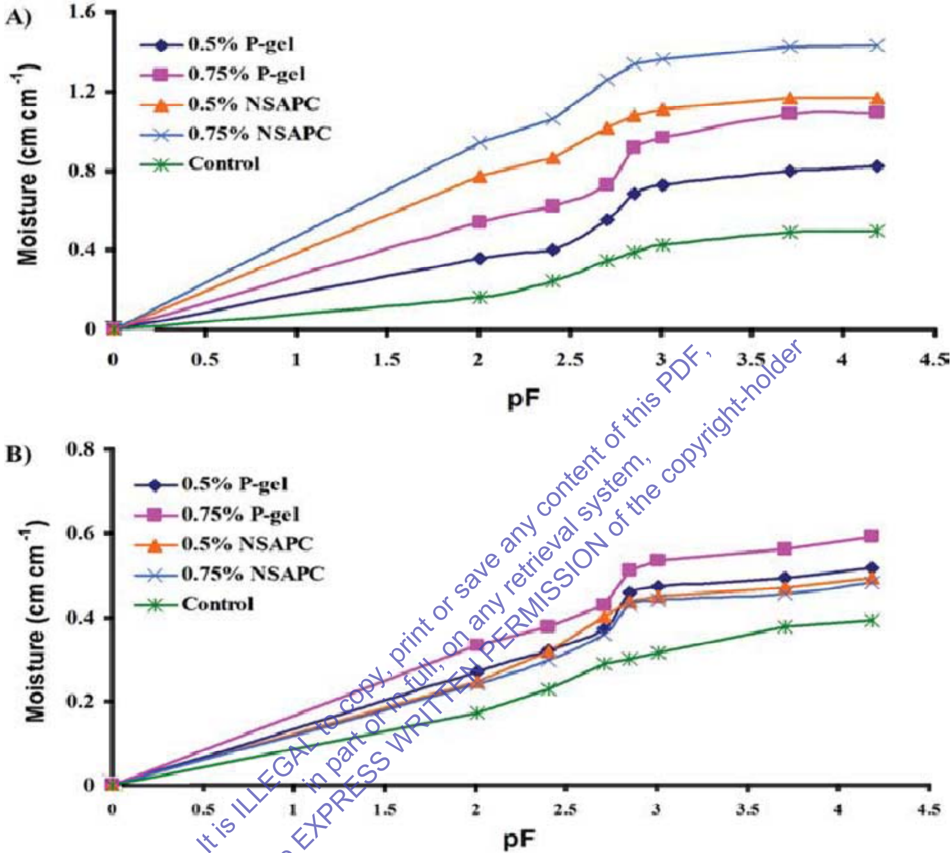

Fig. 6: Moisture Release Curves of Soil (A) and Soil-less Media (B) Amended with P-gel and NSAPC

INTERACTION OF MICROBES WITH NANOMATERIALS UNDER CHANGING TEMPERATURES

Resistance and resilience are considered as the ecological concepts of high policy relevance. Almost any study could be considered in terms of resilience, in that the common experimental format–the effect of X on Y–will have information about the effect of a disturbance on the system if X is a disturbance. To get an understanding of resilience, there needs to be a measurement soon after the disturbance to gauge resistance and then several subsequent measurements to assess the pattern of resilience. The time period can be a matter of days in a laboratory incubation, or even minutes for some physical measurements (Zhang *et al.*, 2005), through to years for field-based observations and is generally related to the nature of the disturbance. Studies have investigated the resilience of microbial communities to disturbance due to human activities such as land use and agricultural practices. But, impact assessment of nanomaterial addition (Zn and Fe nanomaterial) as extraneous substances added to soil system on soils resistance and resilience were still unidentified under heat stress and thus the hypothesis of the current experiment was that the addition of nanomaterials could have considerable implications on the resistance and resilience of soil organisms against abiotic stress, such as high temperature.

Kumar *et al*. (2016) showed that Fluorescien Diacetate Hydrolysing (FDA) activity was significantly reduced when the concentration of nano Fe was increased from 10 ppm (22.37 μg fluorescein released g^{-1} dry soil h^{-1}) to 40 ppm (18.08 μg fluorescein released g^{-1} dry soil h^{-1}) at $P < 0.05$. Data showed no significant differences between nano Zn @ 10 ppm (25.00 μg fluorescein released g^{-1} dry soil h^{-1}) and nano Zn @ 40 ppm (24.74 μg fluorescein released g^{-1} dry soil h^{-1} reflecting no changes in FDA activity at different doses of nano Zn. With respect to resistance and resilience indices of FDA activity against heat stress, it was observed that the nano Zn @ 10 ppm and nano Fe @ 10 ppm treatment had the greatest stress resistance, with an index rating of 0.48 and 0.43 respectively (Figure 7). Resistance index values of control was 0.37, there was no significant difference between treatments supplied with higher doses of nanomaterial (Zn or Fe @ 40 ppm) ($P < 0.05$).

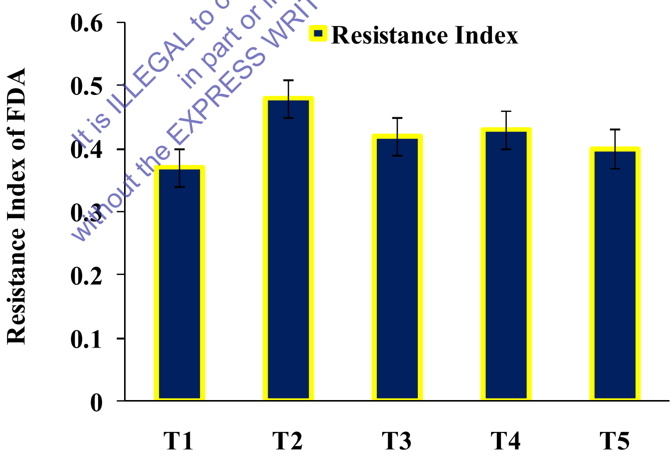

Fig. 7: Resistance Index of FDA Activity in Soil after Heat Stress (48°C for 24 hours) under Various Doses of Nanomaterial. T_1 Represents Control; T_2 Represents Nano Zn@ 10 ppm; T_3 Represents Nano Zn@ 40 ppm; T_4 Represents Nano Fe@ 10 ppm; T_5 Represents Nano Fe@ 40 ppm. Bars Indicate the CD Values

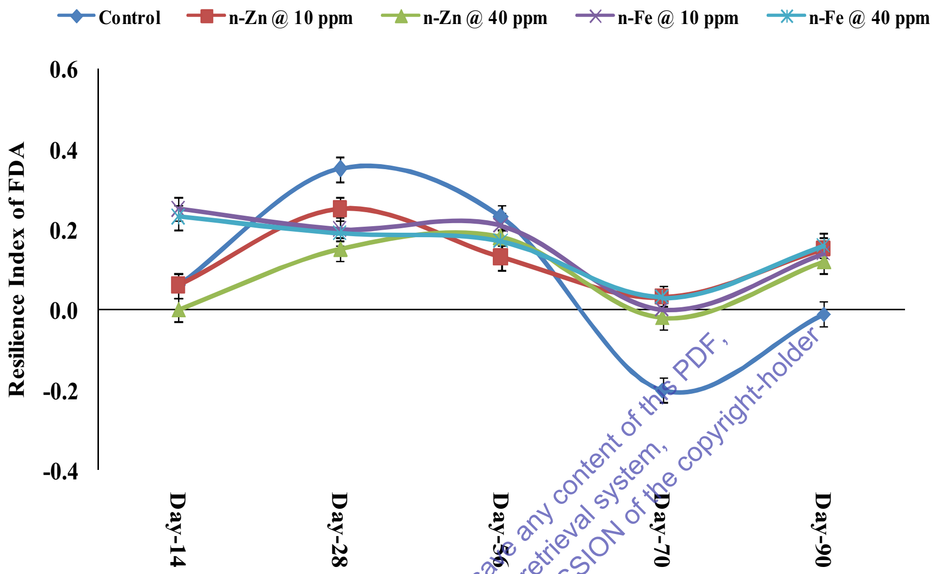

Fig. 8: Resilience Index of FDA Activity in Soil after Heat Stress (48°C for 24 Hours) under Various Doses of Nanomaterial

Resilience indices of all the treatments varies from-0.01 to 0.16 after 90 days of incubation. It was observed that all the treatments supplied with nanomaterials showed a statistically similar resiliency against the heat stress after 90 days (Figure 8). Although the control treatment showed a higher resilience index upto 56 days, but there was sharp decline in the resilience indices after 70 (-0.20) and 90 days (-0.01).

With respect to resistance indices of microbial biomass carbon against heat stress, it was observed that the nano Fe @ 40 ppm treatment had the greatest stress resistance, with an index rating of 0.69, which was statistically comparable to nano Zn@ 40 ppm with an index rating of 0.68 and nano Fe@ 10 ppm with an index rating of 0.67 (Figure 9). Recovery rate of microbial biomass carbon showed a similar pattern as in the enzymatic activity. Although the resilience indices were lower during the first 56 days, but the recovery indices were maximum after 90 days of incubation. nano Zn @ 40 ppm and nano Fe @ 40 ppm had the greatest stress resilience with an index rating of 0.28 and 0.29 respectively after 90 days of incubation. The lower dose (10 ppm of nano Zn and nano Fe) of nanomaterials used in this experiment also showed a positive resilience index (index rating of 0.14 and 0.24 for nano Zn and nano Fe respectively) (Figure 10).

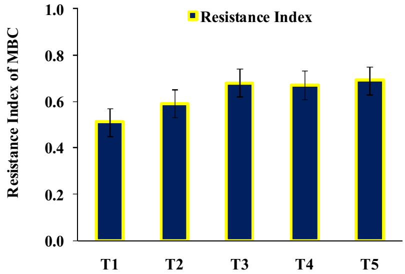

Fig. 9: Resistance Index of MBC in Soil after Heat Stress (48°C for 24 Hours) under Various doses of Nanomaterial. T_1 Represents Control; T_2 Represents Nano Zn@ 10 ppm; T_3 Represents Nano Zn@ 40 ppm; T_4 Represents Nano Fe@ 10 ppm; T_5 Represents Nano Fe@ 40 ppm. Bars Indicate the CD Values

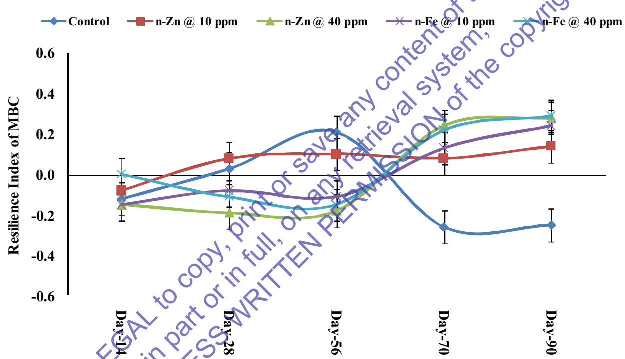

Fig. 10: Resilience Index of MBC Activity in Soil after Heat Stress (48°C for 24 Hours) under Various doses of Nanomaterial

THERMAL AND HYDROLYTIC STABILITY OF SOIL ENZYMES: IMMOBILIZATION OF SOIL ENZYMES ON DOUBLE LAYER

Acid phosphatase was immobilized on layered double hydroxides of uncalcined-and calcined-Mg/Al-CO_3 (Unc-LDH-CO_3, C-LDH-CO_3) by the means of direct adsorption by Zhu *et al*., 2010. Optimal pH and temperature for the activity of free and immobilized enzyme were exhibited at pH 5.5 and 37°C. The Michaelis constant (Km) for free enzyme was 1.09mmolmL^{-1} while that for immobilized enzyme on Unc-LDH-CO_3 and C-LDHCO_3 was increased to 1.22 and 1.19mmolmL^{-1}, respectively, indicating the decreased affinity of substrate for immobilized enzymes. The residual activity of immobilized enzyme on Unc-LDH-CO_3 and C-LDH-CO_3at optimal pH and temperature was 80% and 88%, respectively, suggesting that only little activity was lostduring immobilization.

The deactivation energy (Ed) for free and immobilized enzyme on Unc-LDH-$CO_3$and C-LDH-CO_3 was 65.44, 35.24 and 40.66 kJ mol^{-1}, respectively, indicating the improving of thermal stability of acid phosphatase after the immobilization on LDH-CO_3 especially the uncalcined form. Both chemical assays and isothermal titration calorimetry (ITC) observations implied that hydrolytic stability of acid phosphatase was promoted significantly after the immobilization on LDH-CO_3 especially the calcined form (Fig. 11).

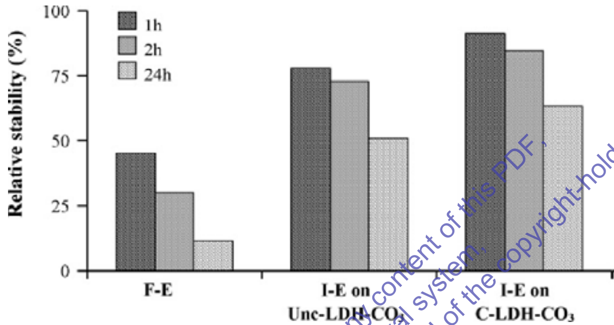

Fig. 11: Hydrolytic Stability of Free (F-E) and Immobilized Acid Phosphatase on LDHs (I-E on Unc-LDH-CO_3 and I-E on C-LDH-CO_3)

Reusability investigation showed that more than 60% (Fig 12a & 12b)) of the initial activity was remained after six reuses of immobilized enzyme on Unc-LDH-CO_3 and C-LDH-CO_3. A half-life (t1/2) of 10 days was calculated for free enzyme, 55 and 79 days for the immobilized enzyme on Unc-LDH-CO_3 and C-LDH-$CO_3$when stored at 4□C.

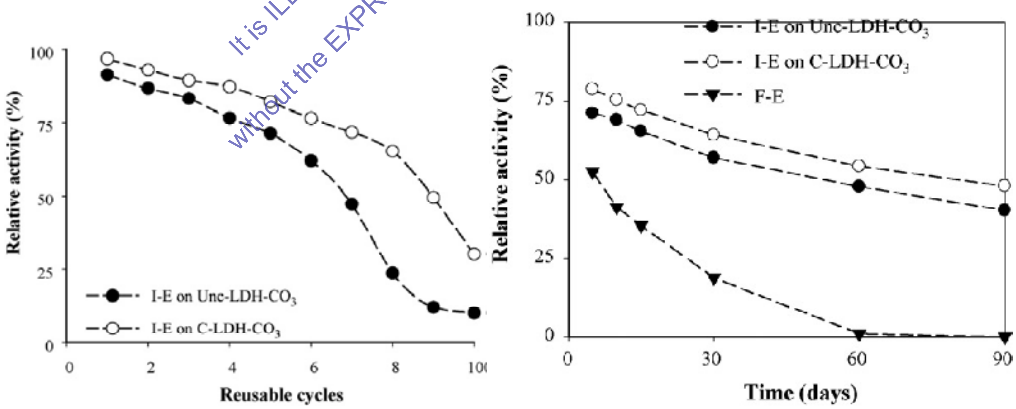

Fig. 12: (a) Reusability of Immobilized Acid Phosphatase on LDHs (I-E on Unc-LDH-$CO_3$and I-E on C-LDH-CO_3). (b) Storage Stability of Free (F-E) and Immobilized Acid Phosphatase on LDHs (I-E on Unc-LDH-CO_3 and I-E on C-LDH-CO_3)

Layered double hydroxides of uncalcined-and calcined-Mg/Al-CO_3 were used successfully as supports for the immobilization of acid phosphatase by the means of direct adsorption. Little activity loss, excellent thermal stability, hydrolytic stability, reusability and storage stability of the immobilized acid phosphatases revealed their promising potentials for practical application in the fields such as agricultural production and environmental remediation.

NANOBIOSENSORS FOR IN CHANGING CLIMATE

Nowadays, nanotechnology and nanomaterials are intertwined in the construction of almost every bioelectronics or biosensor devices due to their exceptional physicochemical, electrical, optical and mechanical properties. Nanomaterials have overcome the obstacles of low sensitivity, selectivity and analytical interference of old methods by controlling the size, shape and composite (Marx *et al*. 2004).

REAL TIME UREASE ACTIVITY MONITORING NANOBIOCOMPOSITE SENSORS

Biosensors are reported for different enzymatic activity detection. Presence of urea can be detected based on the detection of Urease (Ur) and Glutamate dehydrogenase (GLDH). Ur catalyzes decomposition of urea into hydrogen bicarbonate and ammonium ions (NH_4^+). NH_4^+ ions are known to be unstable and easily disperse in the environment. GLDH immediately catalyzes the reaction between NH_4^+,□-ketoglutarate (□-KG) and nicotinamide adenine di nucleotide (NADH) to produce NAD^+ and □-glutamate. Immobilization of Ur onto a suitable matrix is crucial for the development of an electrochemical urea sensor. In this context, metal oxide nanoparticles-chitosan (CH) based hybrid composites have attracted much interest for the development of a desired biosensor.

Metal oxide nanoparticles such as iron oxide (Fe_3O_4), zinc oxide (ZnO), cerium oxide (CeO_2) etc. have been suggested as promising matrices for the immobilization of desired biomolecules. These nanomaterials exhibit large surface to volume ratio, high surface reaction activity, high catalytic ef□ciency and strong adsorption ability that can be helpful to obtain improved stability and sensitivity of a biosensor. Moreover, nanoparticles have a unique ability to promote fast electron transfer between electrode and the active site of an enzyme. Among various metal oxide nanoparticles, Fe_3O_4 nanoparticles due to biocompatibility, strong super paramagnetic behaviour and low toxicity have been considered as interesting for immobilization of desired biomolecules.

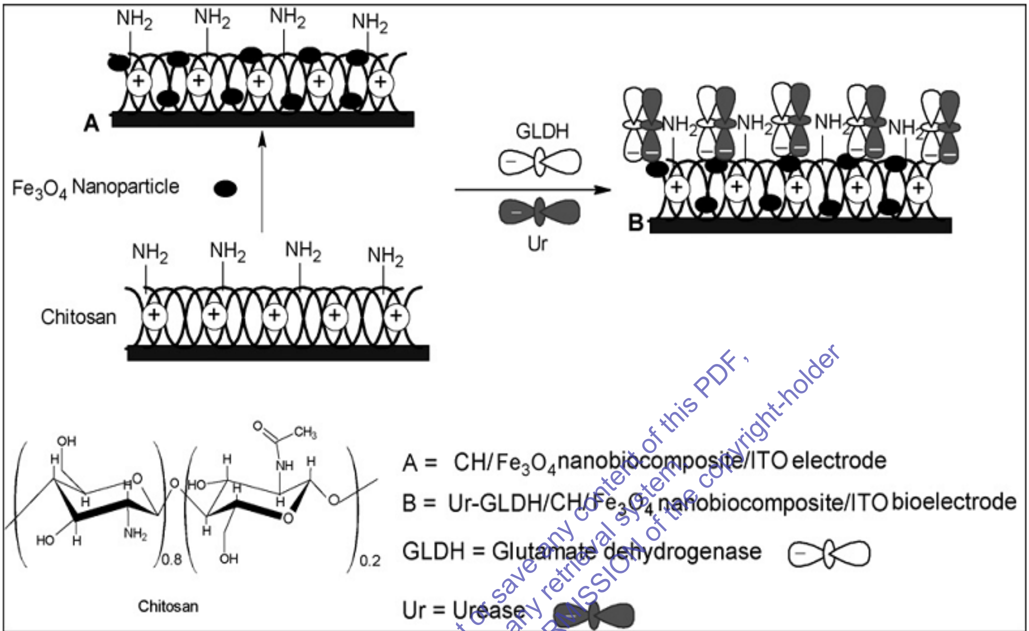

Fig. 13: Proposed Mechanism for Preparation of CH-Fe_3O_4 Nanobiocomposite and Immobilization of Ur-GLDH onto CH-Fe_3O4 Nanobiocomposite Film

The proposed mechanism relating to the preparation of CH-Fe_3O_4 nanobiocomposite film and immobilization of Ur-GLDH onto CH-Fe_3O_4 nanobiocomposite film is shown in Fig. 13. It can be seen that surface charged Fe3O4 nanoparticles interact with cationic biopolymermatrix of CH via electrostatic interactions and hydrogen bonding with NH_2/OH group to form hybrid nanobiocomposite. The Ur-GLDH molecules exist in anionic form at pH 7 because pH of solution is above isoelectric point (5.5) of Ur-GLDH molecules that facilitate interactions with positively charged CH of nanobiocomposite via electrostatic interactions (Fig. 13). In the nanobiocomposite, presence of Fe_3O_4 nanoparticles results in increased electroactive surface area of CH for loading of the enzymes due to affinity of the Fe_3O_4 nanoparticles towards oxygen atoms of enzymes. This suggests that Ur-GLDH molecules easily bind with charged CH-Fe_3O_4 hybrid nanobiocomposite matrix via electrostatic interactions.

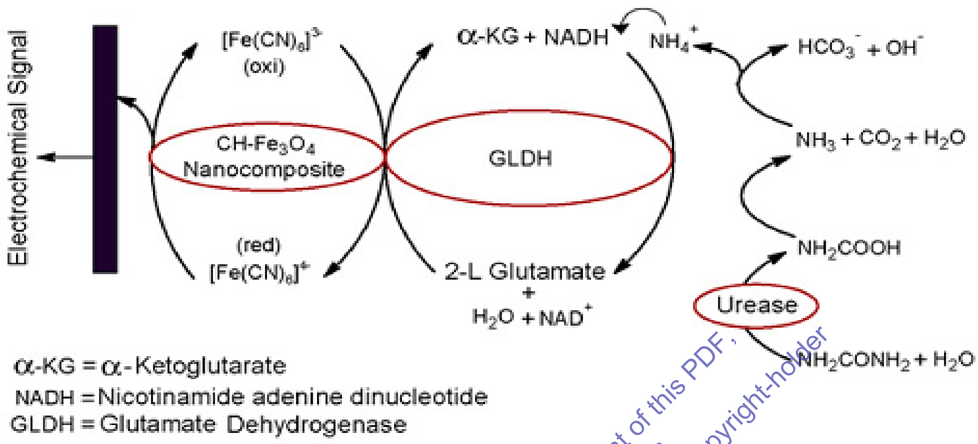

Fig. 14: Biochemical Reaction during Electrctrochemical Detection of Urea using Ur-GLDH/CH-Fe_3O_4 Nanobiocomposite

The proposed biochemical reaction during the urea detection is shown in Fig. 14. Ur catalyzes hydrolysis of urea to carbamine acid that gets hydrolyzed to ammonia (NH_3) and carbon dioxide (CO_2). GLDH catalyzes the reversible reaction between □-KG and NH_3 to NAD^+ and linked oxidative deamination of L-glutamate in two steps. The □rst step involves a Schiff base intermediate being formed between NH3 and □-KG. The second step involves the Schiff base intermediate being protonated due to the transfer of the hydride ion from NADH resulting in L-glutamate. NAD^+ is utilized in the forward reaction of □-KG and free NH_3 that are converted to L-glutamate via hydride transfer from NADH to glutamate. NAD^+ is utilized in the reverse reaction, involving L-glutamate being converted to □-KG and free NH_3 via oxidative deamination reaction. The electrons generated from the biochemical reactions are transferred to the CH-Fe_3O_4/ITO electrode through the Fe(III)/Fe(IV) couples that help in amplifying the electrochemical signal resulting in increased sensitivity of the sensor (Kaushik *et al*., 2009).

PESTICIDE DETECTION

Along with the existing practices, nanomaterials including carbon nanotubes (CNTs) (multi-wall CNTs and single-wall CNTs), metal nanoparticles (MNPs) [gold (Au) and silver (Ag)], graphene and graphene-based nanocomposites, nanocrystal coordination polymers, quantum dots (QDs) and magnetic NPs have had the opportunity to be used in various OPs biodetection systems (Laschi *et al*. 2008).

CONCLUSION

Nanotechnology seems to play important role in development of intelligent delivery of agrochemicals, development of noel superabsorbent polymers, real time monitoring of agrochemicals via nanobiosensors, increased resilience and resilience of microbes under heat stress which are very relevant in changing climate scenario.

FUTURE PROSPECTS

Nanotechnological developments in agricultural sciences are still in infancy. Long term evaluation of nanoproducts (fertilizers, pesticides, nanogels, biosensors and heat stable enzymes) under various agroclimatic conditions, diverse soil types and crop ecologies would give specific solutions for tacking ever changing agricultural production constraints.

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Impact of Climate Change on Insect Pests Activity and Diversity: An Appraisal

S.N. Rai and Tamoghna Saha*

Department of Entomology,
Bihar Agricultural University, Sabour, Bhagalpur–813210, Bihar, India
*E-mail: *tamoghnasaha1984@gmail.com*

INTRODUCTION

Crop plants are damaged by over 10,000 species of insects, and cause an estimated annual loss of 13.6% globally (Benedict, 2003) and 23.3% in India (Dhaliwal *et al*., 2004). Many of insects are the pest of crops, animals, household and stored products and in terms of monetary value, the Indian agriculture currently suffers an annual loss of about Rs 8, 63, 884 million due to insect pests (Dhaliwal *et al*., 2010). Losses due to insect pests' damage are likely to rise as a result of changes in crop diversity and increased incidence of insect pests due to global warming. The possible effects of changing climate on insects could result in their outbreaks, migration, change in biodiversity, species extinction, change in host shift, and emergence of new pests or biotypes.

Bio-pesticides, natural enemies, host-plant resistance and synthetic chemicals are some of the potential options for integrated pest management. However, the relative efficacy of many of these pest control measures is likely to change as a result of global warming. Geographical distribution of insect pests confined to tropical and subtropical regions will extend to temperate regions along with a shift in the areas of production of their host plants, while distribution and relative abundance of some insect species vulnerable to high temperatures in the temperate regions may decrease as a result of global warming. Climate change will also result in increased problems with insect transmitted diseases. These changes will have major implications for crop protection and food security, particularly in the developing countries, where the need to increase and sustain food production is most urgent.

EFFECT OF INCREASING TEMPERATURE ON INSECTS

As we know that temperature effects are the most imperative environmental effects mediating the growth of insects. Generally, temperature play significant role in overall progress of insect and the speed of insect dispersal through different means can be impacted. In general, higher the temperature, the more quickly insects develop and spread. Higher temperature decreases the time taken for completion of life history which helps insect species to complete many generations within a short period of time. Numerous studies conducted over rising altitude and latitude reveal that areas with cooler temperatures tend to have less species diversity and lower numbers of insects than areas with warmer temperatures (Petzoldt and Seamann, 2012).

HOW CHANGING RAINFALL AFFECT INSECTS

As warmer environment has an affinity to hold more water, it results in more strong and regular rainfalls. For small body-sized insects might be physically dislodged from the host plant by heavy rainfall, and is often more of a problem during dry seasons when the mortality factor is missing. The result of climate change in more numerous and/or heavy rainfall would tend to restrain populations of small insects. However, increase in the rate of flooding of fields could tend to restrain some soil dwelling insect populations. As a result of global warming, more droughts could be observed due to changes in rainfall pattern and increment in evaporation. The majority of the entomopathogenic fungi which are known to cause various diseases in insects depend on high relative humidity for successful epidemics, thus reducing insect pest populations.

HOW MOUNTING CO_2 LEVEL AFFECT INSECTS

Generally CO_2 impacts on insects are thought to be indirect-impact on insect damage results from changes in the host crop. Some researchers have found that rising CO_2 can potentially have important effects on insect pest problems. Some of the research has also shown that CO_2 effect on insect pests could occur through indirect effects on host biochemical composition. A number of field studies have shown that several insect pests increase their feeding on soybeans in high CO_2 atmospheres. This is thought to be the result of insect feeding stimulation caused by increased simple sugars in the leaves of the soybean plants. Greenhouse and lab studies have shown that plants grown in high CO_2 atmosphere have a higher C: N ratio. Insects have been shown to respond this ratio by increasing their feeding in order to fulfill their metabolic needs for nitrogen (Petzoldt and Seamann, 2012).

Table 1: List of Insect Pests Likely to Become Serious Due to Changes in Ecosystems and Habitats

Insect pest	Scientific name	Crop(s)
American bollworm	Helicoverpa armigera (Hubner)	Cotton, chickpea, pigeonpea, tomato
Whitefly	Bemisia tabaci (Gennadius)	Cotton, tobacco
Brown planthopper	Nilaparvata lugens (Stal)	Rice
Green leafhopper	Nephotettix spp.	Rice
Serpentine leaf miner	Liriomyza trifolii (Burgess)	Cotton, tomato, cucurbits, several other vegetables
Fruit fly	Bactrocera spp.	Fruits and vegetables

Mealy bugs	Several species	Several field and horticultural crops
Thrips	Several species	Groundnut, cotton, chillies, roses, grapes, citrus and pomegranate
Wheat aphid	Macrosiphum miscanthi (Takahashi)	Wheat, barley, oats
Pink stem borer	Sesamia inferens (Walker)	Wheat
Gall midge	Orseolia oryzae (Wood-Mason)	Rice
Gall midge	Several species	Fruit crops
Diamondback moth	Plutella xylostella (Linnaeus)	Cabbage
Hoppers	Several species	Mango
Pyrilla	Pyrilla perpusilla (Walker)	Sugarcane or rice at times
Polyphagous pests like	Several species	Many agroecosystems
Termites, whitegrubs,		
Hairy caterpillars and		
Tobacco caterpillar		

Source: Modified from Puri and Ramamurthy (2009)

EFFECT OF CLIMATE CHANGE ON THE ACTIVITY OF NATURAL ENEMIES

To combat climate change adaptation and mitigation practices and its variability such as reduced tillage, use of mulches, increasing crop diversity on farms, increasing vegetation diversity both on farms and landscapes are likely to persuade the abundance of insect pests and their natural enemies. The positive effects on parasitoid and predator diversity and abundance are likely with resulting benefits on increased natural regulation of pests (Table 2), sustainable crop production and mitigation of climate change (Thomson *et al.*, 2010). The majority of insects are benign to agro-ecosystems, and there is substantial data to suggest that this is due to population control through interspecific interactions amongst insect pests and their natural enemies–pathogens, parasites, and predators (Price 1987).

Table 2: Effect of Temperature Changes on Natural Enemies

Parameter	Nature of Effect	Natural Enemy	Reference
Survival	Reduced when exposed to abrupt change Reduced at lower (<120C) and higher temperatures (>350C)	Egg parasitoid, Trichogramma carverae Oatman and Pinto Campoletis chlorideae Uchida on chickpea pod borer, Helicoverpa armigera	Scott et al., 1997 Dhillon and Sharma, 2009
Distribution range	Lower mortality of herbivore due to escape from parasitoids in the expanded range	Parasitoids of Argus butterfly, Aricia agestis Dennis & Schiffermuller	Menendez et al., 2008
Host searching ability	Decreased at higher temperatures	Egg parasitoid, T. carverae	Thomson et al., 2001
Diapause	Prevention of diapause induction due to changes in day length and temperature	Coccinellid predator, Harmonia axyridis	Soares et al., 2008

WHAT FARMERS CAN DO TO ACCLIMATIZE?

Farmers should understand that climate change is likely to be a continuing process that will give them some opportunity to acclimatize. Warmer climate will increases in yield offset losses to pests, or will losses to pests outweigh yield advantages from warmer temperatures. It seems that new pests will become recognized in more northern areas and be able to damage plants in new regions. It is expected that plants in some regions will be attacked more often by certain pests. Some pests may be less likely to damage crops as alteration occurs. It is probable that we will not know the actual impacts of climate change on pests until they arise. Obviously, it will be vital for farmers to be aware of crop pest trends in their region and flexible in choosing both their management methods and in the crops they grow. Farmers who personally monitor the occurrence of pests in their fields and keep records of the severity, frequency, and cost of managing pests over time will be in a better position to make decisions about whether it remains economical to continue to grow a particular crop or use a certain pest management technique. If more fungicide or insecticide applications are mandatory in order to successfully cultivate a particular crop, farmers will recognize carefully and evaluate whether growing that crop remains economical. Those farmers who make the greatest use of the basics of integrated pest management (IPM) such as field monitoring, pest forecasting, recordkeeping, and choosing economically and environmentally sound control measures will be most likely to be successful in dealing with the effects of climate change (Petzoldt and Seamann, 2012).

FUTURE THRUSTS

To complete understand the effect of changing climate on insect pests, the attempts on time lag bio-diversity mapping in essential agro-climatic regions should be undertaken. There is a need to understand in details regarding the biology and the population dynamics of major insect pests under changing climate would assist in developing better and efficient pest control practices in relation to climate. Moreover, improvement of forewarning systems based on short as well as long term studies on population dynamics and migration pattern of insects would eventually help in formulating robust management strategies.

CONCLUSION

Various insect responds differently to atmospheric temperature and carbon dioxide rise and it is obvious of having varied impact depend on insect and regions. Understanding how climate change will impact on various pests especially crop pests helps agricultural scientist to orient their research on various futuristic possibilities that can help in mitigating and adapting to menace of anticipated climate change.

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Information and Communication Management for Climate Smart Agriculture

Dr. S.R. Singh and Dr. C.K. Panda*
Department of Extension Education, Bihar Agricultural College, Sabour, Bhagalpur
*E-mail: *dr.ckpanda@gmail.com*

Climate-smart agriculture (CSA) is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA aims to tackle three main objectives: sustainably increasing agricultural productivity and income; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where ever possible. Different elements of climate-smart agricultural system include– a)management of farms, crops, livestock, aquaculture and capture fisheries to balance near-term food security and livelihoods needs with priorities for adaptation and mitigation; b) ecosystem and landscape management to conserve ecosystem services that are important for food security, agricultural development, adaptation and mitigation and c) services for farmers and land managers to enable better management of climate risks/impacts and mitigation actions (FAO, 2010). Sources of technologies of CSA for the farmers are research institutions, farmers' indigenous and traditional knowledge and farmers' technologies refined at research station. These technologies in the form of useful information need to be communicated among end users/clients/farmers. Conversely, CSA Technology performances need to be sent back to its source, i.e. technology performance feedback. Ultimately, there is a need for a platform for effective Information and Communication Management. Formerly traditional media, radio and Television were the important extension methods for technology transfer, however, with the development of science and technologies, the basket of tools of extension methods have also been enriched. There is a plethora of information today in the internet high way. However, there are huge gaps among the 'information-haves' and 'information-have-not's i.e, . there is a digital divide. Actually, digital divide is widening as agricultural holding is reducing, access to formal education is limited, extension exposure is limited, rural to urban connectivity is limited etc. For the extension scientists and workers of developing and less developed nations in general and India in particular, is how to reach those small and marginal farmers, those are squeezing with those aforesaid constraints.

Actually, success of implementation of CSA is largely depends on flawless linkage of following subsystem:

INFORMATION AND COMMUNICATION MANAGEMENT

Information management is the management of organizational processes and systems that acquire, create, organize, distribute, and use information. Communication Management is the systematic planning, implementing, monitoring, and revision of all the channels of communication; it also includes the organization and dissemination of new communication directives, network, or communications technology. Aspects of communications management include developing communication strategies, designing internal and external communications directives, and managing the flow of information, including online communication.

Information and Communication Management responsiveness to CSA technology adoption by farmers may be monitor and evaluate on the basis of following issues addressing ability:

How can such high responsiveness and extreme availability be achieved in CSA?

How is it possible to update and query large amounts of data in real time?

How can fast and reliable communication be ensured?

How must such systems be architected in order to be maintainable without disrupting service availability?

How can they grow to adapt to ever changing user needs and new technologies without ending in complete chaos?

How can data integrity and communication security be ensured?

How can we trust that such systems are not vulnerable?

How can we assess their quality?

Answer veiled with how far Information and Communication Technology(ICT) as tool being able to satisfy need of the CSA technology to heterogeneous farming community under the per view elements of climate-smart agricultural systems and action implemented for CSA Approach:

a. Elements of climate-smart agricultural systems

- Management of farms, crops, livestock, aquaculture

- Conserve ecosystem services for food security, agricultural development, adaptation and mitigation
- Services for better management of climate risks/impacts and mitigation actions.
- Changes in the wider food system including demand-side measures

b. Actions to implement CSA approaches as recommended by FAO

- Expanding the evidence base: The evidence base is identifying key vulnerabilities in the agricultural sector and estimates of the potential reduction in greenhouse gas emissions generated by adaptation strategies, information on costs and barriers to the adoption of different practices.
- Supporting enabling policy frameworks: This include relevant policies, plans, investments and coordination across processes and institutions responsible for agriculture, climate change, food security and land use.
- Strengthening national and local institutions: Strong local institutions to empower, enable and motivate farmers for climate change adaptation and also building the capacity of national policy makers.
- Enhancing financing options: Innovative financing mechanisms that link and blend climate and agricultural finance and investments from public and private sectors are a key means of implementing CSA.
- Implementing practices at field level: Farmers are the primary custodians of knowledge about their environment, agro-ecosystems, crops, livestock, and local climatic patterns. Adapting to CSA must be related to local farmers' knowledge, requirements and priorities.

However, there is heterogeneity within and amongst the farming community as given below:

- Education
- Culture
- Norms, belief, value, customs
- Social capital
- Agricultural Holding
- Irrigation facilities

- Inputs availability
- Access to credit institutions
- Access to grassroots institutions
- Extension exposure
- Access to market, etc.

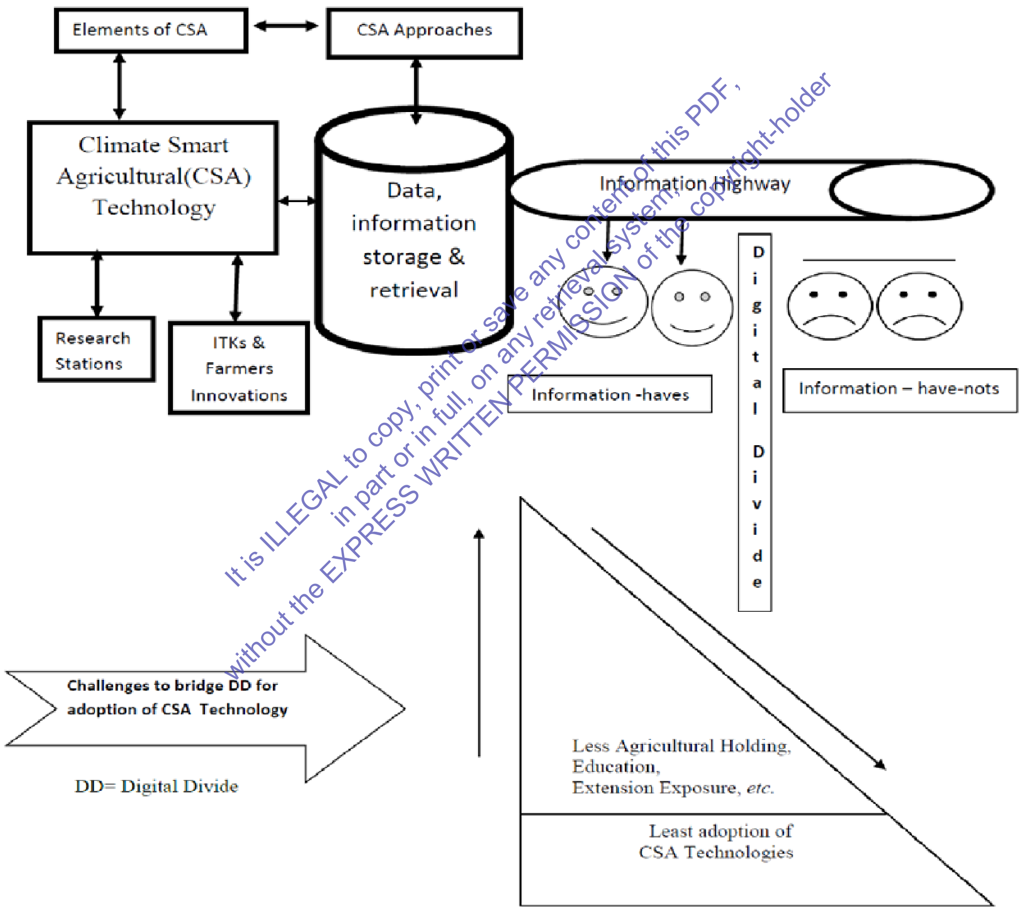

Fig. 1: CSA Technology & Farmers Interface

CONNECTING FARMERS WITH INFORMATION HIGHWAY

Mobile SMS Service: Most of the farmers have mobile and this is one of the cheapest ICT tool to reach to all categories of farmers through SMS service. The success of mobile SMS service depends on language used in SMS, timeliness, farmers' information need satisfaction etc. Government of India through *mKisan* Portal supporting the farmers. It was noted that 3.55 lakh advisors had sent about 438 crores messages and 1368 crores SMSs to the farmers across the nation till date. Praiseworthiness of mobile SMS service is that it can work without internet connectivity and with basic mobile. Subject Matter Specialist, Scientists, Extension personnel, Agriculture Officers and other stakeholders can send message relevant to CSA to the farmers with shortest possible time. SMS may include weather information, plant protection measures, inputs, market information etc.

Agri-Info-Kiosk: Rapid development of information technology has increased the awareness levels. Access to information has never been this easy, especially for urban areas. However this awareness levels have been largely limited to commercial information promoted by enterprises. Agriculture related information available in the rural areas is still restricted to information on seeds, fertilizers, pesticides, agriculture tools, implements, motors, pumps and pipes. Knowledge relevant to quality information on management and conservation of natural resources are still not accessible in rural areas. Agricultural Information Kiosk makes it is possible for disseminate field data as well as information to farmers in an inexpensive way. Agri-Info-Kiosk has used Information Technology (IT) as a tool for knowledge up gradation. IT tools including computerized data base, package of practice for crop cultivation, animal rearing and fisheries etc. It also provide market information, Government Offices etc.

Kisan Call Centre: In order to harness the potential of ICT in Agriculture, Ministry of Agriculture launched the scheme "Kisan Call Centres (KCCs)" on January 21, 2004. Main aim of the project is to answer farmers' queries on a telephone call in their own dialect. These call Centres are working in 14 different locations covering all the States and UTs. A countrywide common eleven digit Toll Free number 1800-180-1551 has been allotted for Kisan Call Centre. This number is accessible through mobile phones and landlines of all telecom networks including private service providers. Replies to the farmers' queries are given in 22 local languages. Queries which cannot be answered by Farm Tele Advisor(FTAs) are transferred to higher level experts (Call Conferencing Experts) in a call conferencing mode. These experts are subject matter specialists of State Development Departments, ICAR and State Agricultural Universities.

Pico Projector: Pico projectors (or alternatively ultra-light portable projectors) have been found to be very appropriate in rural areas and these are easier to operate without any laptop. The films would focus on specific themes and preferably directed by farmers themselves so as to have greater acceptability among the audience. Video need be of broadcast quality and with have to be in High Definition Video formats such as.mp4; which can be easily played on laptops or projectors. These films will also be made available on the internet for display through e-Panchayats and Common Service Centres and also for direct use. This task of showing agriculture related films and success stories will be performed by the ATMs. Existing films in the DAC, ICAR, SAUs, States and non-Government entities will also be used after dubbing in regional language.

While developing any videos dealing with crops and trees; water management; plant health; soil health; livestock and fisheries would be best produced adhering to the zooming-in, zooming-out (ZiZo) approach whereby videos are made with inputs from experts and farmers who were involved in regional collaborative research and development. The ZiZo approach leads to regionally relevant and locally appropriate videos(Van Mele, 2010)

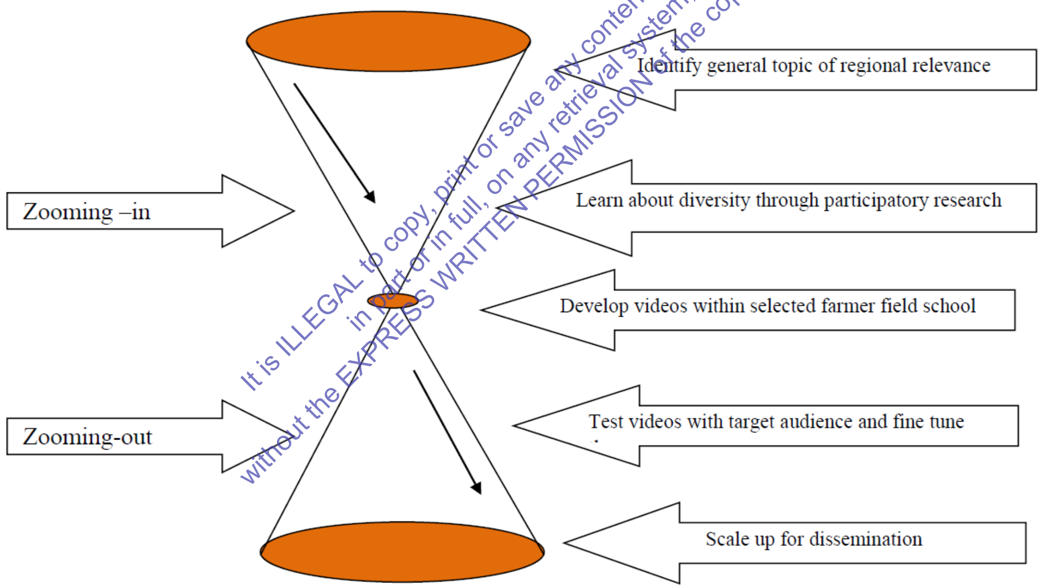

Fig. 2: The Zooming-in, Zooming-out Approach

Social Media: The increasing pluralism in extension funding and delivery demands new relationships, knowledge flows and partnerships among the wide range of EAS providers and other actors in the Agricultural Innovations Systems (Davis and Heemskerk, 2012). Social Media can play an important role in enhancing interactions and information flows among different actors involved in agricultural innovation and also enhance capacities of agricultural extension and advisory service providers. Social media refers to the means of interactions among people in which they create, share, consume and exchange information and ideas in virtual communities and networks. For example Agricultural Extension in South Asia (AESA) (https://www.facebook.com/groups/428431183848161/) members post links to relevant publications on extension and advisory services, announcements of workshops and conferences, major policy decisions on extension, reports of meetings and workshops relevant to the broader theme of extension. Global Forum for Rural Advisory Services (GFRAS) (https://www.facebook.com/groups/gfras/) provides information related to advocacy and leadership on pluralistic, demand-driven rural advisory services. Let us Learn Agriculture-(https://www.facebook.com/groups/madhualan) this group, exchange information on improved farm technologies, initiates discussion with other farmers and extension personnel, share information and photos on best practices by other farmers, government schemes, etc. Question and answers, information on Terrace garden, hydroponics are most discussed topics in this group.

SD Card (Secure Digital Card): It is an ultra small flash memory card designed to provide high-capacity memory in a small size. SD Cards are used in many small portable devices such as digital video camcorders, digital cameras, handheld computers, audio players and mobile phones. At present SD card is used in agricultural extension. In SD Card agricultural and allied sectors related small videos is uploaded and it is placed in mobile having capacity to play videos. Farms can watch those videos as per their convenient.

Mobile Apps: A mobile app is a software application designed to run on mobile devices such as smart phones and tablet computers. At present number of mobile application (Mobile Apps.) is available and these are farmer friendly with its design and local language utility. Following are some of the Mobile Apps. available in mKisan-

Climate-smart agriculture (CSA) is the need of the time to support the farming community, especially small and marginal farmers who are the more than eighty per cent of farming community in India. They are being characterized by less formal education, less extension exposure, limited access to internet, credit, bank and market. So, it becomes imperative to manage information on CSA technologies so that it reaches to those small and marginal farmers right way. ICT as tool can play important role for this cause, however, the people traditional medias and their own communication channels also need to be protected and narture for transferring CSA technologies.

Table 1

Subject Areas	Name of the Apps.	Utility
Agriculture	Kisan Suvidha	Farmers can get the information on weather of current day and next 5 days, dealers, market prices, agro advisories, plant protection, IPM Practices etc. Unique features like extreme weather alerts and market prices of commodity in nearest area and the maximum price in state as well as India have been added to empower farmers in the best possible manner.
	Pusa Krishi	It promotes Agribusiness Ventures through technology development and commercialization for everyone from a corporate to an individual farmer.
	MKisan Application	It enables farmers and all other stakeholders to obtain advisories and information being sent by experts and government officials at different levels through mkisan portal without registering on the portal.
	Farm-o-pedia	This mobile app is able to capture parameters-photograph of field with latitude and longitude, name of crop, date of sowing, date of likely harvesting and source of irrigation.
	Crop Insurance mobile app	Crop Insurance mobile app can be used to calculate the Insurance Premium for notified crops based on area, coverage amount and loan amount in case of loanee farmer.
	AgriMarket	This app automatically captures the location of person using mobile GPS and fetches the market price of crops in those markets which falls within the range of 50 km.
Horticulture	Sikkim Horticulture and Cash Crop Assistance	This app is used for submitting online application for obtaining Departmental assistance by farmers of Sikkim.
Animal Husbandry	Sikkim Allotment of Breeding Bull	This app is used for making request for allotment of breeding bull under Animal Husbandry department of government of Sikkim.
	Application for Poultry	The Animal Husbandry Department of Himachal Pradesh has introduced Backyard Poultry Scheme under the Centrally Sponsored Scheme, where low input technology birds of colored strain but disease resistant type are supplied to the farmers of the state. With the help of this app, an applicant who wants to obtain assistance under Poultry Chick and Backyard Poultry Schemes of Govt. of Himachal Pradesh can apply online.
	Pashu Poshan	NDDB has developed an android based software that can be used on phones as well as tablets. With the help of this software balanced ration is formulated while optimizing the cost considering animal profile, i.e. cattle or buffalo, age, milk production, milk fat, and feeding regime etc. and milk producers are advised to adjust the quantity of locally available feed ingredients offered to their animals along with mineral mixture.
Other Use full Apps. for Farmers	Digital Mandi India	This App helps in checking the latest Indian agricultural commodities Mandi prices from different states and districts.
	HP Soil Testing	With the help of this app farmers of Haryana can submit soil health samples of their land to the concerned soil health testing lab of their district/ Block.
	Intelligent Advisory System for Farmers	Farmers can get different farming season details, month based atmospheric and ideal conditions for variety of crops.

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