Souvenir

Indian Ecological Society: International Conference 2016

Natural Resource Management Ecological Perspectives

18-20 February 2016

Sher-e-Kashmir University of Agricultural Sciences &
Technology of Jammu, India


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Souvenir

Indian Ecological Society: International Conference 2016

Natural Resource Management: Ecological Perspectives

18-20 February 2016

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Acknowledgements

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We are also grateful to our sponsors the United Nations Food and Agriculture Organization (FAO), Excel Crop Care Ltd., Saraswati Agrochemicals India Pvt. Ltd. Jammu, BASF India and Biostadt India Limited.

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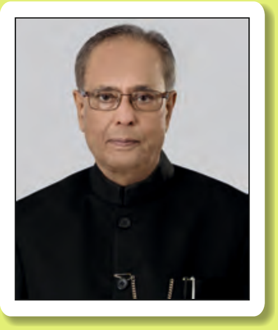

Pranab Mukherjee
President of India

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 Indian Ecological Society (IES) is organising an International Conference on "Natural Resource Management: Ecological Perspectives" from February 18-20, 2016 at the Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST of Jammu).

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

IES - JAMMU 2016
NRM for Sustainable Productivity

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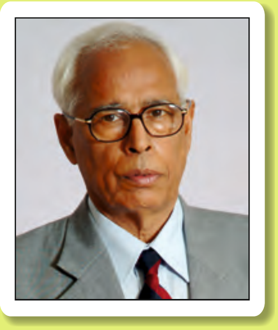

N.N. Vohra
GOVERNOR
JAMMU & KASHMIR

RAJ BHAVAN
SRINAGAR-190001

Message

I learn that the Indian Ecological Society (IES) is shortly organizing an international Conference on "Natural Resource Management: Ecological Perspectives" at the Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu (SKUAST-J).

It is gratifying to note that the forthcoming Conference shall deliberate on important issues relating to the conservation of natural resources and the latest advances in crop production management. This would provide a valuable opportunity for participating scientists from various institutions all over the country to share their experiences and evolve viable approaches for dealing with the rapidly advancing challenges of climate change, particularly the serious problems being posed by the fast depleting land and water resources.

I compliment SKUAST-Jammu for hosting this important Conference and trust that the scientists of the University would benefit from learning about the latest advances in the field.

(N.N. Vohra)

3rd February, 2016
Jammu

राधा मोहन सिंह
Radha Mohan Singh

कृषि मंत्री
भारत सरकार
MINISTER OF AGRICULTURE
GOVERNMENT OF INDIA

सत्यमेव जयते

D.O. No. 231/AM
4th February, 2016

Message

I am delighted to learn that Indian Ecological Society, in collaboration with Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST of Jammu), is organizing three days' international conference on "Natural Resource Management: Ecological Perspectives" from 18-20th February, 2016 at SKUAST of Jammu, Main Campus Chatha, Jammu, India. I complement the Indian Ecological Society and Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu for shouldering the responsibility of organizing this conference on natural resource management.

The organization of this international conference is very timely and it will have a greater impact at national and international level in view of our commitment to ensure food and nutritional security to the ever increasing population without putting a strain on natural resources. In the Indian context, the Congress would provide solutions in achieving our goal of sustaining agricultural growth at 4 per cent per annum, maintaining sound health of soil and water, enhancing input use efficiencies, and applying environmentally sound conservation agricultural practices. I am happy to note that the seven themes of the conference, namely, land and water resource, crop environment interactions, integrated nutrient management, integrated pest management, forestry tree plantations, policies for sustainable development of agriculture and farmer industry scientists interface, cover the most pertinent issues in the context of overall agricultural development. I hope that the deliberations of the Conference will result in a road map in support of holistic development agenda, demand-driven research programme and their applications in the entire value chain with fanners and market occupying the central place.

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

Radha Mohan Singh
(Radha Mohan Singh)

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प्रकाश जावडेकर
Prakash Javadekar

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राज्य मंत्री (स्वतंत्र प्रभार)
MINISTER OF STATE (INDEPENDENT CHARGE)
पर्यावरण, वन एवं जलवायु परिवर्तन
ENVIRONMENT, FOREST & CLIMATE CHANGE
भारत सरकार/**GOVERNMENT OF INDIA**

Message

Indian agriculture continues to be vulnerable to weather vagaries despite self-sufficiency in food grain production. Climate change and increased extreme weather events in recent decades further add to the woes of the farmers. Forests are not only the source of timber and non-timber raw material but related to environment and economic development of the nation. The developing nations arc today facing a near crisis situation both economic as well as environmental due to the overuse, abuse and shrinking of the natural resources. Despite framing of National Forest Polices and enacting new acts in post independence period, it has not been possible to conserve and enhance the forest cover one hand and save the deteriorating environment on the other. The consequences of this mishap today are reflected not only in the wide gap between demand and supply of forest based products but in ecological disasters as well. New initiatives in recent years at national and international level for enhancing tree cover will be counterproductive in meeting forest products and mitigating changing climate. 'Har Med Pe Pe' (tree on every farm build) initiative of the Prime Minister need to be promoted to act as buffer against the negative impacts of climate extremes. Another concern in agriculture is also to assess the long term impact of GM crop on ecologies and to choose between potential risk and potential benefits of these crops. Government will take appropriate decision through scientific realities for future of the agriculture growth and human health. I am indeed delighted to know that the Sher-e-Kashmir University of Agricultural Sciences and Technology (Jammu) and Indian Ecological Society are jointly organizing an International conference on Natural Resource Management in collaboration with Centre for International Projects Trust (CI PT), World Wide Fund for Nature (WWF), Indian Council of Agricultural Research(ICAR), International Union of Forestry Research Organizations (IUFRO) and with the objective to address the current problems and devise research priorities and policy strategies to address all these issues of national and international concern. The conference will provide an opportunity to establish synergistic interactions among the stakeholders.

I am sure the deliberations would be fruitful to generate concrete recommendations on judicious use of natural resources, increased productivity in different land use systems, enhanced usage of renewable/ bio-energy, sustainable environment, mitigation of green house gases, risk management, national and international trade, etc. to effectively deal with changing scenario.

I wish a grand success for the conference.

(Prakash Javadekar)

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डॉ० जितेन्द्र सिंह
Dr. Jitendra Singh

राज्य मंत्री (स्वतंत्र प्रभार)
उत्तर पूर्वी क्षेत्र विकास मंत्रालय,
राज्य मंत्री, प्रधान मंत्री कार्यालय,
कार्मिक, लोक शिकायत एवं पेंशन मंत्रालय,
परमाणु ऊर्जा विभाग तथा अंतरिक्ष विभाग,
भारत सरकार

सत्यमेव जयते

Minister of State (Independent Charge),
Ministry of Development of North Eastern Region;
Minister of State, Prime Minister's Office,
Ministry of Personnel, Public Grievances and Pensions,
Department of Atomic Energy and Department of Space,
Government of India

New Delhi, dt. 1st February 2016

Message

I am pleased to learn that the Indian Ecological Society and Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST) of Jammu are jointly organizing an International Conference on "Natural Resource Management: Ecological Perspectives" in collaboration with Centre for International Projects Trust (CIPT), World Wide Fund for Nature (WWF) and Indian Council of Agricultural Research(ICAR), from 18-20 February, 2016. The key challenge confronting agriculture is to produce more for ever growing population and that too on a sustainable basis. Our research must be strategic to address upcoming issues like climate change, soil health, shrinking water resources, eroding biodiversity, diversification, declining productivity, increasing cost of cultivation, and social issues such as changing life styles of people, quality and safe food, migration of youth away from agriculture, and like. The issues involved are inherently complex. All these are dynamic and interrelated. In addition to the natural systems, natural resource management also has to address various stakeholders and their interests, policies, politics, geographical boundaries, economic implications and so on. As we seek to make our farms yield more, reduce the intensity of our water use, or increase the nutrient content of our farm output, we should also integrate traditional techniques, local practices and organic farming to make our agriculture less resource intensive and more resilient.

More emphasis is required for technology and institutional development to increase awareness of natural resource management issues and facilitate participatory management of land & water resources. Extension agencies must take a lead for adaptive agricultural research to provide technical solutions for soil conservation, integrated pest management, disposal of crop residues, crop diversification and protection of natural habitat.

I extend my best wishes to the organizers of the conference and hope that discussions and deliberations of the conference will help in meeting the challenges of natural resources management.

(Dr. Jitendra Singh)

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डा. एस. अय्यप्पन
सचिव एवं महानिदेशक
Dr. S. Ayyappan
Secretary & Director-General

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद्
कृषि मंत्रालय, कृषि भवन, नई दिल्ली–110 001

GOVERNMENT OF INDIA
Department of Agricultural Research & Education
and
Indian Council of Agricultural Research
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Message

Sustainable development has a strong linkage between the socio-cultural and principles of ecological economics in natural resource management. Land, water and vegetation are vital ecological components of our socio-economic system and mainstay of Indian agriculture. India has a total geographical area of 329 Mha which is 2.3% of the world's land area. Out of which, about 120 Mha is suffering from various forms of land degradation. Likewise, total water resources of India have been estimated to be 1869 billion cubic meter (4% of global water resources) and presently agriculture consumes about 80% of available water. The growing population and competing demands of water are projected to reduce the share of water diverted to agriculture in future. The challenge, therefore, is to produce more for growing population with limited water availability, shrinking land resources, declining factor productivity and under new threats of climate change affecting water resources availability and their distribution.

In view of the above, there is an urgent need to conserve the ecological balance between land, water and bio-resources and maintain their productivity for sustainable food production. Furthermore, it is also important to ensure that the impact of climate change does not affect the ecological components in the biosphere, whereby, the sustainable development is affected per se. Thus, it is important need to develop adaptation and mitigation strategies to counter the challenges of climate change.

It is a pleasure to know that the Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST of Jammu) and Indian Ecological Society (IES) is organizing a Conference on "Natural Resource Management: Ecological Perspectives" in Jammu on 18-20 February, 2016. I hope the recommendations of the Seminar will be useful to all the stakeholders environmental arena including farmers, foresters and policy makers alike.

I wish the Seminar a great success.

(S. Ayyappan)

Dated the 18th June, 2015
New Delhi

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NRM for Sustainable Productivity

डा. गुरबचन सिंह
अध्यक्ष
Dr. Gurbachan Singh
Chairman

कृषि वैज्ञानिक चयन मंडल
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E-mail: gurbachansingh@icar.org.in, chairman@asrb.org.in

Message

I am happy to learn that Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu and the Indian Ecological Society are organizing a three days' multidisciplinary Conference on "Natural Resource Management: Ecological Perspectives" from 18-20 February, 2016. It is good that the Association of CIPT, WWF and IUFRO is also participating in this event.

The nature has provided best kind of natural resources for the survival of the mankind. There is enough to meet mankind need but not the greed. Over exploitation of natural resources such as soil, water and bio-diversity has set in the process of degradation of these precious resources. There is a strong case to reverse the present degradation process through the promotion of science based conservation practices.

I consider the timing of the present Conference immensely appropriate to devise collective vision and strategy for conservation and judicious use of natural resources for meeting the present and future food, nutrition, environment and livelihood security. I am sure this Conference would generate concrete recommendations for promotion of sustainable and equitable agriculture for prosperity in the country.

I wish the IES 2016 Conference a grand success.

8/7/2015

(Gurbachan Singh)

डा. आलोक कुमार सिक्का
उप महानिदेशक (प्रा सं प्र)
Dr. Alok K. Sikka
Deputy Director General (NRM)

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Message

I am happy to know that a 3-day International Conference entitled, "Natural Resource Management: Ecological Perspectives" is being organized by the Indian Ecological Society from 18-20 February, 2016 at Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu (SKUAST of Jammu), Main Campus Chatha, Jammu.

Experience since the onset of the Green Revolution in the early sixties of last century has shown that if farm ecology and economics go wrong, nothing else will go right in agriculture. This is why we should now work for an evergreen revolution leading to enhancement of productivity in perpetuity without associated ecological or social problems. The importance of natural resources, comprising land, water and vegetation, is far more greater than ever before to ensure sustainability in the face of changing climate, increased biotic pressure and declining resource productivity. Economic growth can be inclusive only if the natural resources are sustainably managed for livelihood and food security. Introduction of natural resources management technologies is particularly urgent in the heartland of the green revolution in Indian sub-continent, where farmers are facing problems arising from deterioration of soil health and depletion of groundwater and ecological degradation. This has serious ramifications on economics, employment generation and social aspects.

I hope the presentation and discussion at the International Conference will lead to the recommendations that would be helpful in fine tuning of policies for natural resource management.

I wish the conference a grand success.

(Alok K Sikka)

February 2016

डा. एन.के. कृष्ण कुमार
उप महानिदेशक (बाग.वि.)
Dr. N.K. Krishna Kumar
Deputy Director General
(Horticultural Science)

भारतीय कृषि अनुसंधान परिषद
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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAVAN-II,
PUSA, NEW DELHI-110 012

Message

Livelihood improvement is not just about the positive change towards better quality of life and human well-being but takes into account the local and global changes. Land-use options that increase livelihood security and reduce vulnerability to climate and environmental change are the matters of immediate concern. A sustainable development is the global concern. Excess of ecological footprint urges for a more efficient use of natural resources with multi-functionality and the co-production of goods and services in a land- use system. Increased awareness and selection of products with low footprint is needed to make space for sustainable development for reduction in poverty.

I am glad to learn that the Indian Ecological Society in association of the Sher-e-Kashmir University of Agricultural Sciences and Technology (Jammu) is organizing International Conference on Natural Resource Management during 18-20 February, 2016 at Jammu. The conference will provide an opportunity to establish synergistic interactions among the stakeholders. I hope that the participants will deliberate on relevant issues and devise research priorities and policy strategies to address the issues of concern like land and water resources, crop environment interactions, integrated nutrient management, integrated pest management, forestry tree plantations and policies for sustainable development of agriculture for sustainable development at National and International level.

I congratulate the organizers and wish the conference a grand success.

(N.K. Krishna Kumar)

डा. अशोक कुमार सिंह
उप महानिदेशक (कृषि प्रसार)
Dr. A.K. Singh
Deputy Director General
(Agricultural Education)

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Message

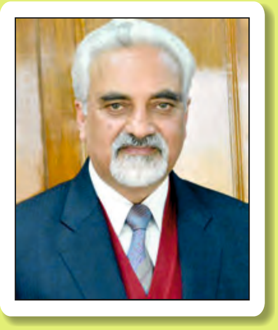
I am pleased to know that Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu in collaboration with the Indian Ecological Society is organizing a three days multidisciplinary conference on "Natural Resource Management: Ecological Perspectives" during 18-20 February 2016. The theme chosen in context to ecology is a step forward in the right direction. I congratulate the organizers for planning a special session on Farmers-Industry-Scientists Interface which would help in working out a holistic strategy for addressing natural resource management and climate change in the socio economic perspective.

I hope that the conference will come up with significant achievable recommendations for technology development, refinement and dissemination.

I wish the conference a grand success.

(A.K. Singh)

Date: 30.06.2015



Pradeep K. Sharma
Vice-Chancellor,
SKUAST of Jammu

Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu

Message

Over and unscientific exploitation of natural resources by human beings to meet their basic requirements have threatened the ecology and degraded the environment to such an extent that sustainability has become a serious issue. Land, water, biodiversity and weather are essential natural resources for food production. The external inputs too are dependent directly or indirectly on these resources. And these resources are under great threat today. Per capita cultivable land is shrinking, water resources are shrinking and whatever is available are being polluted, biodiversity is dwindling, and weather parameters are becoming hostile. The external inputs are in limited supply and are expensive. The factor productivity is showing a progressive decline. The demand for food, on other hand, is on the increase; thanks to the increasing population pressure. Livestock sector, which is an important ecological component along with human beings, is also under pressure. The situation, therefore, appears precarious. Under such a situation, it is important for all of us to become wise in conserving the natural resources while using them efficiently so that the food production is sustained, ecological balance is maintained and environment remains safe for us and the coming generations.

I congratulate the organizers to bring such an important subject for discussion, and wish the conference on "Natural Resource Management – Ecological Perspectives" a great success.

(Pradeep K. Sharma)

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"An institute for sustainable agriculture for food and nutritional security"

IES - JAMMU 2016
NRM for Sustainable Productivity

Prof (Dr) Nazeer Ahmed
Vice-Chancellor,
SKUAST of Kashmir

Sher-e-Kashmir University of
Agricultural Sciences and Technology of Kashmir
www.skuastkashmir.ac.in

Message

Globally it is an accepted fact where several evidences exists on agri-environmental degradation, and its impact on poverty and hunger. Due to increasing deterioration of natural resources base of agriculture, the first priority would be to have sustainable natural resources management by enhancing capacities to revive and manage natural capital in a sustainable manner. There is also a need to stabilize the production systems of rainfed agriculture which is being practiced in millions of hectares in the country.

The importance of natural resources, comprising land, water and vegetation is higher than ever before due to widespread, serious and continuing degradation of natural resources. The declining soil health, soil productivity and the water resources primarily through depletion of groundwater along with salinity and alkalinity due to overdraft from ground water sources is mounting pressure and impacting productivity and quality. The livestock population too has become victim of shrinking natural resources.

I feel the theme of the International Conference on Natural Resource Management: Ecological Perspective is very relevant and timely, and hope it addresses most of the important issues on natural resources management. I congratulate the organizers for selecting this very important topic and wish them a great success.

(Nazeer Ahmed)

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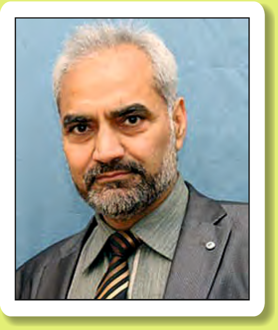

Prof. R.D. Sharma
Vice-Chancellor,
University of Jammu

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Message

It is matter of great satisfaction that the Sher-e-Kashmir University of Agricultural Sciences & Technology (SKUAST), Jammu in collaboration with Indian Ecological Society (IES) is organizing a 3-day Conference on "Natural Resource Management : Ecological Perspectives" from 18th to 20th February-2016 at SKAUST main Campus Chatha, Jammu.

The SKUAST, Jammu is one of the pioneer Institutes of Agricultural Sciences in the Country and came into existence on 20th September, 1999 following the amendment in Sher-e-Kashmir University of Agricultural Sciences and Technology Act, 1982 by the State Legislature. The University is mandated to address the basic, strategic and applied research related to enhanced production in agriculture and allied sectors. SKUAST-Jammu is striving to achieve high standards of excellence in education, research and extension for the betterment of farming community of the region.

The theme of the Conference is very relevant in context to present ecol ogical conditions. A natural resource is an asset that we can obtain from our environment: water, soil, plants, wind, animals, minerals, the energy of the sun and many others. Natural resources are often seen in terms of economic value, because so many of them are crucial for people's livelihoods. People are also an integral part —unbreakably linked to our environment. Without water, air, soil, and minerals we would not be alive. We need to be very aware of how we use the natural resources in our environment. We should use resources in a way that does not dangerously reduce their supply and we should preserve the balance between the different resources and organism in the environment.

The Experts, Researchers & Academicians who are participating in the Conference will exchange their ideas and I am sure that the deliberations of the Conference would go a long way in updating the knowledge of those belonging to concerned field particularly young faculty & students.

I extend my warm greetings and felicitations to the participating delegates, organizers, faculty members, students and send my best wishes for the success of the Conference.

23/06/15

(Prof. R.D. Sharma)

"A" Grade University ..... NAAC Accredited / ISO 9001 : 2000 Certified

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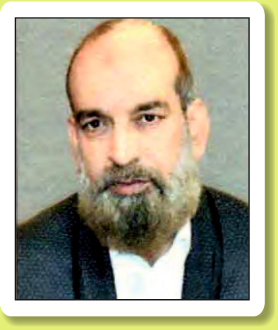

Prof. Khurshid I. Andrabi
Vice-Chancellor,
University of Kashmir

The University of Kashmir

University Campus
Hazratbal
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Kashmir

Message

It is really heartening to learn Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu and Indian Ecological Society is organizing three days' Conference on "Natural Resource, Management: Ecological Perspectives" from 18-20 February, 2016 and a Souvenir is also being brought out.

I am sure that it would be a very interactive and high quality programme where a considerable number of delegates including senior academicians, experts and subject specialists from state and other parts of the country are expected to participate. The scientists and students of our state also need to take advantage of these programmes and policies so as to create, share and use knowledge for inclusive development.

I do hope that the deliberations in the Conference will be fruitful and wish the event all the grand success.

(Prof. Khurshid I. Andrabi)

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NRM for Sustainable Productivity

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Dr. A.R. Trag
Vice-Chancellor, IUST

ISLAMIC UNIVERSITY OF SCIENCE & TECHNOLOGY

Message

Our blue planet is blessed with abundant natural resources, however the growing population, unabated and careless misuse of these resources is posing serious threat for their sustainability. This has resulted in major challenges like food insecurity, depletion of fresh water bodies, exhaustion of fossil fuel reserves, pollution etc. It is high time for us to take necessary measures for preservation and protection of these natural resources lest we may risk the existence of our future generations.

Proper management and judicious use of the natural resources are the only options that can improve the chances of their sustainability. These will not only ensure that the needs of present generation are met but also secure the needs of coming generations.

Management of natural resources involves an interdisciplinary approach towards conservation of basic resources like land, water and air. The efforts can yield satisfactory results only when there is understanding and cooperation at the regional and global level. Attempts are already on to evolve an international consensus on the issues like global warming, pollution, food security, water management etc but so far the results are not much encouraging and a lot more needs to be done.

Conferences the like the one being organized conducted by the SKUAST-J are important as they provide a platform for the brighter minds to get together, ponder on such issues and suggest innovative actions to meet the challenges.

I wish the conference a grand success.

(Dr. A.R. Trag)

IES - JAMMU 2016
NRM for Sustainable Productivity

M.A. Bukhari
IAS

Commissioner/Secretary to Government
Agriculture Production Department
J&K

D.O. No.: Agri/PC-212/2015-16
Dated: 10.02.2016

Message

I am happy to learn that Indian Ecological Society and Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu are jointly organizing international conference on "Natural Resource Management: Ecological Perspectives" from February 18-20, 2016.

Natural Resource Management issues are inherently complex as they involve the ecological cycles, hydrological cycles, climate, animals, plants and geography etc. I am sure that the research scholars and academicians also will deliberate ,upon land water resources, crop environment, integrated nutrient management, integrated pest management, horticulture crops, forestry tree plantations, eco-responsive livestock and fisheries production, policies for sustainable development of agriculture, farmer-industry-scientist interface during the conference and discover new dimensions of issues that are critical to sustainable use of natural resources for improving food security and overall development of our nation.

I extend my best wishes to the organizers and participants for success of the conference.

(Mohammad Ashraf Bukhari)IAS

IES - JAMMU 2016
NRM for Sustainable Productivity

Jmu: (O) 0191-2546883 / 2540531 Sgr: (O) 0194-2506114 / 2506222

Abdul Razak
IFS

Chairman
J&K State Pollution Control Board
Jammu / Kashmir

D.O. No.; SPCB/PS/CH/DO/15/641
Date: 24.7.2015

Message

It is my pleasure to express my warmest greeting to the conference on "Natural Resource Management: Ecological perspective" being organized by Sher-e- Kashmir University of Agricultural Science and Technology (SKUAST) of Jammu and Indian Ecological Society.

The theme of the conference has a great social relevance as it is known fact that the natural resources are precious and their proper management and conservation is of pivotal importance to the survival and progress of human race. Natural resources management is one of the applications of ecology that looks into the sustainable management of not just individual ecosystems but entire landscape systems and functions. It identifies and highlights the prospects for institutional, technological, and policy innovations for community-based management of resources to reduce poverty, enhance food security, and ensure biodiversity and watershed management. It helps in answering some of the questions as to how the current natural resources can be managed in a way that will ensure they remain accessible for future generations; how the increasing energy demand can be met in sustainable way or what technological innovations would enhance their sustainability; and what type of institutions and regulations are needed to prevent the over-utilization and exploitation of land-based biological resource.

Our state is bestowed with abundance of natural resources and these resources are under tremendous pressure of over-exploitation. The ever increasing population, expansion of settlements and infrastructural development are taking its toll. The responses of the fragile ecosystems to the changes taking place due to these developmental processes are dynamic in nature. Therefore, judicious utilization of resources has to be the cornerstone of all the management strategies. A multipronged approach is required to adequately address the concerns of the humankind at the global, regional and local scale. In this context, the deliberations among the academicians, researchers and policy makers for formulating such strategies attain utmost importance.

I wish the organizers a very successful and fruitful conference.

(Abdul Razak)

May to October:
Parivesh Bhawan
Raj Bagh, Srinagar
0194-2313966 (Tel./Fax)

Nov. to April:
Parivesh Bhawan
Transport Nagar, Narwal, Jammu
0191-2476927 (Tel./Fax)

e.mail: chairman87jkspcb@gmail.com

Shankar A. Pande
Chief General Managar

National Bank for Agriculture and Rural Development (NABARD) Jammu

Message

It gives me immense pleasure that Sher-e-Kashmir University of Agricultural Sciences & Technology (SKUAST), Jammu, in collaboration with “Indian Ecological Society” (IES) is organizing International Conference on “Natural Resource Management: Ecological Perspectives”, at its main campus Chatha, Jammu, from 18-20 February 2016.

I believe that this Conference is a very timely initiative and will offer a platform for all stakeholders associated with agricultural and rural development to deliberate on formulating strategies for development of mankind while maintaining harmony with our natural eco system. I hope the Conference shall also come up with its recommendations for meeting the challenges of agriculture and especially the problems encountered by small and marginal farmers.

I am pleased to inform the learned delegates that NABARD is accredited by Government of India as National Implementing Entity (NIE) for Green Climate Fund (GCF) and National Adaptation Fund (NAF) in the country, and we are working in close coordination with Government of India and State Government of Jammu & Kashmir to initialize a few green climate projects in the State.

Natural resource management and conservation is important for sustained development of Indian economy. The concern for maintaining ecological balance, i.e. man's relationship with nature assumes even greater significance in the context of much debated issue of Climate Change across the globe.

NABARD is happy to be associated with this initiative of SKUAST-Jammu, and I wish the Conference a great success.

(Shankar A. Pande)

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Dr. K.S. Risam
Director Extension,
SKUAST Jammu &
Convener, IESIC-2016

Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu

Message

I am pleased that Indian Ecological Society in collaboration with Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J) is organizing three days international conference on "Natural Resource Management: Ecological Perspective" at SKUAST of Jammu, main campus Chatha Jammu (Jammu and Kashmir) India from 18 – 20 February 2016.

The deteriorating natural resource base in the current century has diverted the attention of scientists worldwide and is a matter of serious consideration today. As the natural resource management issues are complex, the contribution of experts in providing a solution to the threats is imperative. Natur resource management will thus specifically focus on a scientific and technical understanding of resources and ecology and the life-supporting capacity of those resources.

The international conference thus is a step towards the aim of developing location specific, cost-effective, eco-friendly conservation and management technologies for higher input use efficiency, agricultural productivity and profitability without deteriorating natural resource base and overall natural resource management.

I wish for the successful organization of the conference and strongly believe that the work presented by experts in various theme areas and the deliberations and recommendations of the conference will be a step towards the overall management of natural resources.

(K.S. Risam)

IES - JAMMU 2016
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Dr. A.K. Dhawan
President
Indian Ecological Society

The Indian Ecological Society
Ludhiana-141004, India

Message

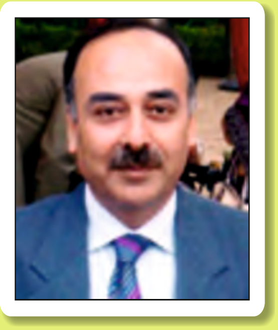
The sustainable utilization of major natural resources such as land, water, air, minerals, forests, fisheries, and wild flora and fauna which underpin human life is the greatest priority of the 21st century. With the realization that people and their livelihoods rely on the health and productivity of natural resources, the role played by humans has turned to be critical to its sustenance. The greatest priority then today needs to be given on creating platforms where experts can discuss on ways to mitigate the ever increasing threat to natural resources.

The Indian Ecological Society (IES) on various occasions in the past has successfully engaged in diverting brains of the world to think of ways to protect the environment and promote ecological studies.

The Indian Ecological Society International Conference 2016, Jammu chapter is again the brain child of the Society. IES in collaboration with Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J) is organizing three days conference from 18 – 20 February 2016 on "Natural Resource Management: Ecological Perspective" at SKUAST of Jammu, main campus Chatha Jammu (Jammu and Kashmir) India. The conference will focus on the areas of developing location specific, cost-effective, eco-friendly conservation and management technologies for higher input use efficiency, agricultural productivity and profitability without deteriorating natural resource base.

I hope that this conference will succeed in its aim and the meaningful deliberations by experts will help in contributing in the holistic development sustainable natural resource management.

(A.K. Dhawan)



Dr. Rajinder Peshin
Organizing Secretary,
IESIC-2016 &
Vice President
Indian Ecological Society

From the Desk of Organizing Secretary

Natural resource management issues are inherently complex as they involve the ecological and hydrological cycles, climate, animals, plants and geography etc. All these are dynamic and inter-related. In addition to the natural systems, natural resource management also has to manage various stakeholders and their interests, policies, politics, geographical boundaries, economic implications and so on. It is very difficult to deal with all aspects at the same time. Therefore the emphasis has been placed to understand the ecological nature of the agriculture and allied areas. Hence an integrated approach is needed for recognizing and implementing the intertwined social, cultural, economic and political aspects of resource management. A more holistic global perspective evolved from the Brundtland Commission for the advocacy of sustainable development. Most nations subscribed to new principles for the integrated management of land, water and forests in the United Nations Conference for the Environment and Development (UNCED) held in Rio de Janeiro in 1992.

Developing location specific, cost effective, eco-friendly conservation and management technologies for higher input use efficiency, agricultural productivity & profitability without deteriorating natural resource base is vital for sustainable management of natural resources to ensure agricultural development. In view of these facts the Indian Ecological Society and Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST) of Jammu is organizing three days' international conference on "Natural Resource Management: Ecological Perspectives" from 18-20 February, 2016 at SKUAST of Jammu, Main Campus Chatha, Jammu, Jammu & Kashmir, India.

I wish this conference brings together a holistic development agenda for sensitizing the scientists and fine tuning of policies for natural resource management. I look forward to the meaningful deliberations and recommendations for policy planners, private sector and development administrators to be emanated through the conference.

I hope that this international conference will be of great success and the work done by researchers will definitely contribute towards our goal of sustainable natural resource management.

(Rajinder Peshin)

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NRM for Sustainable Productivity

CORE COMMITTEE

CHIEF PATRON	
Dr. S. Ayyappan	Secretary Department of Agricultural Research & Education, Ministry of Agriculture, Government of India & Director General Indian Council of Agricultural Research, Krishi Bhavan, New Delhi -110 001, India
PATRON	
Prof. Pradeep K. Sharma	Vice-Chancellor, Sher-e- Kashmir University of Agricultural Sciences and Technology of Jammu, India
CO PATRONS	
Dr. Nazeer Ahmed	Vice-Chancellor, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, India
Dr. A.R. Trag	Vice-Chancellor, Islamic University of Science & Technology, University Avenue, Awantipora, Jammu and Kashmir-192122, India
Dr. R.D. Sharma	Vice-Chancellor, University of Jammu, Jammu- 180006, India
Dr. Ashok Aima	Vice-Chancellor, Central University of Jammu, Bagla (RahyaSuchani) District Samba, Jammu and Kashmir, India
Dr. M. Premjit Singh	Vice-Chancellor, Central Agricultural University, Imphal, Manipur, India
Prof. K.I. Andrabi	Vice-Chancellor, University of Kashmir, India
Dr. Gurbachan Singh	Chairman, Agricultural Scientists Recruitment Board, New Delhi, India
Dr. Jeet Singh Sandhu	Deputy Director General (Crop Science), Division of Crop Science, Indian Council of Agricultural Research, KrishiBhavan, New Delhi, India
Dr. N.K. Krishna Kumar	Deputy Director General (Horticultural Science),Division of Horticultural Science, Indian Council of Agricultural Research, Krishi Anusandhan Bhawan – II, New Delhi, India
Dr. A.K. Sikka	Deputy Director General (Natural Resource Management), Division of Natural Resource Management, Indian Council of Agricultural Research, New Delhi, India
Dr. A.K. Singh	Deputy Director General (Agricultural Extension), Indian Council of Agricultural Research, New Delhi, India
Dr. G.S. Goraya, IFS	Deputy Director General (Research), Indian Council of Forestry Research and Education, Dehra Dun, India
Padma Shri Chewang Norphel	The Ice Man of Ladakh, India

NATIONAL ADVISORY COMMITTEE	
Dr. A.K. Chakravarthy	Head, Division of Entomology and Nematology, Indian Institute of Horticultural Research, Bangalore – 560 089
Dr. Chanda Siddoo-Atwal	1349 Marine Drive, West Vancouver, B.C. Canada V7T 1B6
Dr. G.S. Dhaliwal	President Indian Ecological Society, Ludhiana, India
Dr. Govind Singh	Director of Research, Swami Keshwanand Rajasthan Agricultural University, Bikaner, India
Dr. H. Philip	Director of Extension Education, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India
Dr. J.P. Sharma	Director Research, Sher-e- Kashmir University of Agricultural Sciences and Technology of Jammu, India
Dr. K.S. Verma	Dean, College of Forestry, UHF Solan, India
Dr. Kamal Vatta	Director Centers for International Projects Trust (Columbia Water Center India), New Delhi and Adjunct Research Scientist, Earth Institute, Columbia University, New York, USA
Dr. Keshav K. Kranthi	Director Central Institute for Cotton Research, Indian Council of Agricultural Research, Nagpur, India
Dr. M. Maheswaran	Director of Research, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India
Mr. Murli Dhar	Director, Sustainable Agriculture Program, WWF-India, New Delhi, India
Dr. Opender Koul	Director, Insect Biopesticides Research Centre, Jalandhar
Dr. P.S. Minhas	Director, National Institute of Abiotic Stress Management (NIASM), Malegaon, Baramati, India
Dr. P.K. Mishra	Indian Institute of Soil and Water Conservation (ICAR-IISWC), Dehradun UK, India
Dr. Pratap Singh Birthal	National Center for Agricultural Economics and Policy Research (NCAP), New Delhi, India

Dr. R. M. Bhagat	Dean, Faculty of Agriculture, Sher-e- Kashmir University of Agricultural Sciences and Technology of Jammu, India
Dr. Rajbir Singh	Zonal, Project Directorate, Zone-I, PAU Campus, Ludhiana, India
Dr. S.K. Ambast	Director, ICAR-Indian Institute of Water Management, Bhubaneswar, India
Dr. Dr. Subhash Mehetre	Director of Research, Mahatma PhuleKrishiVidyapeeth, Rahuri, India
Dr. Surendra Kumar Singh	Director, National Bureau Soil Survey & Land Use Planning, Nagpur, India
Dr. T.V.K. Singh	Dean of Agriculture, Professor JayashankarTelangana State Agricultural University, Hyderabad, India
Dr. Tasleem Ahmad Shamas Ganai	Director Education, Sher-e- Kashmir University of Agricultural Sciences and Technology of Jammu
Dr. V.P. Singh	Regional Representative for ICRAF- South Asia, World Agro forestry Centre; CGIAR, Regional Office for South Asia, New Delhi, India

CONVENERS	
Dr. K.S. Risam	Director Extension, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu & Kashmir, India
Dr. A.K. Dhawan	General Secretary, President, The Indian Ecological Society, Former Additional Director of Research & Head Division of Entomology, Punjab Agricultural University, Ludhiana-141 004

CORE ORGANIZING COMMITTEE	
Prof. V.K. Razdan	University Librarian, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India
Prof. V. Kaul	Head, Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India
Prof. V. K. Wali	Head, Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India
Prof. K.R. Sharma	Head, Division of Soil Sciences & Agricultural Chemistry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu-180009,India
Prof. Rakesh Nanda	Ex-head, Division of Agricultural Extension Education, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India
Prof. K.K. Sood	Head, Division of Agro-forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India
Prof. A.K. Razdan	Head, Division of Plant Breeding and Genetics, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India
Prof. Anil Gupta	Head, Division of Plant Pathology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India
Prof. R.K. Sharma	Head, Division of Animal Nutrition, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India
Dr. J.V.N.S. Prasad	Division of Resource Management, CRIDA, Hyderabad, India
Dr. Santanu Kumar Bal	National Institute of Abiotic Stress Management (NIASM), Malegaon, Baramati, India
Prof. Sanjeev K. Chauhan	Department of Forestry & Natural Resources, Punjab Agricultural University, Ludhiana, India
Dr. Sohan Singh Walia	Department of Agronomy, Punjab Agricultural University, Ludhiana, India
Dr. Vaneet Inder Kaur	College of Fisheries, GADVASU, Ludhiana, India

ORGANIZING SECRETARY	
Dr. Rajinder Peshin	Vice President Indian Ecological Society, Division of Agricultural Extension Education, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu, India

1. Reception Committee

Name of the officer/official	Designation	Position
Dr. K.S. Risam	Director Extension, SKUAST-J	Convener
Dr. J.P. Sharma	Director Research, SKUAST-J	Co-convener
Dr. T.A.S. Ganai	Director Education, SKUAST-J	Member
Dr. M.M.S. Zama	Dean, F.V.Sc& AH, SKUAST-J	Member
Dr. R.M. Bhagat	Dean, FoA, Chatha, SKUAST-J	Member
Dr. B.B. Gupta	Registrar, SKUAST-J	Member
Dr. Deepak Kher	PPMO, SKUAST-J	Member
Dr. V.K. Razdan	University Librarian, SKUAST-J	Member
Dr. S.K. Sen	Comptroller, SKUAST-J	Member
Sh. T.R. Bhagat	Estates Officer, SKUAST-J	Member

2. Registration Committee (Online)

Name of the officer/official	Designation	Position
Dr. Rajinder Peshin	Assoc. Prof (Organizing Secretary)	Convener
Dr. Rakesh Sharma	Sr. Scientist, KVK Jammu	Co-convener
Mr. Soneal Kumar Dhar	Computer Assistant, DOAEE	Member
Mr. Raj Kumar	FCLA, DOAEE	Member

3. Registration Committee (Spot Registration)

Name of the officer/official	Designation	Position
Dr. Raj Kumari Koul	Prof., Food Science & Technology	Convener
Dr. A.K. Mondal	Professor, Soil Science	Co-convener
Dr. Sehar Masood	Associate Professor Fisheries, FSR	Member
Dr. Anju Bhat	Associate Professor, FST	Member
Dr. Poonam Parihar	Asstt. Prof., DOAEE	Member
Dr. Sheetal Dogra	Asstt. Prof., Floriculture	Member
Dr. Arti Sharma	Asstt. Prof., Fruit Science	Member
Dr. Neeraj Gupta	Asstt. Prof., Fruit Science	Member
Dr. Raj Kumar Gupta	Asstt. Prof., Fisheries FSR	Member
Dr. Ajay Kumar	Farm Manager, KVK-Kathua	Member
Miss Poonam Abrol	Prog. Asstt., KVK-Jammu	Member
Miss Parvani Sharma	Ph. D Student, DOAEE	Member
Sh. Anwar Hussan	Ph. D Student	Member
Miss Beena Muna	Ph. D. Student	Member
Miss Shafia Rafiq	Ph. D.Student	Member
Miss Awasi Dalal	Ph. D.Student	Member
Miss Nadia Bashir	Ph. D.Student	Member
Mr. Ankit Dayal	Ph. D.Student	Member

4. Transport/Accommodation Committee

Name of the officer/official	Designation	Position
Dr. Rakesh Nanda	Professor, DOAEE	Convener
Dr. Sushil Sharma	Professor& Head, Agri. Engineering	Co-convener
Dr. J.P. Singh	Assoc Prof, Agri. Engineering	Member

Dr. R.K. Srivastava	Assoc Prof, Agri. Engineering	Member
Dr. Rakesh Sharma	Senior Scientist, KVK Jammu	Member
Dr. Vinod Gupta	Senior Scientist, KVK-Rajouri	Member
Dr. Manoj Kumar	Assistant Professor, Veg. Science	Member
Dr. Rakesh Kumar	Junior Scientist, Fruit Science, Raya	Member
Dr. J.S. Manhas	Asstt. Professor, DOAEE	Member
Mr. Suraj Parkash	SMS KVK-Poonch	Member
Mr. Pawan Sharma	SMS KVK-Poonch	Member
Dr. Anil Bhat	Assistant Professor, Econ. & ABM	Member
Mr. Pankaj Sharma	Programme Assistant(Computer)	Member
Mr. Raju Gupta	Programme Assistant(Farm)	Member
Mr. Raj Kumar	FCLA, DOAEE	Member
Mr. Enoch Spalber	Ph.D student, Soil Science	Member
Mr. Rakesh Kumar	Ph.D. student, DOAEE	Member
Mr. Arvinder Kumar	Ph.D. student, DOAEE	Member
Tariq. Iqbal	M.Sc. student, DOAEE	Member

5. Liaisoning, Media/Publicity Committee

Name of the officer/official	Designation	Position
Dr. Narinder Singh Raina	Associate Professor, Agro-forestry	Convener
Dr. Sanjay Khar	Senior Scientist & Head, KVK-Jammu	Co-convener
Dr. Prashant Bakshi	Associate Professor, Fruit Science	Member
Dr. Vivek Arya	Assistant Prof., Soil Sciences	Member
Dr. Narinder Paul	SMS Agril Extn. KVK Doda	Member
Mr. Ajay Sharma	SVC to Vice-Chancellor	Member
Mr. Prince RajanKhajuria	Computer Assistant, VC Office	Member
Mr. Bharat Bhushan	Stenographer, KVK-Kathua	Member
Mr. Anil Bushan	Ph.D. Student, Veg. Sciences	Member
Miss StanzinYangsdon	M.Sc. Student, DOAEE	Member
Mr. Youdhister Singh Bagal	M.Sc. Student, DOAEE	Member

6. Poster Session Committee

Name of the officer/official	Designation	Position
Dr. Anil Gupta	Prof. & Head, Plant Pathology	Convener
Dr. P.S. Slathia	Associate Professor, DOAEE	Co-convener
Dr. VikasTandon	Senior Scientist & Head, KVK Rajouri	Member
Dr. Moni Gupta	Associate Professor, Biochemistry	Member
Dr. Sandeep Chopra	Associate Prof. Veg. Science	Member
Dr. Rakesh Bandral	Senior Scientist & Head, KVK Doda	Member
Dr. Sachin Gupta	Asstt. Prof., Plant Pathology	Member
Dr. Satesh Kumar	Asstt. Prof., Veg. Science	Member
Dr. Akash Sharma	Asstt. Prof., Fruit Sciences	Member
Dr. Sarabdeep Kour	Asstt. Prof., Soil Science	Member

7. Photograph Session Committee

Name of the officer/official	Designation	Position
Dr. S.K Gupta	Professor, PBG	Convener
Dr. A.K. Mondal	Professor, Soil Science	Co- Convener
Dr. L.M. Gupta	Assoc. Prof., Agroforestry	Member
Dr. Uma Shanker	Asstt. Prof., Entomology	Member
Mr. Mukesh Kumar	Photographer, DOAEE	Member
Mr. Pankaj Sharma	Photographer, Directorate of Extension	Member
Mr. Ashwani Kumar	Ph.D student, PBG	Member
Mr. Sunil Kotwal	M.Sc. student, PBG	Member

8. Technical Committee

Name of the officer/official	Technical Session
i. Dr. D.P. Abrol, Professor Entomology ii. Dr. S.B. Bakshi, DDSW, SKUAST-J	Keynote sessions
i. Dr. V. Kaul Prof. & Head, Entomology ii. Dr. Davinder Sharma, Asstt. Prof. Entomology	Integrated Pest Management
i. Dr. S.K. Gupta Professor, PBG ii. Dr. S.K. Bal(NIASM)	Crop Environment Interactions
i. Dr. V.K. Wali Prof. & Head Division of Fruit Science ii. Dr. Sandeep Chopra, Asstt. Prof. Entomology	INM and Horticulture Crops.
i. Dr. K.R. Sharma Prof. & Head, Soil Science ii. Dr. Vikas Sharma Assoc. Prof, Soil Science iii. Dr. Sushmita Dadish, Asstt. Prof., Ag. Engineering	Land and Water Resources
i. Dr. K.K. Sood Head, Division of Agro-forestry ii. Dr. Sushil. K. Gupta, Prof. Agroforestry	Forestry Tree Plantation
i. Dr. R.K. Sharma Prof. &Head, Animal Nutrition ii. Dr. Akhil Gupta, Associate Prof. Fisheries FSR	Animal sciences and Fisheries
i. Dr. M. H. Wani Professor, Rajiv Gandhi Chair SKUAST-K ii. Dr. Sudhakar Dwivedi Associate Professor, Agril. Econ.	Policies for Sustainable Development of Agriculture
i. Dr. Anil Bhat Assistant Professor, Agril. Econ	Success Stories
i. Dr. R.K. Arora Assoc. Director Extension, SKUAT-J ii. Dr. Amrish Vaid, Head, KVK Kathua	Farmer Scientist Interaction
i. Mr. Romit Sen CIPT Delhi ii. Dr. Munish Sharma, Assoc. Prof. Stat. & Compt. Sciences	Panel Discussion

9. Conference Secretariat Committee

Name of the officer/official	Designation	Position
Dr. Rajinder Peshin	Associate Professor, DOAEE	Convener
Dr. P.S. Slathia	Associate Professor, DOAEE	Co-convener
Dr. Vikas Sharma	Associate Professor, Soil Sciences	Member
Dr. L. K. Sharma	Assistant Professor, DOAEE	Member
Mr. Soneal Kumar Dhar	Computer Assistant, DOAEE	Member
Mr. Raj Kumar	FCLA, DOAAEE	Member
Mr. Mukesh Kumar	Artist-cum-Photographer, DOAAEE	Member
Mr. Bharat Bhushan	Stenographer, KVK Kathua	Member
Mr. Rakesh Kumar	Ph.D. Student, DOAAEE	Member
Miss Fatima Bano	Ph.D. Student, DOAAEE	Member

10. Hall Arrangement for concurrent sessions Committee

Name of the Hall Incharge	Designation	Supporting Official
Dr. Varinder Kaul University Library (3 Halls)	Prof. & Head, Entomology / Controller Examination	1. Mr. Jagdish Kumar Prog. Asstt. KVK 2. Mr. Shami Kumar, Comp. Asstt Exam. Cell 3. Mr. Deepak Sharma, AV Operator 4. Madan Lal, OCC, Entomology 5. Surinder Kumar, OCC, Exam. Cell 6. Thoru Ram, OCC, Exam. Cell
Dr. S.B. Bakshi Conference Hall	Deputy Director Students Welfare, SKUAST-J	1. Hardeep Singh, Computer Assistant, Dean Office 2. Bachan Lal, Telecom Operator 3. Shiv Dev, FCLA 4. Janak Raj, OCC, Agroforestry 5. Satnam Singh, OCC KVK RS. Pura
Dr. P.S. Slathia Seminar Halls, DOAEE	Associate Prof. DOAEE	1. Mr. Mukesh Kumar, ACP, DOAEE 2. Sh. Bharat Bhushan, Stenographer KVK Kathua 3. Sh. Joginder Kumar, OCC, DOAEE
Dr. S.K. Dwivedi Seminar Hall Agri. Economics & ABM)	Assoc. Prof. Economics	1. SahilTalgotra, Stenographer, KVK Poonch 2. Manjit Singh, OCC, Economics
Dr. Sachin Gupta Seminar Hall	Asstt. Prof. Plant Pathology	1. Naresh Choudhary, Compt Asstt. 2. Sh. Shukar Dass, OCC Plant Pathology
Dr. V.K. Wali Seminar Hall Central Library	Professor PBG	1. Amit Sharma, Library Asstt. 2. Sumir Raina, FCLA, Microbiology 3. S. Iqbal Singh, OCC, Library 4. Sh. BishanDass, OCC, Library

11. Conference Hall Arrangement Committee

Name of the officer/official	Designation	Position
Dr. A.K. Razdan	Prof. & Head, PBG	Convener
Dr. S.K. Gupta	Professor, Agro-forestry	Co-convener
Dr. S.B. Bakshi	Dy. Director, Students Welfare	Member
Dr. Munish Kumar Sharma	Associate Professor, Statics	Member
Dr. Lalit Mohan Gupta	Associate Professor, Agro-forestry	Member
Dr. Moni Gupta	Associate Professor, Biochemistry	Member
Dr. Arvinder Singh	Asstt. Prof., Biotechnology	Member
Dr. SushmitaDadich	Asstt. Prof., Ag. Engineering	Member
Dr. Komal Bhat	Computer Prog. FoA, Chatha	Member
Sh. Deepak Sharma	AV operator of DEE	Member
Sh. Bachan Kumar	Telephone Technician	Member
Sh. Shiv Dev	FCLA, Dean Office	Member
Suheel Ahmad Ganai	Ph.D. Student, Entomology	Member
Ms. Fatima Bano	Ph.D. Student, DOAEE	Member
Ms. Shanu Pathiana	M.Sc. Student, DOAEE	Member

MS. Sonika Sharma	Ph.D. Student, Fruit Science	Member
Sh. Sansar Chand	OCC, Soil Science	Member
Sh. Janak Raj-II	OCC, Dean Office	Member
Sh. Bansi Lal	OCC, Gymnasium, Chatha	Member

12. Finance committee

Name of the officer/official	Designation	Position
Dr. Virender Kaul	Prof. & Head, Entomology	Convener
Dr. S.K. Gupta	Professor, Agro forestry	Co-convener
Dr. Rajinder Peshin	Associate Prof. DOAEE	Member
Dr. Sanjay Khar	Programme Coordinator KVK-Jammu	Member Secretary

13. Invitation Committee

Name of the officer/official	Designation	Position
Dr. K.R. Sharma	Professor & Head, Soil Science	Convener
Dr. Vikas Tandon	Senior Scientist & Head, KVK Rajouri	Co-convener
Dr. Bharat Bhushan	Deputy Registrar, Academics	Member
Dr. Puneet Choudhary	SMS, KVK-Jammu	Member
Dr. Kamlesh Bali	Assistant Professor, Sericulture	Member
Mr. Suraj Parkash	SMS, KVK Poonch	Member
Dr. Davinder Sharma	Assistant Professor, Entomology	Member
Dr. NarinderPanotra	Junior Scientist, RARS Rajouri	Member
Mr. Avneesh Gupta	Prog. Asstt.(Computer), KVK Kathua	Member
Mr Vishal Mahajan	Ph.D student, Agroforestry	Member
Mr. Rakesh Kumar	Ph.D student, DOAEE	Member
Mr. Arvinder Kumar	Ph.D student, DOAEE	Member

14. Farmer Scientist Interaction Committee

Name of the officer/official	Designation	Position
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Dr. AmrishVaid	Senior Scientist & Head, KVK-Kathua	Co-convener
Dr. Vinod Gupta	Senior Scientist, KVK-Rajouri	Member
Dr. Berjesh Ajrawat	SMS, KVK-Kathua	Member
Dr. Prem Kumar	SMS, KVK-Jammu	Member

15. Food Committee

Name of the officer/official	Designation	Position
Dr. Vinod Wali	Prof. & Head, Fruit Sciences	Convener
Dr. R.K. Sharma	Prof. & Head, Animal Nutrition	Co-convener
Dr. Puneet Choudhary	SMS, KVK-Jammu	Member
Dr. L.K. Sharma	Assistant Professor, DOAEE	Member
Dr. Arvind Ishar	SMS, KVK-Rajouri	Member
Dr. Deep ji Bhat	Assistant Professor, Fruit Sciences	Member
S. Sarbjeet Singh	FCLA, DOAEE	Member
Mr. SameerJi Raina	FCLA, Microbiology	Member

16. Exhibition Committee

Name of the officer/official	Designation	Position
Dr. Parmodh Baru	Associate Director Research, SKUAST-J	Convener
Dr. Vikas Tandon	Senior Scientist & Head, KVK-Rajouri	Co-convener
Dr. Rakesh Bandral	Senior Scientist & Head, KVK-Doda	Member
Dr. Sanjay Swami	Senior Scientist & Head, KVK- Poonch	Member
Mr. Ajay Kumar	Prog. Asstt. (Farm) KVK-Kathua	Member
Mr. Raju Gupta	Prog. Asstt. (Farm) KVK-Jammu	Member

17. Protocol committee for dignitaries from outside the state

Name of the officer/official	Designation	Position
Dr. Narinder Singh	Associate Professor, Agroforestry	Convener
Dr. Rakesh Sharma	Senior Scientist, KVK-Jammu	Co-Convener
Dr. Arvind Ishar	SMS, KVK- Rajouri	Member
Mr. Suraj Prakash	SMS, KVK-Poonch	Member
Mr. Pawan Sharma	SMS, KVK-Poonch	Member
Dr. Narinder Panotra	Junior Scientist, RARS Rajouri	Member
Dr. Anil Bhat	Asstt. Professor, Agri. Econ.&ABM	Member

18. Banner Committee

Name of the officer/official	Designation	Position
Dr. Puneet Chowdhary	SMS, KVK-Jammu	Convener
Dr. Mandeep Singh Azad	SMS, KVK-Reasi	Co-Convener
Mr. Satvir Singh	Programme Asstt, KVK-Reasi	Member
Mr. Ajay Kumar	Programme Asstt. KVK-Kathua	Member
Mr. Pankaj Kumar	Artist Cum Photographer, Directorate of Extn	Member

19. Conference Website Maintenance Committee

Name of the officer/official	Designation	Position
Dr. Manish Kumar Sharma	Associate Professor, Statistics	Convener
Dr. Manmohan Sharma	Associate Professor, Bio-Technology	Co-Convener
Sh. Atulya Giri	Computer Programmer, Data Centre, Chatha	Member
Sh. Jagdish Kumar	Programme Asstt, KVK-Reasi	Member

CONTENTS

Atmospheric Stressors: Concern for Crops in Future

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1. Introduction

As climate change becomes a reality rather than a jargon, we find ourselves often bewildered by weather, climate and the environment. The weather is changing and we seem to have caused it. Over the last couple of years Kuwait reported snow, Hurricane Katrina decimated New Orleans and Paris sweltered in 40 degrees Celsius heat. In India Mumbai sunk under 900 mm of heavy rainfall in a single day, Delhi froze with below zero degree Celsius, Rajasthan had floods twice whereas Maharashtra, Madhya Pradesh and Karnataka had unprecedented hailstorms and many more such events. These events have signalled to accept that there is a drastic change in behaviour of the atmospheric variables and we must get prepared to deal with it.

In the last 100 years or so, the Earth's surface and lowest part of the atmosphere have warmed up on average by about 0.6^{o}C (IPCC, 2013). During this period, the amount of greenhouse gases in the atmosphere has increased, largely as a result of the burning of fossil fuels for energy and transportation, and land use changes, for food by mankind. In the last 25 years, concern has grown that these two phenomena are, at least in part, associated with each other. That is to say, global warming is now considered most probably to be due to the man-made increases in greenhouse gas emissions, the balance of evidence now indicates that there is a discernible human influence on the global climate). 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 changeinvolve any process that can alter the global energy balance, and the energy flows within the climate system.

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 regulate the intake of water, nutrients and gas exchanges. Thus any change / deviation in the atmospheric variables will certainly affect the SPAC effect 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. In quantitative and qualitative terms, aberrant changes in atmospheric variables on agriculture can be conjectured and most of them are estimated to be negative. These effects include:

- The overall predictability of weather and climate would decrease, making the day-to-day and medium-term planning of farm operations more difficult
- Sea-level rise would submerge some valuable coastal agricultural land
- The incidence of diseases and pests, especially alien ones, could increase
- Present agro-ecological zones could shift in some cases over hundreds of kilometres horizontally, and hundreds of meters altitudinally
- Higher temperatures would allow seasonally longer plant growth and crop growing in cool and mountainous areas, allowing in some cases increased cropping and production In contrast, in already warm areas climate change can cause reduced productivity
- Changes in rainfall pattern will increase the risk of crop production
- The CO_2 fertilization effect will be nullified due to its impact on global warming and extreme events
- Increase in extreme weather events would increase the risk in farming as a profession besides direct crop loss.

2. Altered Composition of the Atmosphere

Atmosphere serves as a conduit for the transport of toxic material added sometimes inadvertently by the output of industrial system. When fossil fuels are burnt, the carbon-based petrochemical products are broken up in combustion to form, among many other products, carbon dioxide (CO_2), carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NOx), sulphur oxides (SOx) and very fine particulates. When a sufficient concentration of sulphur and nitrogen oxides and hydrocarbons builds up in the atmosphere and is bombarded by sunlight, a complex series of chemical reactions takes place that creates more chemicals, including nitrogen dioxide (NO_2) and ozone (O_3). Also, very fine acidic particles are formed, such as sulphates and nitrates. When nitrogen oxides and reactive organic gases combine, especially on sunny, still days, a photochemical (ozone) smog is formed and this can also cause crop damage.

The burning of surphur containing fuels release SO_2 and when the atmosphere is sufficiently moist, the SO_2 transform into tiny droplets of sulphuric acid and cause acid rain. The effects of SO_2 on crops are influenced by other biological and environmental factors such as plant type, age, sunlight levels, temperature, humidity and the presence of other pollutants (ozone and nitrogen oxides). Thus, even though sulphur dioxide levels may be extremely high, the levels may not affect vegetation because of the surrounding environmental conditions. Acid deposition directly reduces the yield of radishes, beets, carrots and broccoli. Scientists believe that acid rain damages the protective waxy coating of leaves and allows acids to diffuse into them, which interrupts the evaporation of water and gas exchange so that the plant can no longer breathe. This stops the plant's conversion of nutrients and water into a form useful for plant growth and affects crop yields.

In addition to cosmetic damage, there is the possibility that crops grown under acidic conditions have lower nutritional value with fewer minerals. The acidic nature of acid rain leaches plant nutrients out of the soil and can make it less productive for agriculture. Soils with high alkaline content, such as those containing calcium carbonate or limestone, can neutralize the acids and are less sensitive. Other soils normally contain the minerals that plants need, but the acid in acid rain dissolves them and replaces the metallic ions with hydrogen. When the plants absorb water that normally contains the minerals, they get hydrogen instead and can't grow as large or as quickly as before. In severe cases, this lack of minerals can kill the plants.

3. Ozone Depletion and UV Radiation Exposure

Ozone, combination of three oxygen atoms into a single molecule (O3) is a gas produced naturally in the stratosphere where it strongly absorbs incoming UV radiation. But as stratospheric ozone decreases, UV radiation is allowed to pass through, and exposure at the Earth's surface increases. Exposure to shorter wavelengths increases by a larger percentage than exposure to longer wavelengths. At mid-latitudes, a decrease of one percent in ozone may result in an increase of between one (310 nm) and three (305 nm) percent of potentially harmful UV-B at the surface during mid-summer when UV-B is highest (USDA, 2001).

Cloud cover plays a highly influential role in the amount of both UV-A and UV-B radiation reaching the ground. Each water droplet in a cloud scatters some incoming UV radiation back into space, so a thick cover of clouds protects organisms UV. The larger the percentage of the sky that is covered by clouds, the less UV reaches the ground. Unlike clouds, aerosols in the troposphere, such as dust and smoke, not only scatter but also absorb UV-B radiation. Ozone depletion is greater at higher latitudes and negligible at lower latitudes. However, places at lower latitudes generally receive more sunlight because they are nearer the equator, so UV levels are higher even in the absence of ozone depletion. Living organisms at high elevations are generally exposed to more solar radiation and with it, more UV-B than organisms at low elevations. This is because at high elevations UV-B radiation travels through less atmosphere before it reaches the ground, and so it has fewer chances of encountering radiation-absorbing aerosols or chemical substances such as ozone and sulphur dioxide than it does at lower elevations.

With regard to plants, UV-B (280-320 nm) impairs photosynthesis in many species. However, the 'Biological Action Factor' of UV-B can vary over several orders of magnitude with even slight changes in the amount and wavelength of UV-B. In particular it can be noted that there are damaging effects of increasing UV-B on crops and plankton growth. Overexposure to UV-B reduces size, productivity, and quality in many of the crop plant species like rice, soybean, wheat, cotton, and corn. Similarly, overexposure to UV-B impairs the productivity of phytoplankton in aquatic ecosystems. UV-B increases plants' susceptibility to disease. Scientists have found it affects enzyme reactions that conduct fundamental biological functions. If the ozone hole should remain for longer time periods, or if ozone were to be reduced over a wider area every year, sooner or later, we could expect to see major ecosystem changes. Excess ultraviolet radiation B can directly affect plant physiology and cause massive amounts of mutations, and indirectly through changed pollinator behavior, though such changes are simple to quantify. However, it has not yet been ascertained whether an increase in greenhouse gases would decrease stratospheric ozone levels. In addition, a possible effect of rising temperatures is significantly higher levels of ground-level ozone, which would substantially lower yields. So many studies in both the laboratory and the field have demonstrated serious consequences of increased UV-B radiation on the biosphere that we need to improve our understanding of the complex Earth environment and its responses to that radiation.

4. Increased CO_2 Concentration

The levels of carbon dioxide (CO_2) in the atmosphere are higher than they have been at any time in the past 400,000 years. 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. This recent relentless rise in CO_2 shows a remarkably constant relationship with fossil-fuel burning, and can be well accounted for based on the simple premise that about 60 percent of fossil-fuel emissions stay in the air. 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).

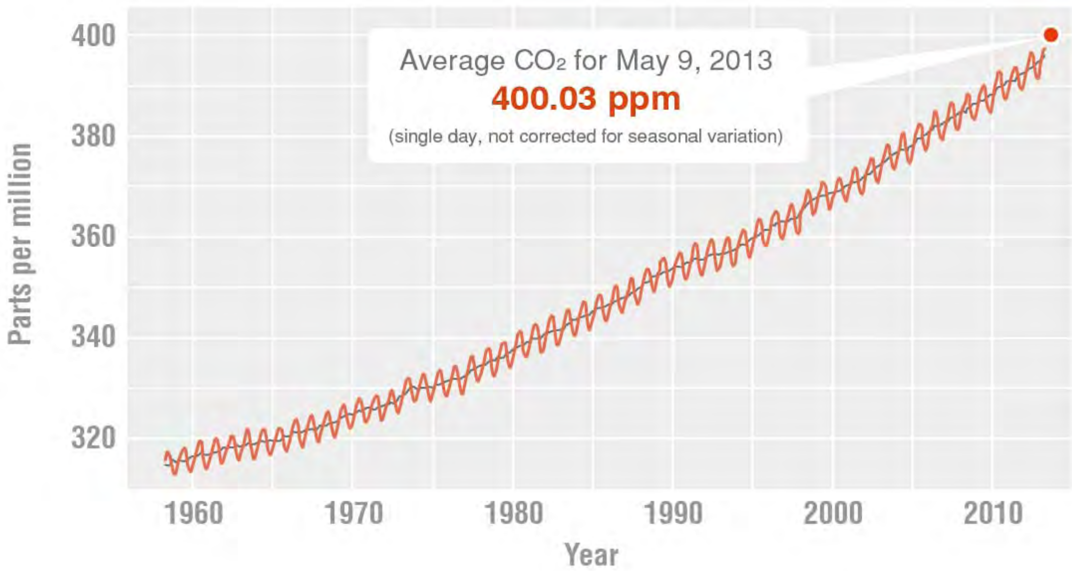

Fig. 1: Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii, measured since 1958. The black curve represents the seasonally corrected data

Carbondioxide is essential to plant growth. Rising CO_2 concentration in the atmosphere can have both positive and negative consequences. Increased CO_2 will have positive physiological effects by increasing the rate of photosynthesis. Currently, the amount of carbondioxide in the atmosphere is hovering around 400 ppm compared to 210,000 ppm of oxygen. This means that often plants may be starved of carbondioxide, due to the enzyme that fixes CO_2, rubisco also fixes oxygen in the process of photorespiration. The photo-synthetic metabolism above and even more below ground effects of an increase in carbondioxide would be higher on C_3crops (such as wheat) than on C_4 crops (such as maize), because the former is more susceptible to carbondioxide shortage (Garbutt *et al.*, 1990). Studies have shown that increased CO_2 leads to fewer stomata developing on plants which lead to reduced water usage. The main mechanism of CO_2 fertilization is that it depresses photo-respiration, more so in C_3 than in C_4 plants. Under optimum conditions of temperature and humidity, the yield will increase but the impact of elevated carbondioxide concentrations on whole farming systems has to be looked into where the relationship between CO_2 and productivity in isolation from other factors associated with climatechange, such as an increased frequency of extreme weather events, seasonal shifts, and so on. A section of scientists believe that the purported benefits of elevated carbondioxide concentrations are “likely to be far lower than previously estimated” when associated factors are taken into consideration.

Plants are classified as C_3, C_4 or CAM according to the products formed in the initial phases of photosynthesis. C_3 species respond more to increased CO_2; C_4 species respond better than C_3 plants to higher temperature and their water-use efficiency increases more than for C_3 plants. With increased atmospheric CO_2 the consumptive use of water becomes more efficient because of reduced transpiration (CO_2 anti-transpirant effect). This is induced by a contraction of plant stomata and/or a decrease in the number of stomata per unit leaf area. This restricts the escape of water vapour from the leaf more than it restricts photosynthesis (Wolfe and Erickson, 1993). A total of 10 to 20% of the approximate doubling of crop productivity over the past 100 years could be due to this effect (Tans *et al.,* 1990) and forest growth or regrowth may have been stimulated as well. Further productivity increases may occur in the coming century, in the order of 30% or more where plant nutrients and moisture are adequate. Higher CO_2 values would also mitigate the plant growth damage caused by pollutants such as NO_x and SO_2 because of smaller stomatal openings.

CO_2 elevation in the atmosphere can alter plant growth as well as that of organisms in the soil. This can lead to major changes in the cycling of carbon in ecosystems, including plant growth and succession. Nodule number and nitrogenase activity may both be increased by elevated concentrations of CO_2 in the atmosphere. In field-grown soybean exposed to elevated atmospheric CO_2 and reduced precipitation, nodule numbers were 134–229% greater as driven by greater nodule density per unit of root length (Sharon *et al*., 2013). CO_2 elevation can alter microbial biomass of C and N, microbial number, respiration rates, organic matter decomposition, soil enzyme activities, microbial community composition, and functional groups of bacteria mediating trace gas emission such as methane and nitrous oxide. Elevated CO_2 in atmosphere may enhance certain microbial processes such as CH_4 emission from wetlands due to enhanced carbon supply from plants (Freeman *et al*., 2004). Results of some experiments indicate that elevated CO_2 level in the atmosphere may decrease the Soil-available N, particularly in soils that are already low in nitrogen content and during the early period of crop growth. The aforesaid decrease could be due to higher root biomass caused by higher amount of photosynthesis as more root means more extraction of soil nutrients (Ma *et al*., 2007).

However, other expected changes in the future climate are expected to operate in different directions. In one hand, due to CO_2 enriched environment, photosynthesis and root formation would get promoted leading to more N fixation (as C:N ratio is constant) which compensates for soil fertility reduction or even may increase fertility vis-à-vis crop yield (Blanco-Canqui and Lal, 2010). Increased NUE is often observed in response to raising CO_2. Nutrient retrieval and nutrient utilization are found to be higher in elevated CO_2 in field crops like cotton and wheat. However, with increasing NUE under elevated CO_2, N yield in cereals does not automatically increase because of the decrease in plant N concentration. This may be caused by the effect of dilution due to the more rapid growth under elevated CO_2, or due to changes occurring at the level of the photosynthetic apparatus. Increased plant NUE can lead to lower inorganic N concentrations in the soil, and reduced N loss. Elevated CO_2 significantly decrease nitrate (NO_3–N) concentrations below the rooting zone in both soybean and grain sorghum crops indicating improvements in N retention in soil organic pools. Nutrient cycling may be affected further by elevated CO_2 via changed litter decomposition rates. Frederiksen*et al.*(2001) reported that the decomposition of wheat straw was slower when the plants were grown at elevated CO_2. Changes in residue quality due to elevated CO_2 may alter soil C and N dynamics as shown by Torbert *et al.* (1996) using residues collected from experiments with soybean exposed to either ambient or elevated CO_2.

5. Warmer Atmosphere

The annual global combined land and ocean surface temperature is 0.62°C above the 20th century average of 13.9°C. This marks the 37th consecutive year (since 1976) that the yearly global temperature was above average (NOAA, 2015). Currently, the warmest year on record is 2010, which was 0.66°C above average. Including 2013, 9 of the 10 warmest years in the 134-year period of record have occurred in the 21st century. Only one year during the 20th century—1998—was warmer than 2013. 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).

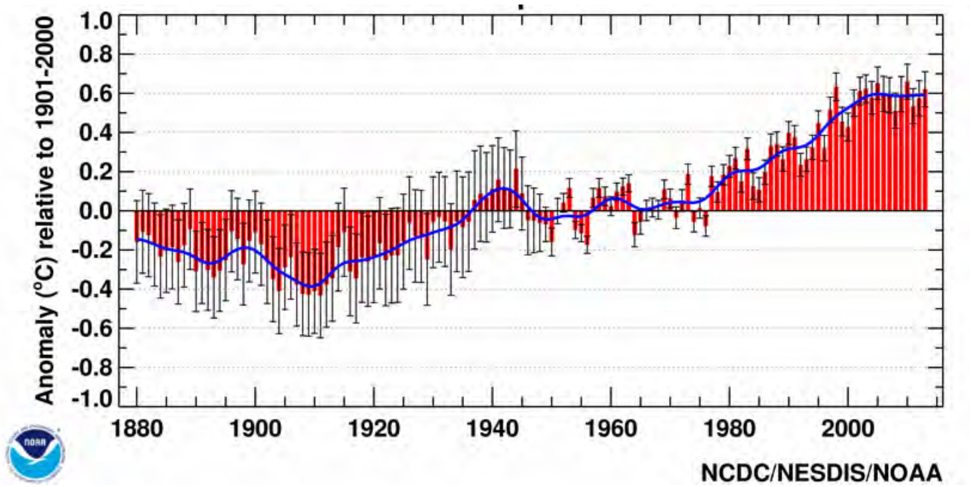

Fig. 2: Global Mean Temperature over Land and Ocean (NOAA, 2014)

Over the period 1901 to 2010, global mean sea level has risen by 0.19 m. The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (IPCC, 2013). Such pace of increase in the sea level threaten the existence of some island nations as well as submergence of coastal areas thereby leading to loss of cultivable lands to erosion, submergence of shorelines, salinity of the water table due to the increased sea levels. This could mainly affect agriculture through inundation of low-lying lands. Low lying areas such as Bangladesh, India and Vietnam will experience major loss of rice crop if sea levels are expected to rise by the end of the century. 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.

In general, higher temperatures are associated with higher radiation and higher water use. It is relatively difficult to separate the physiological effects at organ or plant level to eco-region level. It is generally agreed that rising temperatures - now estimated to be 0.2°C per decade, or 1 °C by 2040 with smallest increases in the tropics would diminish the yields of some crops, especially if night temperatures are increased. The temperature increase since the mid-1940s is mainly due to increasing night-time temperatures, while CO_2-induced warming would result in an almost equally large rise in minimum and maximum temperatures. Among functional types, C3 plants generally had a greater ability for temperature acclimation of photosynthesis across a broad temperature range, CAM plants acclimated day and night photosynthetic process differentially to temperature, and C4 plants was adapted to warm environments (Yamori *et al.*, 2014). CAM plants would also strengthen the CO_2 fertilization effect and the CO_2 anti-transpirant effect of C_3 and C_4 plants unless plants get overheated. Whereas, higher night temperature may increase dark respiration of plants, diminishing net biomass production. Similarly higher cold-season temperatures may lead to earlier ripening of annual crops, diminishing yield per crop, but would allow locally for the growth of more crops per year due to lengthening of the growing season but higher temperatures will allow for more plant growth at high latitudes and altitudes.

In soil, fertility level would also be affected by global warming. However, because the ratio of carbon to nitrogen is a constant, a doubling of carbon is likely to imply a higher storage of nitrogen in soils as nitrates, thus providing higher fertilizing elements for plants, providing better yields. High temperature could accelerate the rate of microbial decomposition of organic matter and lead to faster nutrient cycling in the soil (Salinger, 1989). Davidson and Janssens (2006) also reported that a significant fraction of relatively labile OM is clearly subject to temperature-sensitive decomposition, but another significant fraction of OM remains under environmental constraints that often obscure the intrinsic temperature sensitivity of its decomposition. If only the effect of high temperature is concerned, then in the long run it may adversely affect soil fertility. The aim of modern agricultural practices is to achieve an optimum efficiency in the use of resources such as nutrients and water, thereby preserving resources and minimizing environmental impacts due to resource losses to the environment. Excessive application or low uptake efficiency of nutrients from concentrated inorganic fertilizers or from renewable nutrient sources (e.g. animal manure, cover crops, or green manures) can result in the accumulation of nutrients in the soil. With low nutrient-use efficiency (NUE) nutrients not utilized by the plants may leach to groundwater, be transported in runoff or sediment to surface waters, or be emitted to the atmosphere in the form of nitrous oxide (N_2O), nitric oxide (NO) or ammonia (NH_3). In contrast to elevated CO_2, warming tends to have a negative effect on plant NUE. This can be due to increased sink limitation with increasing temperature, especially in plants with reproductive sinks. At the system level, warmer conditions stimulate soil N availability through higher rates of mineralization, which may lead to increased productivity (Parton *et al.*, 1995), but also to higher system N losses if N demand by the plant is not synchronized with N supply.

6. Changes in Rainfall Pattern and Drought

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). Due to the extremes of climate that would result, the increase in precipitations 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. 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.

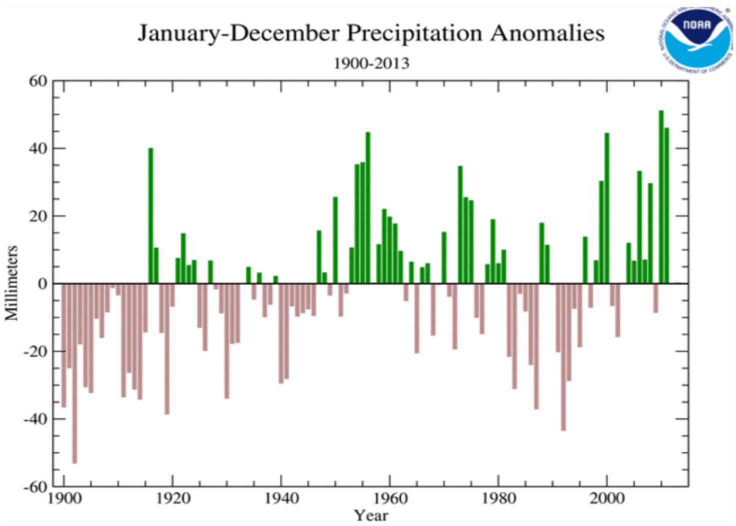

Fig. 3: January–December Global Precipitation Anomalies (NOAA, 2015)

Changes in rainfall distribution with almost same amount of rainfall being distributed in less number of rainy days means there is a reduction in the amount of effective rainfall. Thus though soil texture, structure and root zone dynamics remains same, the intensity of rainfall will alter the available water to the crops (FAO 1985). Similarly decreased rainfall, particularly during summers, could have a dramatic effect on the soil through the increased frequency of dry spells, leading to increased proneness to drought and wind erosion. Increased rainfall in regions that are already moist could lead to increased leaching of minerals, especially nitrates, hence a reduction in soil productivity. Wang *et al.* (2010) reported that N was leached more deeply as the irrigation rate increased. The larger amount of initial accumulated N was in soil profile, the higher percentage of N leaching was and the nitrate leaching in rainy years were significantly higher than those in dry years.

Changes in the water balance and the amount of water available in the soil can be crucial for crop yield. For example in grasslands, 90% of the variance in primary production can be accounted for by annual precipitation, and yield of water-limited crops is determined by crop water use and by water-use efficiency (WUE). In a warmer climate and under small interception losses of water, increased evapo-transpiration favours soil dryness. Calculations using the Penman–Monteith equation predict that potential evaporation increases by about 2–3% for each 1°C raise in temperature (Lockwood, 1999). Thus, 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 (Brumbelow and Georgakakos, 2001). This negative effect of climate warming may be counteracted by effects of elevated CO_2 on the crop tolerance to water stress.

7. Occurrence of Extreme Weather Events

Year to year deviations in the weather and occurrence of climatic anomalies / extremes are cold wave, frost, hailstorm, thunderstorm, dust storm, heat wave, cyclone, Flood etc. Recent weather events such as deadly heat waves and devastating floods have sparked popular interest in understanding the role of global warming in driving extreme weather. These events are part of a new pattern of more extreme weather across the globe, shaped in part by human-induced climate change (NatCatSERVICE, 2013).

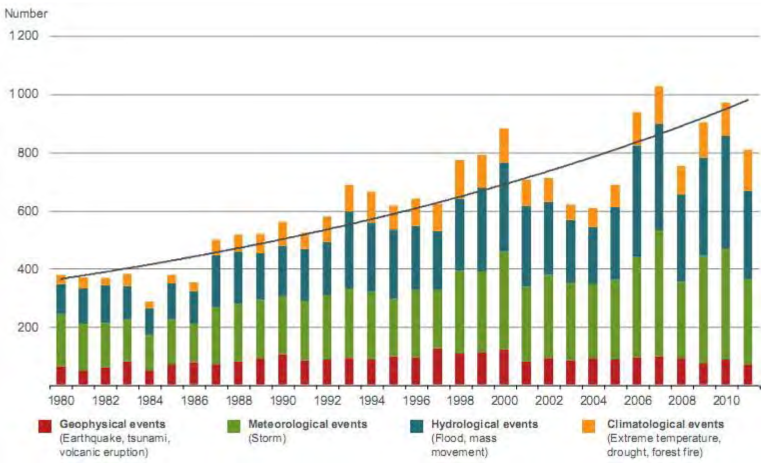

Fig. 4: Natural catastrophe worldwide (1980-2011)

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. Heavy rains and flooding are more frequent. In a wide swing between extremes, drought, too, is more intense and more widespread. Besides these hailstorm has widened its horizon. All weather events are now influenced by climate change because all weather now develops in a different environment than before. While natural variability continues to play a key role in extreme weather, climate change has shifted the odds and changed the natural limits, making certain types of extreme weather more frequent and more intense. The kinds of extreme weather events that would be expected to occur more often in a warming world are indeed increasing.

Food crops are highly sensitive to heat. For example, globally, more than 220 million hectares are annually sown to wheat, making it the most widely grown crop in the world and a vital global food source. Preferring relatively cool temperatures, wheat is harvested before early summer. Relatively higher temperatures above 30°C shorten grain-filling duration, interrupt photosynthesis and then slows or stops grain-filling rates. Extreme heat exposure will undoubtedly lead to crop losses in India. Two of India's major crops (wheat and rice) are projected to decline with continued global warming. In a country where the agriculture sector provides a livelihood source for more than 65 percent of the population the ramifications of this heat event will be widely felt. The Indian government's aim is to be self-sufficient in terms of food production. Given these realities, any decline in agriculture production is bound to be costly for the nation.

Hailstorms are the result of four atmospheric factors which are characterized as strong convective instability creating strong updrafts, abundant moisture at low levels feeding into the updrafts, strong wind shear aloft, usually veering with height, enhancing updrafts and some dynamical mechanisms that can assist the release of instability such as air flow over mountain ridges. The development of hailstones, its size and shape depend on how fast the storm is moving and how strong the updrafts are inside the storm (Bal *et al.,* 2014). Hails can damage the field as well as fruit crops which depend on stage of the crop, size and texture of hailstones, and the speed and force of hail as it hits the ground. A high velocity impact early in the season can also cause substantial damage, the impact of which may not be recovered with time. Damage in mature produce quickly become focal points for diseases like brown/grey rot, smut while the disease may initially be limited to damaged tissues but can quickly spread to intact plant parts in warm, humid conditions.

It is difficult to make projections about thunderstorms because of its localized nature. The warming climate is likely to increase the length and frequency of severe thunderstorm environments especially during summer storm season (IPCC, 2013). Storm damage in crops is especially determined by storm severity and crop maturity. A severe storm close to harvest is more serious than a less severe storm earlier in the season. Fruit can also be stripped from the trees by the force of wind. Severe wind can cause lodging and damage to especially perennial orchard crops.

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. 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.

8. Conclusion

Since climate change is a process that can never be ignored, its dynamic and unpredictable nature already poses and will continue to pose challenges for agriculture and managed ecosystems henceforth. Hence, to make future agriculture remunerative, lesser risky and sustainable; the dynamic characteristics of atmospheric stressors have to be understood so that researches on its impacts on agriculture is take up in a holistic way to formulate adaptation and mitigation options. In recent times, the unusual events are becoming usual events. Thus to tackle the negative impacts of weather/climate linked unusual events, water-intensive crop production has to be taken up only in areas where rainfall is higher and less water-intensive crops, in the north-west and Deccan region in this country, where drought is frequent. To deal heat or cold wave conditions, adaptation and mitigation options have to be explored either through field management or genetic improvement techniques. Events like extreme rain and hailstorm have become a regular phenomena and certainly protective agriculture has to play a significant role. Overall, the Indian agriculture will experience a lots of ups and downs in the coming years due to the unpredictable effects of these atmospheric stressors and only option available will be to fight it in our own way.

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Sustaining Productivity through Efficient Cropping Systems Following Integrated Nutrient Management Concept

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1. Introduction

The climatic, edaphic and socio-economic diversity of the Indian crop production science is dotted with many cropping patterns and systems. The cropping systems considered to be major contributors to the national food basket are rice-wheat (10.2 m ha), rice-rice (5.9 m ha), peach millet- wheat (2.3 m ha), sorghum-wheat (2.3 m ha), maize- wheat (1.9 m ha) and systems where land was kept fallow either Kharif or Rabi season occupy 19 m ha area (Gill *et al.*, 2008). Cropping systems comprise of growing crops in sequence along with their interaction effects with the resources available, other enterprises available at the farm and technological inputs that determine their make-up *w.r.t* water, nutrients and energy for sustaining the productivity and profitability. The inputs must be used in such a manner to achieve for better use efficiency with minimum losses and to make them environment friendly. Cropping system investigations have amply demonstrated that the appropriate choice of the crops and cropping systems play a crucial role to achieve the maximum return and efficiently use of inputs on one hand and to make the resource balance by developing cohesion among the resources applied. Choices of crops primarily focus on productivity; fulfil domestic requirement and better competitive quality products. Hence, the choice of cropping systems has to be examined carefully in the light of these factors prior to recommendations.

In the country like India, it is estimated that almost 50 per cent of the production is accrued through fertilizer management (FAO 1965-76) and majority of the farmers are using chemical fertilizers because of multiple uses of FYM particularly as fuel. The integrated approach increases the organic matter available nutrients in addition to improvement of physical and biological properties. A conservative estimate entail the availability of approximately 300-400 million tonnes of organic sources which may be used for agriculture.

Till date our country has witnessed the contribution of fertilizers to total grain production, 1 per cent in 1950, 32 per cent in 1980 and around 53 per cent in 2000 Thus, clearly showing significance of fertilizers as key input for achieving targets of agricultural production and to feed the burgeon population pressure. Simultaneously, it is strongly felt that soil health has been deteriorated on account of excessive wet tillage, sole use of chemical fertilizer, growing of high nutrient requiring crops and less use of organic sources such as FYM, compost, green manure, crop residue management, biofertilizer, etc. Thereby, inviting the immediate attention for the right choice of cropping systems and integrated nutrient management at focused areas for ensuring the eco-balance and enhancing the total unit productivity. An effort has been made to identify various cropping systems in different agro-ecological regions along with the input of integrated nutrient supply using different census for making an assessment about the scope of increasing productivity, its sustainability, and profitability in the coming time.

2. Different Efficient Cropping Systems and their Role for Sustainability

High intensity cropping system under assured inputs: The high intensity cropping sequences in major ecologies, have shown marked advantage over existing cropping systems. The introduction of new cropping systems or diversification of one or more component crops resulted in enhanced annual productivity ranging between 25 and 117 per cent over the existing cropping systems at different AICARP-CS research centers (Sharma *et al*., 2002). From a 10 year study in an *Ustochrepts* in Punjab, it was seen that the apparent recovery of P declined in rice-wheat>rice-berseem>cotton-wheat>corn-wheat>ground-nut-wheat>pearlmillet–berseem (Acharya *et al.*, 2002). The result of long term studies conducted at PAU, Ludhiana about the evaluation of prominent cropping systems clearly revealed that there are many cropping systems such as Maize-Wheat-Summer moong bean, Maize-Potato-Summer moong bean, Maize-Potato-Onion, Summer groundnut-Potato-Bajra fodder produced rice equivalent yield as 15.6, 18.2, 27.6 and 16.0 t ha^{-1} $annum^{-1}$, respectively as against 13.7 t ha^{-1} in rice-wheat system. The corresponding saving of irrigation water over rice-wheat system was 88, 81, 78 and 100 cm, respectively. But the prevalent rice-wheat system spread over 69% of cultivated areas is not being shifted mainly because of favourable government policies viz, free supply of electricity, committed procurement and fixed support price along with the non-implementation of use of underground water policy formed by the central government do not encourage the farmers to shift from rice-wheat cultivation to other sustainable cropping system. Thereby shifting same area under different cropping systems as stated above may help to make the eco balance effective.

Inter cropping: Inter cropping is one of the important ways to increase the productivity and provide income stability under limited soil moisture conditions. Some of the promising intercropping cropping system are maize + blackgram at Palampur, Ranchi and Banswara; maize + soybean in Ranchi; maize + cowpea at Karjat ; Sorghum + Soyabean at Sehore; Sorghum + Pigeon pea at Indore ; Pigeon pea + green gram at Bichpure and

Hanumangarh ; rice + soybean at kalyani and Jabalpur and wheat + rapeseed at Indore. Net profit from these intercropping systems were quite high 15 to 200 per cent when compared with sole cropping. Most of these intercropping systems were evaluated on farmers' fields and found to be highly remunerative over the sole cropping. In these on –farm trials also, the additional benefits over sole crop varied from 9 to 199 per cent. In kandi area (rainfed) of Punjab comprising of 8-9 per cent where wheat + gram or wheat + raya row are the other promising intercropping system to sustain the productivity.

Growing of crops as per land capability: The crops perform well in different cropping systems if grown as per soil suitability which determine their productivity make-up in relation to soil type, soil depth, water retention, climatic factors, duration of the crops, source of irrigation, frequency of irrigation water available etc. Growing of maize and wheat in a sequence in loamy sand soil under rainfed condition of sub-montaneous Punjab gives less total productivity (23.8 q ha^{-1}) than yield obtained from a sole crop of wheat (25.7 q ha^{-1}) in winter seasons. During kharif, soil water conservation measures should be adopted. While in sandy loam soil with better water retentivity, maize and wheat crops should be grown in a sequence. The coefficient of variability for maize-wheat sequence in loamy sand soil was 60 where as in Fallow–Wheat, it reduced to 25 per cent. It is thus better to grow only one crop in rabi season (write reason) instead of growing two crops in a year (Prihar and Singh, 1983).

Inclusion of legumes in cropping systems: Legumes are known to increase soil fertility through their capacity to fix atmospheric-N and hence, yield of cereals following legumes are reported to be 0.3 to 3 mg/ha; or 30 to 35 per cent higher than those following a cereal based cropping sequences. Besides N –fixation, legumes also help in solubilization of occluded P, soil conservation, increase in soil microbial activity, organic matter restoration and improvement of physical health of soil (Acharya and Bandyopadhyay, 2002).

SSNM (Site Specific Nutrient Management) in different cropping systems: this concept has great potential in different cropping systems in general and rice-wheat; rice-rice cropping systems in particular. The SSNM addresses judicious application of deficient nutrients for fulfilling their full requirement for specific yield target based on soil supply capacity and nutrient removal by the crops grown in cropping systems. The site specific nutrient management planning is designed on soil, crop and cultivars ae well as landscape and crop management. The SSNM approach aims at achieving maximum economic yield of crops by assuring site-specific application of major, secondary and micro- nutrients on soil test basis, which takes into account various sources of nutrients present in the soil. It has been realized that 15-17 t ha^{-1} $annual^{-1}$ grain yield of rice-wheat system can be achieved by applying knowledge of SSNM at several locations (Tiwari, 2006). The multi location data for 13 centre's of All India Coordinated Research Project on cropping systems revealed that site specific systems are probably the best opportunity available to develop a truly sustainable crop-production system (Gill, 2006).

3. Integrated Nutrient Management (INM)

To further increase the nutrient use efficiency the most effective and practical approach is integrated nutrient management approach which aims at exploiting all the available resources of plant nutrients in a judicious way and ensuring their efficient use. Major sources of nutrients are soil reserve, chemical fertilizers, organic manures and crop residues and bio-fertilizers. Under continuous and intensive cropping led to deplete the essential nutrients and under such conditions the use of chemical fertilizers in balance proportions and in a recommended quantities is the quickest way of boosting crop production. But not more than 30-40 per cent of the applied fertilizer nutrient are utilized by the crop and rest are lost through various pathways like leaching, surface runoff, volatilization, denitrification, fixation in soil etc. The renewable local resources like organic manure and crop residues are of great significance to reduce these losses. Locally available material of plant as by-product of farm activities may be recycled and used with considerable benefits. Where such materials are not abundantly available, in situ production of organic manures may be encouraged.

Nutrient use efficiency: Craswell and Godwin (1984) classified nutrient efficiency in to three groups and called them Agronomic efficiency, physiological efficiency and apparent recovery efficiency. Maximum nutrient use efficiency is obtained when nutrient concentration is near the critical level, because near maximum yield occurs at this point without excessive nutrient levels in the plant. Values of nutrient use efficiency declined in the profuse and toxic range because yield levels are often decreased while nutrient concentration increases. De (1998) reported that fertilizers are needed to be applied at the proper time and site with correct method and if they are applied later than usual or at wrong sites they may cause harmful effects on the crop. Tisdale *et al.* (1997) indicated that N promotes P uptake by plants by increasing top and root growth; altering plant metabolism and increasing the solubility and availability. The uptake of nitrogen more decisively reflects on the yield of rice and similar cereals. Much of the photosynthates for the sink are derived from the photosynthesis at and after flowering (Babu, 1995) therefore the nutrient uptake particularly that of nitrogen during flowering stage is more crucial. More the N uptake during this stage better is the sink accumulation and the yield.

Green manuring: Among organic manures, green manure occupies a pivotal position and help to increase the organic matter content of soil, maintain and improve soil structure, reduce loss of nutrients particularly N, provide source of N for the succeeding crop and reduce soil erosion and thereby increase the production of crop (Greenland *et al.*, 1979). Green manuring is an inexpensive, eco-friendly, alternative of mounting prices of fertilizer nitrogen and has become an effective technology in economizing the agriculture production system ensuring productive capacity of soil without causing environmental problem (Bana and Pant, 2000). Green manures particularly the legumes have relatively more N, low C:N ratio and behave almost like chemical nitrogenous fertilizers. It helps to save N fertilizer in range of 50-60 kg/ha. In the extensive on station (Meelu *et al.*, 1980; Narang *et al.*, 1990) and on farm research trials at 24 locations on rice-wheat lands in districts Kapurthala and Jalandhar the green manuring through Dhaincha contributed 60 kg N ha^{-1} equivalent to rice with little or no carry over effect on the succeeding crop in the rotation. Large number of experiments conducted under All India Coordinated Agronomic Research Project at several locations also testifies to the beneficial effect of green manuring in rice-wheat system. The response varied from 18 per cent at Ludhiana, 10 per cent at Pantnagar, 8 per cent at Kanpur, 6 per cent at Varanasi and 4 per cent at Bhubneshwar. Green manuring to rice either resulted in saving of the chemical fertilizers (substitution effect) or it helped boost the productivity (through supplement effects) when applied along with recommended level (Hegde and Dwivedi, 1992). In Karnatka, maize+groundnut cropping system subabul green manuring in alley system at 6 m distance having paired row at 30 cm apart showed significant influence on yield of maize and groundnut. The grain yield of maize at recommended dose of fertilizer alone was at par with that of 75 per cent nitrogen with green manuring. The pod yield of groundnut at 50 per cent recommended dose of fertilizer with green manuring was on par with that of recommended dose of fertilizer (Palled *et al.*, 2000). Thomas and Martin (1999) at TNAU Coimbatore found that integrated use of green manure (*Sesbania rostrata*) and bio-fertilizers (Azolla) along with chemical fertilizers enhanced the growth and yield attributes of wet seeded rice.

Crop residue: Another option to raise soil organic resource reserve could be through enhanced accumulation of root biomass/incorporation of above ground crop residue into the soil; raised through systematic heavy fertilization in this system. There is often observed long gestation period before the accumulated beneficial effect of crop residue become visible. The degree of time lag depending upon the agro-ecological and soil management practices adopted (Anonymous, 1994). Experiments conducted at IARI showed the need for additional application of urea spray along with residue to expedite its mineralization (Pathak and Sarkar, 1994). In medium black soil at Gangavati (Karnatka), Kumar *et al.* (1996) and found that application of organic sources (press mud and paddy husk) substituted 25 per cent of the recommended fertilizers in getting higher cane and sugar yield. Economics worked out indicated that application of press mud in conjunction with 100 per cent recommended fertilizer gave higher returns.

Farm yard manure and bio-fertilizers: Inoculation of azolla at 1.0 t ha^{-1} along with urea resulted in comparable yield with that of succeeding level of urea but with no azolla, suggested a saving of 25 kg N ha^{-1}. In groundnut-wheat cropping system on vertisols of Western Maharashtra plains zone recorded maximum pod yield of groundnut with 2.5 ton FYM+75 per cent recommended fertilizer dose to groundnut and wheat (5.4 t ha^{-1}) with recommended level of fertilizer (Kathmale *et al.*, 2000). At Coimbatore, Chinnamuthu and Venktakrishnan (2001) reported that application of 50 per cent recommended NPK along with vermicompost gave higher seed yield of sunflower than 100 per cent NPK with FYM. Likewise soil application of Vasicular Arbuscular Mycrrohizae (VAM) recorded higher seed yield of sunflower over phosphorus solublising bacteria (PSB) and control. They further reported that combined application of organic manures and chemical fertilizers significantly influence the sunflower seed yield. In sodic soil of Uttar Pradesh, the use of organic sources 50 per cent of the recommended dose of nitrogen for rice may be supplemented economical with additional improvement in grain quality and properties and fertility status of the soil (Ram *et al.*, 2000). Patidar and Mali (2001) determined the most appropriate combination of organic manures, fertilizers and bio-fertilizers to sorghum and to assess their carry over effect on succeeding wheat. Application of 10 ton FYM ha^{-1} increased grain and fodder yield of sorghum by 18.5 and 9.4 per cent, respectively over no FYM. Inoculation of azospirillum alone and in combination with PSB increased significantly grain and fodder yield of sorghum. Grain and straw yield of wheat increased by 8.8 and 6.6 per cent, respectively owing to residual effect of FYM. In cold desert soils of Himachal Pradesh, Sharma *et al.* (2001) found that grain yield of barley with 60 kg N+10t ha^{-1} FYM was at par with 75 kg N alone with a net saving of 15 kg N/ha. Singh *et al* (2001) at Navgaon found the beneficial effect of FYM+chemical fertilizers on rainy season onion yield. They recorded the maximum bulb yield up to 120 kg N+10 ton FYM ha^{-1}. Talashilkar *et al.* (1997) studied the effect of poultry manure alone and in different combination with inorganic fertilizers on yield, uptake of micronutrients and status of micronutrients in lateritic soils of Konkan (Maharashtra). Application of 50 and 100 per cent recommended dose of fertilizers increased the dry pod yield by 3.9 and 5.7q ha^{-1}, respectively over no fertilizer application. Similarly an application of poultry manure in graded dose of 1, 2 and 3t/ha increased the dry pod yield by 2.1, 4.7 and 8.0 q ha^{-1}, respectively over no application of poultry manure. Integrated use of fertilizer and poultry manure exhibited additive effects on groundnut yield. Total uptake of micronutrients such as Zn, Cu, Mn and Fe was increased significantly under integrated nutrient application. In addition application of poultry manure resulted in significant increase in micronutrient content of soil. Basu (1992) found the indications about saving of fertilizer if fertilizer management is done for the cropping system. He found that where use organic manure wherever and whenever available and use of major, secondary and micronutrients according to need will maximize the yield of cotton and crops in the cotton based cropping systems and maintain the soil fertility for sustainability in production. Verma (1996) at Hisar found that use of bio-fertilizers or FYM at the rate of 2.5t ha^{-1} did not improve growth, yield and yield parameters of pearl millet significantly over the control. Combinations of bio-fertilizers or FYM with 20 kg ha^{-1} was found at par with 40 kg N ha^{-1} alone in terms of yield and yield characters. Similarly blue green algae and farm yard manure applied in combination with chemical fertilizers have also been reported to benefit in sustaining the rice-wheat cropping system productivity (Parsad, 1994).

FYM and GM: At Meerut, on an average of 3 years cane yield of late planted sugarcane can be increased by 19.4 and 29.0 per cent over farmer’s practice (250 kg N, 60 kg P_2O_5 ha^{-1}) by using recommended dose of 160 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} in conjunction with FYM at the rate of 10t ha^{-1} and in situ incorporation of cowpeas at the rate of 6t/ha respectively. Among the different fertility, treatments incorporation of cowpeas @ 6t ha^{-1} contributed sugarcane yield 5.3t ha^{-1} (Gangawar and Sharma, 1997). Green manuring of legumes in sugarcane farming contributes about 41 to 85 kg N ha^{-1} depending upon the type of green manure and its time of incorporation. It is necessary to apply a part of fertilizer N in form of organic N to sugarcane to sustain the productivity of soil and crop. Integrated use of cane trash, sulphitation press mud cake and bio-fertilizers each with inorganic fertilizers and green leaf manuring brings 20-50 per cent economy in fertilizer N applied to sugarcane by improving the use efficiency of N, P and other nutrients (Singh and Yadav, 1992). Research investigations conducted in the Department of Agronomy at PAU Ludhiana further purported that use of green manure before paddy transplanting or application of farm yard manure to substitute 50 per cent of recommended nitrogen helped both the crops in rice-wheat system to get more yield than the recommended NPK fertilizers along with fertility improvement (Gill *et al*., 2000).

Work done on integrated nutrient management on potato and potato based systems show that potato is a highly responsive crop when compared to cereals. It responded to FYM and green manures more than the cereals. Among the organic manures, FYM at 30t ha^{-1} was more effective than green manure (GM). The use of organic manures improves the yield optima as well as can reduce the fertilizer dose especially of P and K fertilizer. The studies further showed that N applied to potato has significant residual effect on succeeding wheat crop and N dose of wheat could be reduced by 50 per cent. While the residual effect of P and K applied to potato obviates the need of fresh application of these nutrients to wheat in HP conditions (Grewal and Sharma, 1992).

4. Conclusion

i. There are numerous options of alternative cropping systems in comparison to the existing one in different agro-ecological regions, which not only give better productivity but also ensure the utilization of resources more rationally. The productivity improvement varied from 25-117 per cent and warrant attention for creating awareness of those cropping systems among farmers coupled with incentives as a policy matter.

ii. Under limited irrigation conditions, selection of crops and cropping system should be based on soil type, soil depth, rainfall pattern and make the use of inputs accordingly.

iii. Inter cropping /mixed cropping and inclusion of legumes in different cropping systems are the other tools for making cropping system profitable and stable.

iv. The integrated use of organic manures (FYM, green manures, compost, vermi-compost, crop residues etc.) not only help to increase the yield of crops over the sole use of chemical fertilizers but also help to make the fertilizer economy along with soil fertility build up in all the individual crops as well as crops grown in a system. Use of organic manures is only criteria for maintaining soil health; and to make the different cropping system more sustainable, productive, and profitable.

v. The yield barrier can be broken in the existing cropping systems by following site specific nutrient management concept.

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Cropping Systems in India and Their Constraints

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1. Introduction

Undoubtedly, India got self-sufficiency in food grain production the ushering in the green revolution. The self-sufficiency in foodgrain production was achieved at the cost of degradation (physically, chemically and biologically), diminishing biodiversity, depletion of ground water table, increase in environmental pollution, elimination of useful birds on account of high pesticide use and contamination in foods, ultimately affecting the human health. These emerging threats in the irrigated agriculture system have put greater challenge before agricultural scientists to maintain the balance between production and consumption to fulfill the food and nutritional security across the regions and sustainability of resources. The recommendation with regard to important production factors like fertilizer management, water management, weed control, disease and pest management has been formulated for component crops need to be integrated into cropping system mode. Substantial saving in input resources is accrued, when recommendations on cropping system basis are adopted.

The cropping systems vary from region to region as they are designated on the basis of climate, soil type, irrigation facilities, market demand, input supply, labour availability and farmers' perception to adopt the systems. Therefore, all efforts are being made to develop production and protection technologies in all the agro-climatic regions of the country. The description of agro-climatic parameters is needed to determine the potential cropping system within a cropping pattern in a particular area (Table 1).

Table 1: Important agro-climatic features, soil type and predominant cropping systems of India

Agro-climatic region/zone	**Rainfall (mm)**	**Climate**	**Soils**	**Predominant cropping systems**
Western Himalayan Region	1650-2000	Cold arid to humid and sub-humid	Hills soils, sub-mountain, meadow sheletal	Rice-wheat, maize-wheat and rice-potato-potato
Eastern Himalayan Region	1840-3528	Per humid to humid	Brown hills, acidic soils, alluvial, tarai soils, red sandy, laterite soils	Rice-fallow, rice-rice and rice-pulses/oilseeds
Lower Gangetic Plains	1302-1607	Moist sub-humid to dry sub-humid	Recent alluvial, red, yellow loamy soils	Rice-rice, rice-wheat, rice-potato-jute and rice-potato-vegetable
Middle Gangetic Plains	1211-1470	Moist sub-humid to dry sub-humid	Alluvial, calcareous, tarai soils	Rice-wheat, rice-maize and rice-potato-sunflower
Upper Gangetic Plains	721-979	Dry sub-humid to semi-arid	Alluvial, tarai soils	Rice-wheat, sugarcane-ratoon-wheat, pearl millet-mustard
Trans Gangetic Plains	360-890	Semi-arid to dry sub-humid and arid	Alluvial, calcareous soils	Rice-wheat, cotton-wheat and pearl millet-wheat
Eastern Plateau and Hills	1296-1436	Dry sub-humid to moist sub-humid	Red, yellow, sandy loam to laterite	Rice-black gram/niger/linseed, rice-groundnut and rice- vegetable
Central Plateau and Hills	490-1570	Semi-arid and dry sub-humid	Mixed red and black, medium black, grey, brown and alluvial soils	Maize/sorghum+ soybean-wheat, sorghum+ pigeon pea-Bengal gram/linseed, maize+ soybean-wheat and sorghum-wheat
Western Plateau and Hills	602-1040	Semi-arid to dry sub-humid	Medium to deep black, shallow red loamy soils	Cotton-wheat, sorghum+ soybean-Bengal gram/ durum wheat, pearl millet+ black gram/green gram-safflower
Southern Plateau and Hills	677-1001	Arid, semi-arid to dry sub-humid	Medium to deep black, red sandy to loamy coastal and deltaic alluvium	Sorghum-cotton-groundnut, rice- Bengal gram/green gram, rice-rice, rice-*rabi* maize-fodder

East Cost Plains and Hills	780-1287	Moist sub-humid to semi-arid	Delta coastal alluvial, laterite red and medium black soils	Rice-groundnut-green gram, rice-green gram/ black gram and rice-rice
West Cost Plains and Hills	2226-3640	Per humid to dry humid	Lateritic and coastal alluvium, red loamy soils	Soybean-wheat, cowpea/ groundnut/rice-green gram, cotton+ foxtail millet-green gram, rice-rice
Gujarat Plains and Hills	340-1793	Semi-arid to dry sub-humid	Deep black, coastal alluvium, medium black and brown soils	Castor-chillies-fallow, pearl millet - mustard/ isabgol/cumin, cotton-wheat, pearl millet+ moth/guar-barley-fallow
Western Dry	55-395	Arid to extremely arid	Desert, grey brown soils	Pearl millet+ black gram- mustard, maize+ soybean- durum wheat, groundnut- durum wheat-summer bajra, rice –*rabi* maize/ groundnut-summer moong, cotton-durum wheat
Andaman & Nicobar Islands	1600-3000	Hot per humid	Medium to very deep, red loamy and sandy soils	Rice-fallow

Source: Gill *et al.* (2008)

Wide divergence has been noticed with respect to rainfall and soil types in the country and accordingly various cropping systems exist in different agro-climatic zones (Table 1).

2. Site-specific crop diversification: Crop diversification in area, where continuous cropping of cereals-cereal systems is in vogue, has been advocated as one of the effective tools for minimizing the second-generation problems and to make a breakthrough in the productivity and profitability. The crop diversification can deliver many agronomic and ecological benefits simultaneously, while maintaining or enhancing the scale of efficiency of production. In this regard, besides adoption of proper input management technologies, diversification of the system through introduction of crops of diverse nature may be a good preposition to break the monotony of the predominant cereal based systems and to sustain productivity over a period of time. For diversification of rice-wheat system, several options are available different zones (Table 2).

Singh *et al.* (2003) reported that clusterbean-wheat is more economical than cowpea-wheat and pearl millet-wh eat crop sequences in parts of Rajasthan. With assured availability of irrigation, cottton-groundnut for Vidarbha and central Maharashtra plateau zones, and sugarcane-based cropping systems for western Maharashtra scarcity zone were found to be more productive, profitable and efficient (Gangwar *et al.*, 2003). Gangwar *et al.* (2004) reported that under limited irrigation water situations of Vindhyan plateau zone of Madhya Pradesh, soybean-based systems *viz.* soybean-wheat and soybean-chickpea systems were identified to be more efficient only in term of production (5128 and 4990 kg ha^{-1} year^{-1} as wheat grain-equivalent yield), productivity (14.50 and 13.67 kg ha^{-1} year^{-1}) and stability (0.56 and 0.62), but, in terms of economic viability, blackgram-linseed and maize-linseed were more viable in terms of net return and benefit: cost ratioon. In mid high altitude of Jammu rice-wheat-sorghum + cowpea fodder system was identified be most productive with rice equivalent yield of 11835 kg ha^{-1} year^{-1} and yield stability of 0.45 (Gangwar *et al.*, 2006). The next best seuence was rice-mustard-greengram with 11221 kg ha^{-1} year^{-1} rice-equivalent yield and yield stability of 0.42. These systems were distinctly better than existing rice-wheat offering an opportunity to diversify the existing system.

Effective nutrient management is essential to sustain any cropping system over years. To check or reverse the present declining trend in factor productivity, it is essential to follow system-based integrated nutrient management approach. In fact site specific nutrient management approachb to achieve targeted yield is being focussed in recent years (Shukla *et al.*, 2004). Nutrient management based on system basis, rather than to indivisual crop, leads to higher efficiency and economics besides system sustainability (Hegde and Babu, 2002). Recent studies on loamy sand soils at Ludhiana have shown that the best approach for P management in rice-wheat system is to apply recommended doses of phosphorus to both the crrops (Singh *et al.*, 2002). Sseven cropping patterns *viz;* rice-berseem, rice-lentil, rice-canola, rice-wheat-mungbean, rice-wheat-cowpeas, rice-sunflower and rice-wheat-sesbania (rostrata) with commonly practiced rice-wheat cropping pattern cropping systems were evaluated for their productivity and to assess their effect on the soil organic carbon contents and available soil NPK. The results revealed that the green manuring and leguminous cropping patterns gave higher paddy yield as compared to commonly practiced rice-wheat cropping pattern. The maximum paddy yield of rice (3.73 t ha^{-1}) was obtained from rice-wheat-sesbania cropping pattern where sesbania was sown and incorporated in the soil as green manuring crop just before rice transplanting. This increase in paddy yield was statistically at par with the paddy yields received from rice-wheat-mungbean (3.57 t ha^{-1}) and rice-berseem (3.52 t ha^{-1}) cropping pattern. The yield of succeeding wheat crop was also higher in case of green manuring (sesbania) and leguminous crops (mungbean and cowpeas) which yielded 2.81, 2.69 and 2.63 t ha^{-1}, respectively. The yield in case of rice-wheat cropping pattern was only 2.59 t ha^{-1}. As regards cost benefit ratio, the highest ratio was received in case of rice-lentil (1:2.38) cropping system followed by rice-canola (1:1.96) and rice-wheat-mungbean (1:1.78) as against the existing cropping pattern (rice-wheat) which gave the ratio (1:1.56). The results further indicated that introduction of green manuring or leguminous crops in the existing rice -wheat system not only increased grain yields but also improved the physio-chemical properties, organic matter contents and nutrients availability in the soil. Increase of NPK over initial soil fertility was N (0.12 %), P (2.8 ppm), and K (52 ppm). Soil pH lowered from 8.2 to 7.8 and organic carbon increased from 0.67 % to 0.72 %. Gangwar and Ram (2005) revealed that the population of *Phalaris minor* in wheat could be reduced through inclusion of vegetable pea as catch crop before wheat and interruptive cropping of mustard instead of wheat (once in 3 years). The soil fertility (Organic carbon, N, P, K and S) in general could be maintained or enhanced in cropping sequences involving vegetable pea, greengram or interruption of wheat through mustard and rice through maize and pigeon pea once in three years.

Table 2: Efficient crop diversification options for rice-wheat farmers

Cropping system K – R – S	**REY ($t\ ha^{-1}yr^{-1}$)**	**Productivity ($kg\ day^{-1}\ ha^{-1}$)**	**Profitability ($Rs.\ ha^{-1}\ day^{-1}$)**	**NUP (kg grain kg^{-1} nutrient use)**
South Alluvial Plain zone of Bihar				
Rice-wheat	7.7	21.1	38.6	21.4
Rice-garlic-maize	11.2	30.6	76.4	23.7
Mid high altitude intermediate zone of J&K				
Rice-wheat	9.2	25.3	87.4	26.4
Rice-cauliflower-french bean	11.0	30.1	93.8	53.2
Central plain zone of Punjab				
Rice-wheat	11.0	30.0	33.0	25.1
Maize-potato-onion	18.2	50.0	84.2	45.1
Central plain zone of U.P.				
Rice-wheat	8.8	240.	36.4	28.1
Maize-potato-sunflower	15.3	41.9	56.4	20.5
Vindhyan plain zone of U.P.				
Rice-wheat	8.5	23.2	32.3	17.7
Rice-potato-green gram	14.3	39.2	58.2	22.2
Bhabar and Tarai zone of Uttarakhand				
Rice-Wheat	11.9	32.7	91.5	23.9
Rice-rapeseed-sunflower	12.6	34.5	93.1	23.1
Plain zone of Chattisgarh				
Rice-Wheat	8.6	23.7	90.2	32.0
Rice-brinjal-green manure	10.7	29.4	112.4	54.0
Plateau and Satpura hill zone of M.P.				
Rice-Wheat	6.7	18.4	53.7	16.7
Rice-Berseem(f)-berseem (S)	10.5	28.7	103.3	47.7
South Gujarat heavy rainfall zone				
Rice-wheat	6.9	18.9	48.3	20.9
Rice-onion-veg. cowpea	8.6	23.5	52.2	22.0
Vindhyan Plateau zone of M.P.				
Rice-wheat	5.4	14.6	33.4	14.1
Rice-berseem(f)-berseem (S)	7.2	19.6	62.4	23.8
Eastern plain zone of U.P.				
Rice-wheat	7.1	19.4	37.0	15.9
Rice-potato-green gram	15.5	42.3	97.9	11.5

Source: Gangwar (2011) K= *Kharif*, R= *Rabi*, S=summer, REY = rice equivalent yield,
NUP= nutrient use productivity

Specific Issues Relating to Some Important Cropping Systems

Cropping Systems	Issues
Rice-Wheat	Over mining of nutrients from soil,Disturbed soil aggregates due to puddling in rice, Decreasing response to nutrients, Declining ground water table, Build up of diseases/pests, Build up of Phalaris minor, Low input use efficiency in north western plains, Low use of fertilizer in eastern and central India, Lack of appropriate varietal combination, Shortage of labour during optimum period for transplanting paddy.
Rice-Rice	Deterioration in soil physical conditions, Micronutrient deficiency, Poor efficiency of nitrogen use, Imbalance in use of nutrients, Non-availability of appropriate transplanter to mitigate labour shortage during critical period of transplanting, Build up of obnoxious weeds such as Echinochloa crusgalli and non-availability of suitable control measures.
Cotton-Wheat	Delayed planting of succeeding wheat after harvest of cotton, Stubbles of cotton create problem of tillage operations and poor tilth for wheat, Susceptibility of high yielding varieties of cotton to boll worm and white fly and consequently high cost on their control leading to unsustainability, Poor nitrogen use efficiency in cotton results in low productivity of the system, Appropriate technology for intercropping in widely spaced cotton is needed to be developed.
Sugarcane-Wheat	Late planting of sugarcane as well as wheat, Imbalance and inadequate use of nutrients, majority of farmers apply only N in sugar cane and the use of P and K is limited, The emerging deficiencies of P, K, S and micro-nutrients are limiting system productivity directly and through interactions with other nutrients, Poor nitrogen use efficiency in sugarcane, Low productivity of ratoon due to poor sprouting of winter harvested sugarcane in north India, Build up of *Trianthema partulacastrum* and *Cyprus rotundus* in sugarcane, Stubble of sugarcane pose tillage problem for succeeding crops and need to be managed properly.
Maize-Wheat	Sowing time, Poor plant population, Poor weed management, Poor use of organic and inorganic fertilizers, Large area under rain fed.

3. Future Areas of Thrust

i. Water will be a scarce resource in future. Therefore, most efficient cropping systems for quantified water availability conditions need to be identified.

ii. Inputs becoming more costly every year resulting increase in cost of crop production. Therefore, *in situ* supplementation of inputs would be helpful. As such, bio-intensive complementary cropping systems need to be identified for partial *in situ* management of nutrients and pests.

iii. Diversification effects through inclusion of spices, medicinal and aromatic and horticultural crops with reference to productivity, profitability, stability and soil health in rice-wheat systems need to be quantified at different locations.

iv. Both short and long-term strategies need to be worked out considering the present trends and future perspectives of globalization of economy with new trade opportunities.

v. Development of synthesized sustainable cropping system models need to be attempted to achieve desirable change in the existing systems.

vi. Location specific resource management strategies need to be worked out for different crops and cropping systems so as to achieve quantum jumps in crop production.

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Present Scenario and Prospects of Horticulture Industry In India - An Overview

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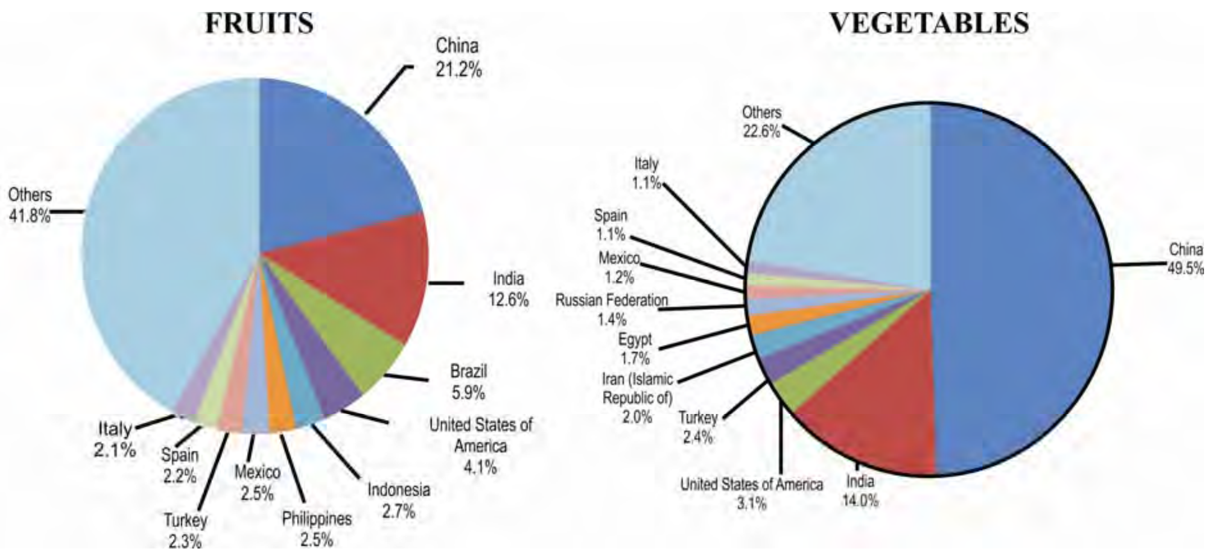
1. Introduction

Horticulture has emerged as one of the potential agricultural enterprise in accelerating the growth of economy in India. Its role in the country's nutritional security, poverty alleviation and employment generation programmes is becoming increasingly important. It offers not only a wide range of options to the farmers for crop diversification, but also provides ample scope for sustaining large number of agro-industries which generate huge employment opportunities. At present, horticulture is contributing 12.7% of GDP from 13% land area. On account of significant production increases in horticultural crops across the country, a Golden Revolution is in the offing and India has emerged as a leading player in the global scenario. We have now emerged as the world's largest producer of coconut and tea and the second largest producer and exporter of tea, coffee, cashew, spices, exports of fresh and processed fruits, vegetables, cut flowers, dried flowers have also been picking up. As a result of a number of thoughtful research, technological and policy initiatives and inputs, horticulture in India, today, has become a sustainable and viable venture for the small and marginal farmers. It is a matter of satisfaction that their food consumption levels and household income have increased. Besides, this sector has also started attracting entrepreneurs for taking up horticulture as a commercial venture. Thus, there is a great scope for the horticulture industry to grow and flourish. Horticulture has a multi-dimensional role to play as they provide fruits, timber, fuel wood, pulp, fodder, fibre and support industrial/commercial enterprises.

India has been bestowed with wide range of climate and physio-geographical conditions and as such is most suitable for growing various kinds of horticultural crops such as fruits, vegetables, flowers, nuts, spices and plantation crops (coconut, cashewnut and cocoa). Its production has increased by 30% in the last five years. This has placed India among the foremost countries in horticulture production, just behind China. During 2012-13, its contribution in the world production of fruits and vegetables was 12.6 % and 14%, respectively. Total production of fruits during 2012-13 was 81.2 million tonnes while that of vegetables was 162 million tonnes, whereas, the second advance estimates put the production at 84.4 million tonnes and 170.2 million tonnes, respectively for 2013-14.

India's significant horticulture production is despite is comparatively higher of lower productivity. Both in case of fruits and vegetables, productivity of India (11.6 and 17.6 t ha^{-1}, respectively) is about half of the productivity of USA (23.3 and 32.2 t ha^{-1}, respectively). During 2012-13, its productivity was marginally better than the world average in case of fruits (11.3), whereas, it was below the world average (19.7 t ha^{-1}) in case of vegetables. Compared to the leading producer of fruits and vegetables China, India lags behind significantly in vegetable productivity whereas its productivity in case of fruits equals to that of China and in case of some fruits like grapes it is amongst the highest in the world.



Share of different countries in global production 2012-13 (Source: FAO & NHB, India)

Table 1: Major fruit producing countries in the world (2012-13)

Country	Area in '000 ha	Production in '000 MT	Productivity in MT ha^{-1}
China	11834	137067	11.6
India	6982	81285	11.6
Brazil	2325	38369	16.5
United States of America	1138	26549	23.3
Indonesia	797	17744	22.3
Philippines	1240	16371	13.2
Mexico	1257	15918	12.7
Turkey	1103	14975	13.6
Spain	1539	13996	9.1
Italy	1126	13889	12.3
Others	27925	270595	9.7
World	57265	646758	11.3

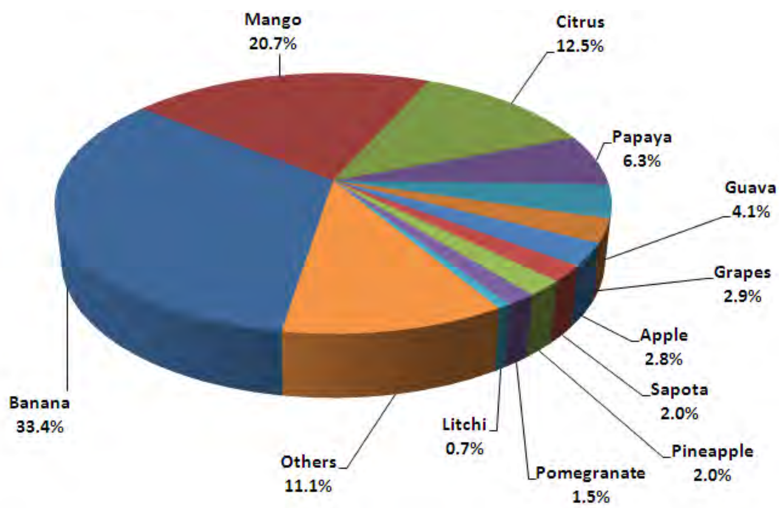
Source: FAO Website and for India: Horticulture Division, D/o Agriculture & Cooperation

During 2014-15, India has emerged as a major producer of horticultural crops (280 million tonnes surpassing food grain production of 251 million tonnes) and is placed second after china in both fruit and vegetable production. Also, horticulture in India with its high annual growth rate has become a major contributor to growth of Indian Agriculture. It is, therefore, important that horticultural crop production is given continued emphasis so that it could sustain the desired growth rate in agriculture sector across the diverse agro-climatic conditions and provide skill development and job opportunities to the emerging youth force.

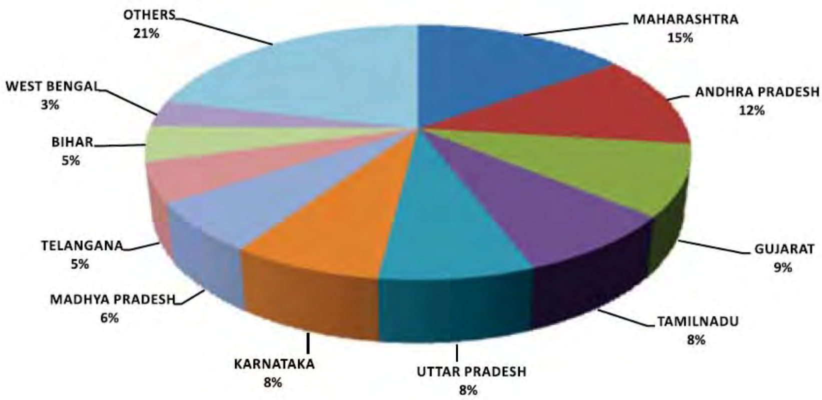
Horticulture growth and development needs to be inclusive to benefit various stakeholders in the system. Hence, it is essential to reassess our programmes and devise overall strategies to make this sector more inclusive under the rapidly changing consumer and market driven economy and rapidly depleting environmental conditions. Today, the challenges are many namely, nutritional security, threat of climate change, need for new plant genotypes for diversified end uses, production deficit and gluts, lack of infrastructure in commodity value-chain, retail chains and organized market systems, farmer producer companies and export promotion. It is therefore, necessary that horticulture sector gears to meet new challenges and to bring overall change in horticulture *per se* and also in the allied sectors leading to re-defining the short and long term goals in research, production system, education and human resource development, public and private sector collaboration, market intelligence and auction system along with diligent policies to boost production, productivity, processing export of fresh and processed horticulture produce and products.

India with an area of 7.21 million ha and annual fruit production of 88.97 million tonnes is the second largest producer of fruits after China. Among fruits, banana and mango accounted for more than half (54 %) of total fruit production during 2013-14, with production of banana alone accounting for about 33.4 %. Share of Citrus fruits was also significant and they accounted for about 12.5 % of overall fruit production.

Production share of major fruit crops in India (2013-14)



2. State-wise comparison: During 2013-14, Maharashtra led in fruits production with a share of about 15% followed by Andhra Pradesh (12% share) and Gujarat (9% share).Tamil Nadu, Karnataka, UP, MP each contributed significantly in total fruit production whereas West Bengal & Kerala were also significant fruit producing states with each contributing about 3-4%. Andhra Pradesh accounted for about 38% in production of citrus fruits and 31% of papaya production. J&K accounted for more than 70% in apple production, Maharashtra for more than 80% in production of grapes and Bihar contributed more than 44% in litchi production. UP and Andhra each accounted for about a quarter in mango production. Horticulture today, is not merely a means of diversification but forms an integral part of food and nutritional security, as also an essential ingredient of economic security. Adoption of horticulture, both by small and marginal farmers, has brought prosperity in many regions of the country, of which, Maharashtra, Karnataka, Andhra Pradesh and Kerala are prime examples.



Leading fruit producing states of India (2013-14)

3. Government initiatives: Research and development in horticulture has received impressive support in the last two decades. As a result, the research infrastructure has increased manifold with the setting up of several new institutes and national research centers on several export oriented crops. The share of plan outlay for Horticulture in Agriculture which was 3.9% during Ninth Plan has increased to 4.6% during the current Twelfth Plan. This share was 11.6% during the Eleventh Plan. The actual expenditure for National Horticulture Mission increased from Rs.917.33 crores during 2007-08 to Rs. 1809.56 crores during 2013-14. Total expenditure on horticulture research and development (Plan & Non Plan) during the Eleventh Plan (2007-08 to 2011-12) Plan was Rs. 1383.13 crores. So far, Indian horticulture has been insulated from forces of outside world. Time bound removal of quantitative curbs on imports and other barriers to access to domestic market under WTO, of which India is a signatory, will require Indian horticultural produce/product to be competitive both in the domestic and export market. This would call for use of hi-tech horticultural technologies. Such technologies can be defined as ‘those, which are modern, less-environment dependent, capital intensive and have the capacity to improve productivity and quality’. These will include, use of genetically modified crop varieties, micro-propagation, integrated nutrient and water management, integrated pest management, protected cultivation, organic farming, use of modern immuno-diagnostic techniques for quick detection of viral diseases and hi-tech post- harvest technologies, including cold chain.

Ensuring the nutritional and aesthetic security of our nation with a population of 130 crores, is a major challenge for the horticulture sector. With shrinking land for agri-horticultural activity, the sensible option before the nation is to increase further the production levels per unit area. Intensive cultivation in hi-tech protected environments with hi-tech production inputs will ensure higher productivity levels. The projected demand of fruits is 124 million tonnes by the year 2020-21. With the opening of global market and removal of quantitative restrictions under the WTO agreement, export-import scenario is likely to change at much faster pace. Horticulture stands as the major beneficiary in such a scenario to contribute to the much needed forex reserves (Singh and Mathur, 2008).

Keeping in view the importance of Horticulture sector, the Government of India has launched a centrally sponsored scheme called the National Horticulture Mission (NHM) in 2005-06. The objectives of the Mission are to enhance Horticulture production and improve Nutritional security and income support to farm households and others through area based regionally differentiated strategies. Crops such as fruits, spices, flowers, medicinal and aromatic plants, plantation crops of cashew and cocoa are included for area expansion whereas vegetables are covered through seed production cultivation, integrated Nutrient management, integrated pest management and organic farming.

All the states and the three Union Territories of Andaman and Nicobar islands, Lakshadweep and Pondicherry are covered under the mission except the 8 North Eastern states including Sikkim and the States of Jammu & Kashmir, Himachal Pradesh and Uttarkhand. The latter are covered under the Horticulture Mission for the North East and Himalayan States. The scheme is being implemented in 372 districts in the country. During 2005-06 to 2009-10 an additional 16.57 lakh hectare of identified Horticulture crops have been covered. Apart from establishments of 2192 Nurseries for production of quality planting material 2.78 lakh hectare has been covered under rejuvenation of old orchards. With the implementation of NHM and other schemes the productions of Horticulture crops have increased from 170.8 million tonnes in 2004-05 to 214.7 million tonnes in 2008-09. The per capita availability of fruits and vegetables has increased from 391 gram per day in 2004-05 to 466 gram per day in 2008-09.

4. Technology Mission for Integrated Development of Horticulture in North Eastern States, Sikkim, J&K, Himachal Pradesh and Uttarakhand

This scheme has launched in 2001-02 to address issues related to Production and productivity, marketing and processing of Horticulture crops in the North Eastern states. In 2003-04, the Mission was extended to 3 Himalayan states of Himachal Pradesh, Jammu & Kashmir and Uttarakhand. This scheme has now been renamed as Horticulture Mission for North Eastern and Himalayan states. Under this Mission, 265435 persons including 53276 women have been trained so far. Various Institutes like Indian Agricultural Research Institute (IARI), Horticulture Wing in Indian Council of Agricultural Research (ICAR), Indian Institute for Horticulture Research, Bangalore, Agricultural universities etc have been continuously striving to improve the quality of the horticultural products as well as to increase their productivity.

5. Sources of horticulture data: Directorate of Economic & Statistics (DES), Ministry of Agriculture, Government of India operates a Centrally Sponsored Scheme "Crop Estimation Survey on Fruits and Vegetables (CES-F&V)" for estimating area and production of horticulture crops. However, CES (F&V) covers only 7 fruits crops 5 vegetables crops and 2 spice crops from 11 states only. The National Horticulture Board (NHB)compiles and publishes annual data base for horticulture sector in respect of all the states and the crops. Food and Agriculture Organization (FAO) maintains the information on area under cultivation of horticultural products, production & productivity for various countries in the world.

6. Challenges: The horticulture sector in India is characterized by small, segregated farms with low per-hectare yields and huge post-harvest losses, owing to outdated practices. A recent study by YES Bank showed India stored only two per cent of its horticulture products in temperature-controlled conditions, while China stored 15% and Europe and North America stored 85% of their products in such conditions. Adequate cold storage facilities are available for just about 10% of India's horticulture production. Of the total annual production, 30-40% is wasted before consumption. During the peak production period, the gap between the demand and supply of cold storage capacity is a mind-boggling 25 million tonnes.

As per National Centre for Cold Chain Development, the biggest wastage happens during the transportation of horticulture products from the farm gate to mandis and thereafter. Storage solutions can be provided only near the mandis, and this does not solve the problem. The answer lies in minimizing the wastage that happens during transportation". From a farm gate to a consumer, a horticulture product passed through seven different distribution channels, and in every step, there was a loss of 5-7%. China processed about 30% of the food (fruits and vegetables) in 2009, whereas, the Indian food processing industry has set a target of raising the level of processing perishable products from 6 to 20% by 2015. The $70-billion Indian food processing industry is dominated by small and medium enterprises, which do not have the capacity to undertake large-scale processing of fruits and vegetables.

Recent initiatives of the government to open Foreign Direct Investment (FDI) in retail are expected to minimize some of these problems. It is expected that entry of international retail chains would improve the situation by augmenting the storage capabilities, processing facilities & through efficient distribution, thereby minimizing wastage and benefitting the farmers as well as the consumers through a more coordinated and systematic approach besides economy of scale operations.

7. Temperate Fruit Production Scenario in India

The geographical features and ago-climatic conditions prevailing in entire North-Western and north-eastern hilly states of the country are conducive for cultivation of temperate fruit crops. The major temperate fruit growing states are Jammu & Kashmir, Himachal Pradesh and Uttrakhand contributing 44.5, 21.0 and 11.55%, respectively in the total fruit production. The fruit production in the country is dominated by tropical and sub-tropical fruits, however, temperate fruits occupy 9.2%t area (0.66 million ha) of the total area under fruits contributing 5.57 million tonnes (6.3%) in the total fruit production of the country. The major temperate fruits under cultivation in India with sizeable acreage are apple (47.4%), walnut (18.45%), grapes (17.98%), pear (6.36%), almond (3.22%), peach (2.72%), kiwifruit (0.71%) and pecan nut (0.22%). A lot of area has been brought under cultivation of pome and stone fruits in the country, still there is a great scope for further expansion of area under fruit crops in both North-West and North-East Himalayan regions of India. Due to introduction and adaptation of low chill varieties the potential for cultivation of temperate fruits has extended to lower elevations which were considered marginal for temperate fruit cultivation. The average productivity of apple has been fluctuating between 2-9 MT ha^{-1} and stone fruits 1.5-2 MT ha^{-1}, which far below the average productivity of advanced countries like China, New Zealand, USA and Italy. Decreased productivity and quality of pome and stone fruits due adverse climate, monoculture of varieties, poor quality planting material, use of seedling rootstocks, low density plantation, poor soil nutrients and moisture conditions and steep topography, rain-fed orcharding, senile orchards and in-efficient insect-pest and disease forecasting and management has become a serious concern. Various strategies like introduction and adoption of spur type and high yielding varieties, use clonal rootstocks and disease free quality planting material, high density plantations, proper canopy management, integrated water and nutrient management, application of good horticultural practices and integrated pest and disease management, can lead to improved productivity and quality of different pome and stone fruits.

8. Potential of Temperate Fruits and Nuts in Sub-Tropical Regions of India

In light of the global warming forecasts, cultivation of low-chill temperate fruits will be a viable and suitable option even in the low valley regions of North-Western and Eastern India. The low-chill temperate fruits are being grown in different states of India *viz.*, Punjab, Uttrakhand, Western Uttar Pradesh, Himachal Pradesh, Jammu & Kashmir, Meghalaya, Tamil Nadu and Chhattisgarh. The states of Punjab (5240 ha), Tamil Nadu (4210 ha), Chhattisgarh (1000 ha) and Uttrakhand have sizeable area under low-chill temperate fruits. Among the low-chill temperate fruits, the major fruits under cultivation in the sub-tropical regions are peach, pear and plum.

The state of Jammu and Kashmir is bestowed with lofty snow mountains, fascinating valleys, sparkling streams, rushing rivers and emerald forests. The state is blessed with diverse ecosystem. In this south lies the Jammu region the lower portion of which is essentially hot in summer and cold in winters, bearing broad leaved forests at lower altitudes in plains and Shiwaliks. The middle part of Jammu region support mostly Chir pine forests where as higher reaches are temperate and support luxuriant coniferous forests, the northwest region between Pir Panjal and Zojila is the Kashmir Valley considered the “paradise on earth". To the north east lies the great landscape of Ladakh bound by snow peaks and friendly people. Its natural vegetations has great diversity, ranging from the lush evergreen conifers on the gentle slopes at high altitudes to deciduous forest on the southern slopes of Shiwaliks.

9. Strengths

- The area under horticulture crops which was 12.77 million hectares during 1991-1992 has increased to 23.69 million hectares during 2012-13. The total production during this period has increased by nearly 2.8 times and corresponding productivity has increased 1.5 times. Earns more than Rs. 32 crores $annum^{-1}$ as toll tax from export of fruits.
- Among the major fruit producing countries, India ranks number two after China.
- Export of horticultural produce to the tune of Rs 14,36,487.85
- Varied agro-climatic zones expressing in a wide variety of agricultural and horticultural produce.
- Potential for diversification
- Home to high quality fresh and dry temperate fruits

10. Problem Areas

- Large area under old/senile plantation
- Poor quality of seeds/planting material and low rate of replacement of cultivars
- Lack of irrigation
- Economy of scales
- Inadequate storage and cold chain
- Inadequate research, extension and credit support
- High wastages of the produce (8-37%)
- Only 0.8% of produce is processed
- Inadequate processing and marketing infrastructure
- Lack of awareness about importance of fruits as nutritional supplement
- Inadequate safety standards, infrastructure for quality check and enforcement mechanism
- Poor HRD infrastructure
- Little hedge against uncertainty/risks
- Less awareness of balanced and judicious use of agricultural inputs

- Fragile soil in hilly areas susceptible to soil erosion
- Small and fragmented land holdings
- Several layers of intermediaries in distribution chain.
- Virtual absence of post harvest infrastructure.

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Sustainable Development Goals: Food Security, Climate Change and Forests

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1. Introduction

The year 2015 was a milestone in the history of United Nations, marking the end of the Millennium Development Goals (MDGs). It is also a milestone for paving the way for United Nations ambitious Sustainable Development Goals. Yes, UN's ambitious Sustainable Development Goals (SDGs) have become effective from January 1, 2016. There are seventeen goals and one hundred and sixty nine targets identified by United Nations to be achieved in next 15 years by 2030. The goals have been framed on the basis of voices from across the world regarding eliminating poverty, hunger, inequality of all forms and ensuring safe environment. Accordingly, United Nations sustainable development goals revolve around economic prosperity, social equality and environmental sustainability not only within the nations but also between the nations and the continents.

The history of sustainable development goals can be traced back to June, 1973 when member countries of United Nations worried about the degrading quality of environment, for the first time met in the United Nations Human and Environment Conference in Sweden and expressed concern on the degrading situation of the environment and called upon the world community to save the environment for future generations. The celebration of world environment day on 5th June is the outcome of this conference. Thereafter, the United Nations famous Conference on Environment and Development (UNCED), popularity known as the Rio de Janeiro Earth Summit or Earth Summit, was a major United Nations conference held in Rio de Janeiro in June 1992. Call for united efforts for sustainable development, biodiversity conservation and environment protection was the main outcome of this conference. Thereafter, a series of conferences integrating sustainable development and environment protection were held but Rio Conference was a milestone in raising awareness about the degrading environment and it greatly influenced the subsequent UN Conferences including Rio+20 Summit held in 2012, to set the future global green agenda.

Millennium Development Goals, covering a range of poverty, hunger, health, gender equality, education and environmental indicators have been the most successful global anti-poverty push in human history. This has been most successful programme of United Nations and the unprecedented efforts have resulted in profound achievements. According to Ban Ki Moon, Secretary General of United Nations, the global mobilization behind the MDGs has produced the most successful anti-poverty movement in history. But in spite of the historical success of MDG, the hunger still prevails in the world and therefore, eliminating the hunger from the world is the top most priority of the UN in SDGs as well. It is heartening to note that the figures for the hungry people in the world continue to decline. According to FAO in spite of successful implementation of MDG, whose core issue was to eliminate hunger and poverty from the world, there are still 795 million hungry people in the world (more than 50% in the Asia Pacific region only). This means that roughly every eighth person in the world sleeps hungry. Asia is the home for most of the hungry people in the world. About two third of the total hungry people, live in Asia and one third of world's hungry people live in India. One person in four being undernourished, Sub-Saharan Africa is the region with the highest percentage of population of hunger. Roughly 100 million children i.e. one out of six children in developing countries is underweight. One in four of the world's children are stunted. Sixty six million primary school-age children attend classes hungry across the developing world, with 23 million in Africa alone. World Food Programme figures reveal that poor nutrition causes nearly half (45%) of deaths in children under five (3.1 million children each year).

The overwhelming success of the MDG has actually laid the foundation for the ambitious sustainable development goals of UN. On the other hand, as follow up action of Rio Earth Summit, the United Nations Conference on Sustainable Development, which is commonly called Rio+20 or Rio Earth Summit 2012, was held in Rio De Janeiro in June 2012. The concept of SDGs, which aimed to produce a set of universally applicable goals that will balance the three dimensions of sustainable development: environmental, social, and economic, was born in this conference and the member nations decided to adopt the same. Accordingly, the UN member nations on October 25, 2015 adopted 2030 agenda for sustainable development in New York. Officially known as "Transforming the World" the SDG have been built upon MDG and accordingly, the SDG aim at completing the unfinished agenda of MDG. UN's document on MDG reveals that the sustainable development goals range from achieving zero hunger challenge to achieving food security, improving nutrition, ending poverty, sustainable development, urgent action to halting climate change, control desertification, halting biodiversity loss, achieving gender equality, reducing inequality between and within countries. In depth study of the SDG of the United Nations reveals that United Nation is determined to end hunger from the world. The member states have decided to have zero tolerance to hunger challenge in the world (http://www.un.org/ sustainabledevelopment/sustainable-development-goals/).

Forests give us and have given us everything we need. Accordingly, forests have to play a big role in achieving the core objectives of SDG of fighting against hunger and changing climate. Four SDG objectives directly or indirectly relates to forests. These objectives are as under:

Objective 1: To achieve food security and improved nutrition and promoting sustainable agriculture. By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.

Objective 2: Ensure availability and sustainable management of water and sanitation for all.

Objective 3: Take urgent action to combat climate change and its impacts

Objective 4: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities.

There is no doubt that the forests are the backbone of all forms life on planet earth and they do everything possible to support life on planet earth. The forests are going to play very important role in achieving the target of United Nations Sustainable Development Goals. It is also to be inferred from the above that the United Nations see greater role for the forests in combating climate change and desertification. They want to conserve the biodiversity and species but at the same time they are in favour of utilizing the forests for the achievement of the SDG objectives by managing the forest on sustainable basis. That means many things are going to come from the forests.

Climate change and food security are the core issues of SDG. In fact economic status has been linked to food security. So, any activity which raises the economic status of people will go into achieving food security as people will have more access to the food. So, the poor people who will collect and sell fuel wood, fodder and minor forest produce for buying the food will be counted towards having access to food and will be treated as a step to achieving food security.

In order to fulfill the dream of a hunger free world, experts suggest a 100% increase in food production that will result in the conversion of roughly 1 billion hectare of land by 2050. Much of this agricultural expansion is speculated to come at the expense of natural systems, including forests. In order to feed the growing global population, much of the attention is focused on increasing production and expanding area under agriculture. This will happen at the expense of natural systems. May be in some parts of the world, forest land has to be sacrificed and even reduction in hunger could be at the cost of other natural resources. This happened in the past in India immediately after independence when a big chunk of forest land was sacrificed to agriculture under "Grow More Food Campaign" and the green revolution led to the exploitation of natural resources. However, now in India, to convert forest land for food production is out of question owing to awareness among people and need to maintain about one third of land under forests as envisaged in National Forest Policy, 1988 and non-conversion of forest land for non-forestry use under Forest Conservation Act, 1980. Some experts opine that we already grow sufficient food but the problem arises due to faulty storage and inadequate distribution between nations and within nations. As a result of inadequate distribution, the food does not reach to the poor. In many cases, the food grains are rotting in godowns and about 15% stored grains are destroyed by rats, rodents and other stored grained pests annually in India, which can otherwise be fed to the poor. Lot of food is also wasted during transportation, cooking and processing.

Four pillars of food security i.e., availability, affordability, accessibility and utilization are well recognized. Availability of food means that sufficient food should be available on consistent basis. While affordability is in terms of purchasing power, accessibility means that the food should be within the reach of everybody. Utilization refers to proper distribution, knowledge about the food components and use. All these pillars may be fine for the time being, but what required is the stability of these pillars. Climate change is going to play a very big role in food security. There is infact big instability within proposed stability. It is now being widely accepted that the climate change is going to create water logging/soil salinity at some places and water crisis at others. Land degradation, floods, droughts, ocean acidification, etc. will be very common but still at uncertain locations. There is going to be a very big threat to food production system from the emerging new insect-pests and diseases. It is going to affect not only to crops/varieties but to natural biodiversity as well. In view of these changes/threats, a crop or variety, which was suitable to a particular area may become unsuitable, which may put our food security at risk (Chander *et al.*, 2015).

The biggest threat to global food security is from our narrow dependence on food items. It is a well recognized fact that 60% of our calories come from just three species of cereals i.e. paddy, maize and wheat. 90% calories in human diet come from just fifteen species of plants (250 plant species are used for food all over the world). In India, 120 species of plants have been recognized important at national level and less than 150 species of plants are cultivated today. World over about 30,000-40,000 species of plants can be used as source of food but only 7000 plant species are used at local level all over the world. But in good olden days, about one hundred thousand species of plants were being used as source of food. With too huge diversity in nature but the sphere of man's dependence is too narrow, which is required to be increased for sustainability.

The history reveals that narrow sphere of dependence has been disastrous for human beings. We cannot forget the "Irish Potato Famine" which happened in 1845-49 (http://www.britannica.com/event/Irish-Potato-Famine). Irish are known for their love for potato and they largely eat potato. There was epidemic of "Late Blight Disease" on potato caused by a fungus called *Phytophthora infestans*. Entire potato crop just perished, resultantly millions died and millions migrated from Ireland to other countries. The diseases did not restrict to Ireland alone but lateron affected 7,00,000 Germans as well. It happened because Irish grew only one variety of potato called 'Irish Lumper', which was very badly attacked by the Blight fungus due to narrow genetic base. Similar devastation happened again in America and Mexico in corn crop in nineteen seventies. The losses of corn were catastrophic, reaching as high as 50-100% in some areas of the US. The corn crop vanished by attacked by blight disease caused by a fungus, *Bipolaris maydis* leading not only to food crisis but the prices of other commodities also increased manifolds. In fact in 1970, almost 85% of US corn fields was planted with one type of corn, called Texas cytoplasmic male sterile (Tcms) corn. Unfortunately, this type of corn proved highly susceptible in wet weather conditions to a new race of the pathogenic fungus *B. maydis* race 'T'. The actual food energy losses were considered to be greater than those caused by the potato late blight epidemic of the 1840's in Ireland. Similar large scale attack was also experienced in rice crop in India, where all rice varieties were affected. Only one wild rice variety was found resistant to the virus. The scientists identified the resistant gene, extracted it and transferred to cultivated rice varieties thus saving the rice from extinction in India.

There is worldwide hunger today not only in terms of quantity alone but also in terms of quality too. A person may be getting sufficient food to eat but it may not necessarily be balanced. The food may be lacking in terms of many essential nutrients. So, on one hand the world is required to produce sufficient food to feed everyone, on the other hand it has to be ensured that everyone gets all essential nutrients in optimum quantity. Therefore, under the SDG, the member nations are required not only to ensure that their citizens get food in terms of quantity but in quality tool.

Forests are the victims of climate change but they also hold the key to climate change and food security. According to FAO, forest foods, such as leaves, seeds, nuts, honey, fruits, mushrooms, insects, etc. have been important components of rural diets for millennia. Accordingly, forests are going to play a big role in food security and nutritional needs of the world. It is widely accepted that global human population will touch a figure of nine billion by 2050 (FAO, 2010). Accordingly, the food production will have to be increased accordingly in addition to new sources. In India, there is hardly any scope to make more land available for agriculture. The wild edible plants and their variability can be protected in forests only, which can be used by the tribal residing in and around the forests. The tribals can well protect the diversity and make use-off judiciously.

It is important to identify the wild edible plants existing in the forest that can be used as the source of food [Edible wild products that can be targeted for fighting hunger include: Bare caper (*Capparis deciduas),* Drumstick/sohanjna (*Moringa oleifera),* Bael/stone apple (*Aegle marmelos),* Kachnar /orchid tree (*Bauhinia variegata),* Christ's thorn (*Carissa carandus*), Bahera/black myrobalon (*Terminalia bellerica)*, Jandi (*Prosopis cineraria*), Seemal/Red Indian silk cotton tree (*Bombax ceiba*), Kangu/Governor's plum (*Flacourtia remontchi*), Yellow Himalayan raspberry (*Rubus ellipticus*), Kasmal/Indian berberry (*Berberris aristata*), Kaphal/box myrtle (*Myrica esculenta)*, Guchhi/ Morale (*Morchella esculenta*), Termitomyces or Termite fungus. Lasora (*Cordia dichotoma*), Pig weed (*Chenopodium album*), False amaranth (*Digera muricata*), Chulai (*Amaranthus viridus*), Bamboo (*Dendrocalamus* sp), Grey leaved saucer berry (*Cordia gharaf),* Jamun *(Syzygium cumini),* Tibetan apricot (*Prunus armeniaca),* Desert date (*Balanites aegyptica*), Himalayan rhubarb (*Rheum emodi*), Fiddle hair fern (*Diplazium esculentum*), Stinging nettle (*Urtica urens*), Nepali butter tree (*Diploknema butyracea),* Hog plum (*Spondias pinnata*), Jacquemont's hazzle nut (*(Corylus jacquemontii),* Sheep sorrel (*Oxalis* sp), Ivy gourd (*Coccinea cordifolia*), Stone flower (*Parmelia perletum*), Blue green algae (*Spirulina* sp.), Fox nut (*Eurale ferox*), etc.]. These probably are lesser utilized species and not exploited to their full potential (Gupta, 1990; Pareek and Sharma, 1993; Singh, 2001; Chander and Chauhan, 2014). International Tropical Timber Organization (ITTO) is going to launch a dedicated website to expanding the use of lesser used trees to facilitate the access to existing knowledge on species availability, wood properties, utilization and processing (www.itto.int).

Wild sources are source of genes for food quality/resistance against insect-pest/diseases. About 12.5% of the 422000 plant species documented worldwide are reported to have medicinal values, but only a few hundred are known to be in cultivation (Rao et al., 2004). The identification of such plants can be done on the basis of traditional knowledge and getting clue from the wild animals and birds eating the wild plants and their parts. The next immediate step would be to conserve the wild genes, varieties and species of edible plants, which can be used as the source of food. Creation of germplasm or gene bank for each species at state and national level would be highly appreciated. This would make the entire genetic wealth of that species available to the scientists for future scientific explorations at one place. Forests being the reservoir for this variability, the forest resource managers are morally bound to conserve this variability in the forests in its original form as preservation plots. The second step in this direction would be to make use of wild genes in breeding program and standardize propagation techniques for their multiplication. This has to be a combined effort of the foresters, the scientists and the local folks. Accordingly, more explorations have to be permitted in the forests but with word of caution as well - no wild plant should be used till it comes under cultivation.

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Biomass Today and Future Perspectives from Global Perspective to a Local Application in the ACMECS Countries

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1. Introduction

Renewable resources are a key element of a sustainable future for our planet. They play a vital role in recent political and scientific approaches to tackle the challenges of global change, which includes population dynamics as well as climate change and environmental concerns. Societal changes (higher demand for energy, changing patterns of consumption with the trend of urbanization) in combination with a growing population pose risks for the environment and ultimately the environmental services humankind relies on. Global warming is a challenge that affects the entire world's population in various ways. While people living at the sea shores suffer from rising sea levels, more extreme weather events, droughts and subsequently crop failure or reduced harvests are threatening others. The recent migration wave in Europe is caused by an ongoing conflict in Syria and other Middle-East countries, emerging due to multiple causes and complex relationships. However, one of the likely reasons is the deterioration of the country's economic conditions due to a shortage of water (Gleick, 2014) caused by a series of years with extreme temperatures and lack of precipitation, likely attributable to climate change. This is a very clear example how climatic conditions may trigger unfavorable events beyond the control of entire regions. Evidence from geological records suggests a number of rapid sudden climate shifts in the Earth's history, sometimes with devastating consequences for life. There is little doubt in the scientific community that the current climate change is largely induced by combustion of fossil fuels that fuel our economy. However, over the course of the past decades, increased demands for energy and natural resources have induced a higher awareness and consideration of alternative and regenerative resources.Evidence of a changing environment caused by anthropogenic influences soon led to a broader public debate on these issues.Scientific consensus is an important step toward public awareness and acceptance and subsequently policy-making (van der Linden *et al.,* 2015). This has led to a number of political decisions to regulate the greenhouse gas (GHG) emissions based on multinational agreements. The term "bioeconomy" gained increasing popularity within the last few years, especially since the European Commission adopted the bioeconomy strategy in February 2012 (European Commission, 2012). The COP 21 negotiations in Paris resulted in even more ambitious commitments of all nations to combat climate change. The role of forests is therein addressed several times, despite it was not well addressed in the initial drafts. Existing mechanisms, such as REDD+, were considered to be key tools to achieve the climate goals, especially in the post-2020 framework. Up to date, most investments were made in ensuring REDD+ readiness trough development of adequate monitoring, measuring, reporting, and verification (MRV) systems and national strategies, while the system became more complex and fragmented (Gupta *et al.,* 2015). However, the authors acknowledge the positive role in bridging organizations across governments and their origin (government, NGO, private etc.). It is expected that the outcome of the COP21 negotiations will be a strong signal for the REDD+ system and therefore can be of significant importance to move beyond the preparations for REDD+ readiness and for financing afforestation and forest protection projects that help to mitigate climate change.

However, there is also no doubt that mitigation alone might not be enough, but it is also necessary to consider appropriate adaptation measures, especially in agriculture and forestry. The challenge associated with the transition from the current, fossil based resource towards more renewable pathways of resource acquisition are drivers and interconnected at global scales. Biomass can play an important role as it has a number of distinct advantages over other renewable resources, e.g. wind and solar power. It can be produced almost everywhere and can be stored and converted into energy according to the demand situation. However, an ideal reliable and efficient future energy system builds on diversification and as such, biomass can play a significant role in the entire renewable energy and raw material supply system.

2. Sustainable Land Use Management is the Key for Biomass Production

The ultimate challenge for a sustainable management of natural resources is to assess and characterize the indispensable environmental (ecosystem) services that a certain site provides, in terms of both tangible and intangible items. For instance, forests represent some of the world's most sensitive but at the same time productive ecosystems and therefore it is necessary to provide a sound scientific basis in order to develop guidelines that protect forest land from degradation and over-exploitation and finally from a loss of biodiversity and the ability to provide services. The same applies for agricultural systems as soil degradation is one of the key challenges threatening a large share of the global population. In addition, degradation is linked with loss of organic carbon, usually to the atmosphere, which further increases greenhouse gas emissions and ultimately climate change. Biomass production depends on more or less fertile land. Arable land is a limited resource and soils are non-renewable in time scales relevant for human development. Year 2015 was declared the international year of the soils at the 68th UN General Assembly to highlight the important services that soil provides to all living organisms. According to World Bank data for 2012, the global share of arable land is close to 11% of the total terrestrial land area, while that of forests is 31% (World Bank, 2015). While biomass produced in agricultural systems is largely used to produce food and animal feed products, only a limited share (e.g. harvest residuals) may be used as feedstock for other purposes as it was shown long ago that residues fulfil an important function in maintaining soil health and productivity (Cassman, 1999). This suggests that large potentials for biomass as a resource for industrial feedstock materials and energy lie in forest ecosystems (both natural and plantations of fast growing woody species) globally. However, on a regional scale, agriculture can be the most significant biomass resource. Policy decisions have to ensure that on regional scales, biomass production has to be performed in a cascade approach by favoring food over feed and finally biomass for energetic/material utilization purposes.

Issues of land tenure are critical in many countries and can be a barrier in sustainable land management, even when internationally recognized mechanisms are involved in protecting forest resources (Sunderlin *et al.*, 2014). Therefore, it must be clearly defined and secured by a stable and reliable policy framework at national level that includes also measures for enforcement. All stakeholders benefit from clear land tenure rights as it ensures a secure basis of livelihood as well as new income opportunities for local communities and a secure and predictable environment for investors. Certification systems were introduced to ensure sustainable production in order to generate trust on the market and indicate sustainable practices. However, it was recently shown that even well-established multi-stakeholder initiatives, such as FSC, weakened over time as a consequence of structural failings and downward pressures on its standards initiated by market forces (Moog *et al.*, 2015). One need to be aware of these issues, and a constant re-evaluation of certification systems might be necessary in order to ensure a long-term reliability on the market.

3. Plantations of Fast Growing Woody Species

A recent study confirms that the biomass production efficiency is indeed higher in managed forest ecosystems and that management as such is the key controlling factor, and not fertility as often perceived (Campioli *et al.*, 2015). Plantations of fast growing woody species can increase site productivity and therefore, more biomass can be produced per unit of area as compared to natural forest ecosystems. Moreover, costs can be reduced as stem densities and spacing may be arranged according to the species characteristics and harvesting methods. The selection of appropriate clones ensures optimal site suitability and minimum variability inquality and quantity of individual trees. Temporary or permanent intercropping may reduce the need for weeding in the stand initiation phase and generate additional income while improving biodiversity. However, intercropping cannot be compared to natural stand conditions and it is not always possible, leading to large plantations of uniform age, species and in case of clones often limited genetic variability. The consequences can be severe in terms of pests and diseases and they can become prominent even in late stages before the anticipated harvesting, which imposes high investment risks. The recent emergence of *Acacia mangium* as one of the key species for short rotation crops in Southeast Asia and specifically in Indonesia for instance, led to the propagation of a number of fungal diseases causing significant mortality (Tarigan *et al.*, 2011) or decreasing yields limiting the number of economically feasible rotations (Francis *et al.*, 2014). During the 3rd ACMECS bioenergy workshop (KAPI, 2015) held in Thailand in 2015, it was therefore concluded that efforts in plantation management should not focus on yield maximization but rather stand optimization which includes plantation health, resistance against diseases and climatic extreme events as well as allowing biodiversity. In general it was recognized that reforestation efforts in tropical countries can have positive effects in terms of climate change mitigation and adaptation (Locatelli *et al.*, 2015), as forest products sequester carbon and bioenergy reduces the carbon footprint. Adaptation can be achieved by reducing the vulnerability of ecosystems and communities to extreme climate conditions.

4. Sustainable Biomass- The Way To Go

Responsible resources management requires a solid scientific basis in order to understand the complex processes and relationships between species and the environment and a well-developed toolbox to practically implement suggestions in daily business operations. Elements of this toolbox might be the formulation of guidelines, best management practices, decision support systems and capacity building (education, exchange of expertise). Existing natural forests need to be protected and conserved to sustain species and habitat diversity. The current epoch, the Anthropocene, is characterized by one of the largest rates of species losses our planet has ever faced, and this is due to human activities. Therefore, new plantations have to be developed on existing non-forest land and both, the biomass production and also the resource use efficiency need to be improved to ensure a safe livelihoodfor further generations. Whenever biomass development is discussed, land availability is an immediate issue. Biomass, a renewable commodity, is produced on soil which represents a non-renewable resource in human timescales.The focus of the development of new plantations should consequently be set on available and in specific degraded land, as certain crops have the potential to restore such sites over a number of rotations (e.g. nitrogen fixing species). It is clear that from an economical point of view, this might not be the most profitable short-term investment, but plantation business should be directed at longer time horizons. Land use change that improves land as in this example or protects habitats e.g. watersheds from over fertilization (buffer belt between water streams and agricultural crops), or alleys that protect agricultural land from wind erosion are examples for favorable practice and should be focused. In order to achieve this ambitious but not impossible aim to consider these issues, we need a strong political commitment towards a bio-economy, international collaboration and a solid scientific basis that is able to provide solutions in all aspects of energy and raw material transition from fossil to renewable resources. A bio-based economy offers a range of co-benefits to the climate change mitigation potential, such as energy and raw material supply security, lower environmental pollution if efficient systems are being used, job opportunities and income in rural areas which is of particular interest in the light of a global urbanization trend.

Fig. 1: Intercropping demonstration project of cassava (Manihot esculenta) in an Acacia plantation in Thailand. The plantation is accepted by the local community as they are allowed to manage cassava on government land. In return the governmental institution managing the SRF plantation benefits from intercrop management as no weeding is required and any excess fertilizer may be taken up by the fast growing Acacia and enhances growth.

There is a broad consensus that the development of bioenergy can have positive impacts if sustainability is considered. The technologies for conversion of biomass to energy are well developed and there is a significant amount of experience available on a global scale. At the same time current systems are constantly being evaluated and further improved. Since the provision of energy is the largest contributor of GHG emissions, bioenergy can help to mitigate climate change by reducing the amount of fossil fuels used. This can be of major concern if carbon trading schemes are to be enforced and offers additional sources of national income. Moreover, domestic production of energy contributes to energy security as a consequence of diversification and creates jobs and income, usually in rural areas. This can have an important socioeconomic impact in regard to the above mentioned trend of urbanization. In addition, regions of higher biomass production potentials may be able to export biomass (e.g. woodchips or pellets) to domestic, regional or even international markets.

Scientific research is needed along the entire supply chain to further improve processes in terms of productivity and efficiency as well as sustainability (best management practices). This starts at the production of biomass (soils and climate, species selection and development of new clones that are resistant to environmental influences and increase the productivity, innovative silvicultural and agricultural methods or a combination of both, that allow efficient land use) includes the conversion technologies (efficient conversion technologies and new pathways of biomass utilization, e.g. bioplastics and biodegradable materials, reduction of production costs, development of solutions across scales, e.g. biomass boilers from industrial to household scale) and finally research in the field of efficient material and energy use (cascade utilization, minimizing losses, intelligent systems etc.).

5. The Role of the Sustainable Forest Biomass Network (SFBN) Task Force

There are worldwide efforts in developing further biomass resources, in particular in SE Asia. One of the reasons is the recent introduction of a feed-in tariff in Japan, as a consequence of the Fukushima incident and the subsequent temporal halt of all nuclear power plants. This led to a rapid development of biomass power plants, while biomass supplies have already nearly reached the maximum (economically viable) capacity (Yokoyama and Matsumura, 2015). At the same time, domestic consumption of biomass for various purposes is increasing and biomass plantations are therefore increasingly promoted. In 2013, a research initiative led by the well-established Kasetsart University (Bangkok, Thailand) aimed to install a regional bioenergy network to foster collaboration within the ACMECS countries Cambodia, Lao PDR, Myanmar, Thailand and Vietnam (KAPI, 2015). The focus here is the development of national harmonized bioenergy strategies while being able to serve domestic and international markets with biomass produced from plantations. It was early mentioned that sustainability is the key for a development that ensures livelihoods and income opportunities for local communities, protects soils and ensures long-term economic viability. The International Union of Forest Research Organizations (IUFRO) SFBN Task Forcerepresents a global network of forest biomass experts (IUFRO, 2015), bringing together some of the world's leading experts in forest biomass issues. It has the capacity to provide state-of the art knowledge and expertise across scientific disciplines including natural sciences as well as social sciences and policy. One of its main aims is to develop a research agenda and a toolbox for implementing research findings into a practical policy framework in Southeast Asia in the region of the ACMECS countries to ensure sustainability. Experts of this Task-Force are situated in key positions in global forest research and can therefore provide valuable inputs from their research background and from practical experience obtained from similar efforts in other countries. Research efforts will be coordinated for a sustainable production of energy in the member countries, which will provide policy implications on energy production and consumption and measures taken in order to ensure sustainability. This includes also potential consequences of increased biomass utilization (especially burning) on air quality, which will be addressed in cooperation with a dedicated group of IUFRO experts on air pollution. Results can also be used to support the REDD+ policy process that has gained momentum at the COP21 meetings in Paris. Responsible government officials were included since the beginning of this process to ensure awareness and recognition during the development of the regional bioenergy strategy. In addition, the implementation of certification schemes for sustainable biomass production may be discussed at some point. The lead mission of the SFBN TF is to develop sustainable biomass resources that provide a multitude of ecological services and raw materials without degrading soils. The livelihood of rural people should be improved by creating income opportunities, which do not pose new risks (e.g. air pollution, etc.).

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Agriculture and Industrial Agroforestry – a Model for Food, Fuel and Wood Security

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1. Introduction

Global warming, on the one hand, and rapidland degradation due the growth of people-land ratio on the other, has created a compelling need to explore multiple land-use practises to maintain social, economic and ecological sustainability in India. One of the more promising methods to optimise land-use and meet the multiple needs of rural households is generally known agroforestry (AF)- growing trees in combination with crops or animals. AF is most commonly associated with small farmers who promote it with the purpose of satisfying family or local needs. It has also been promoted by governments, but with mixed success.

2. Industrial Agroforestry

One form of AF is relatively recent but highly promising in terms of scale and sustainability. These are AF plantations supported by wood-based industry to create a secure and sustainable raw material base for their operations by promoting the production of wood with inter-crops on lands hitherto used only for agriculture. Since these plantations are promoted with the objective of strengthening supply chains, it is expected that, if implemented successfully, they can potentially be on an industrial scale.

By providing productive and multiple land-use options, AF can be a vital intervention in a country like India where land-ownership is overwhelmingly small. It not only hedges farmers significantly from seasonal risks, but the wood harvest income provides farmers with a lump-sum amount for making major investments in the farm. Simultaneously, it emerges as a viable option for businesses interested in wood but unable to promote large-scale captive plantations due to various laws of the land. A partnership between the company and small-holders to produce wood, food and fuel needed by both partners can emerge as a winning model. It also presents a unique opportunity for companies to promote sustainable livelihoods for resource poor households even while ensuring a sustainable supply of raw material for industrial production.

3. ITC's Agroforestry Programme

ITC promotes pulp-wood plantations in districts neighbouring its pulp mill in Khammam district of Telangana state with species such as eucalyptus, subabul, casuarina and bamboo. The programme commenced with multi-location trials in 1992 followed by the Farm Forestry component in 1998-99. Converting an idle asset into one that generates significant incomes made this an attractive proposition for farmers. The intervention also enabled ITC to fine-tune the model before taking it to economically weaker households through Social Forestry in 2001-02, targeting poor, primarily SC/ST households, providing them with the means to turn their underperforming lands into a sustainable livelihood opportunity and an income-generating asset.

Even though the programme successfully promoted over 23,000 ha in 9 years, block plantations were still considered risky by small holders. There was also compelling evidence of growing pressure on agricultural land due to increasing population and competition from urbanization and industrialisation. What was clearly required was an intervention in which trees and field crops production would complement rather than compete for available land. Consequently, ITC launched the AF programme in 2010-11, which enabled pulpwood species and agricultural crops to be grown together throughout the 4-year maturation cycle of Bhadrachalam clonal stock. Using a paired row design with wider spacing, (see Annexure A) the model was standardizedin collaboration with research organisations.

- Two rows of trees planted at a spacing of 1.5 m between rows and 1 m from tree to tree. After two rows of trees, 8.5 m space is available for field crops.
- Tree rows are planted in the East-West direction to further minimise shade effect.
- Land availability is 75% for field crops and 25% for the tree crop.

AF plantations now 24,243 hectares area comprising 46 million trees, clearly making it one of the largest efforts by any private organisation. Implemented in 12 districts of Andhra Pradesh, Telangana and Karnataka, the coverage and spread of the programme is sufficiently large to enable conclusions generalised for the model's implementationelse where.

4. Major Findings

Data is collected for each season in order to capture major impacts, outcomes and emerging trends. In addition, three independent studies were conducted by reputed organisations to assess the programme in terms of its original objectives and suggest improvements. A few of the more significant findings discussed below are based on these sources.

From the evidence available (see Annexure B), AF is preferred by small and marginal farmers compared to large farmers., This was supported by responses gathered during FDGs which revealed that bigger farmers opt for less labour intensive crops (like pulp-wood) and they can also afford to block part of their land holding for trees and await incomes by the fourth year. Whereas it was imperative for small-holders to optimise land-use in order to maximise annual incomes. Diversifying into tree crops also emerged as an important risk mitigation strategy for them.

AF did not constrain farmers from the choice of their intercrop; all field crops cultivated customarily were found in the AF fields (see Annexure C).Commercial crops were the most preferred crops with cotton emerging as the most dominant in rainfed fields within this category.

Economic analysis of how AF performed vis-à-vis pure block plantation of trees and only field cropsclearly shows AF as the clear front-runner in terms of earnings per acre (see Annexure). Its 25% higher than pure block plantation and 18% higher than field crops.

The model a highly attractive proposition for resource starved small and marginal farmers by the lump-sum earnings every four years which can be invested in productive assets or towards improving the HDI of households. Some of the major investments made by households were in the areas of agricultural improvement, irrigation, household assets, health and education, all of which are critical for setting in motion a virtuous cycle of growth (see Annexure E).

Other benefits, which have yet to be quantified, but are attested for by farmers include:

- Takes pressure off from the remaining natural forests for wood supply
- Brings in diversification on farm lands and improves soil health
- A useful model for providing wood and food security for nation and stable and better incomes for farmers
- Once planted, the same set of trees are harvested for a total of four times, giving returns to farmers for 16 years

5. Way-forward

The AF model reduced the land available for field crop by about 20-25%. The challenge is to achieve the gross yields equal to that obtained if the entire land was under agriculture by increasing productivity per hectare.Steps are now being taken to achieve higher productivity with less input usagethrough sustainable agricultural practices. Initiatives aimed at improving soil health and soil moisture are being taken up with farmers' participation. In addition, an exclusive programme has beenplanned for sustainable cotton crop productivity enhancement by adopting standard cultivation practices prescribed by Better Cotton Initiative promoted by WWF India.

6. Conclusion

ITC's agroforestry programme converges business and social goals with multi-dimensional benefits: small-holders are enabled to realise the full potential of their land by growing commercial pulpwood plantations that provide significant incomes, ITC benefits from a cost-effective, sustainable raw material base for its Paper & Paperboards business, while the large-scale green cover creates significant carbon sinks and positively impacts the environment.

The AF model therefore has the potential to bring down pressure on existing forests and, simultaneously, insulate farmers to large extent from extreme climate episodes. Thus, the intervention can contribute to meeting the needs of food, wood and energy through crop intensification within available land. At the same time, Industrial AF can make large-scale reforestation much more practical in economic terms. Such models can be replicated in different geographies and with other trees species based on enabling research.

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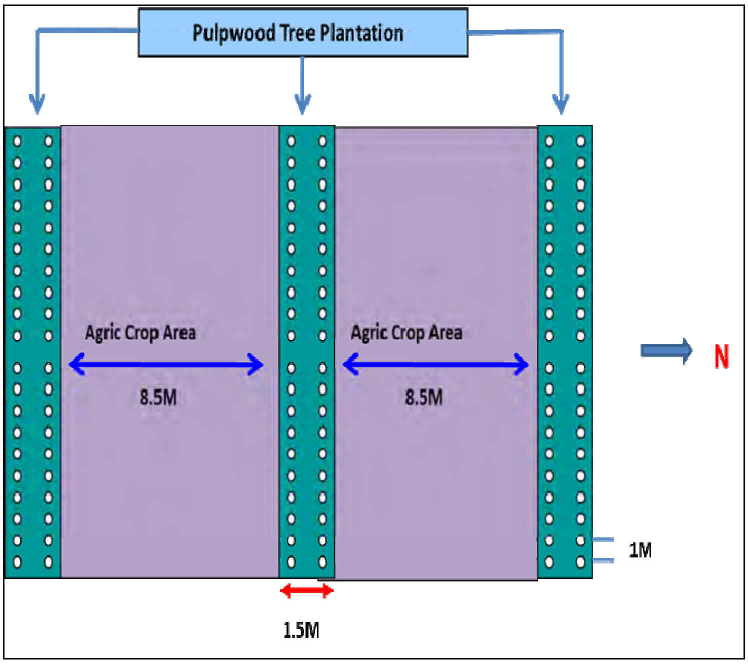
Annexure A. Agroforestry model plot



Annexure B. Distribution of households practising agroforestry by size of land holdings (%)

District	Marginal	Small	Large
East Godavari	28%	34%	38%
West Godavari	3%	43%	55%
Prakasam	22%	47%	30%
Khammam	26%	52%	21%
Warangal	17%	45%	38%
Total	22%	48%	30%

Source: Wassan (2015a)

Annexure C. Distribution of agroforestry area under different crops (%)

Crop	% of total area
Other non-food crops	
Chillies	4%
Cotton	50%
Tobacco	7%
Others	1%
Total of "Other non-food crops"	61%
Pulses	
Cowpea	8%
Green gram	5%
Others	6%
Total of "Pulses"	19%
Oil seeds	
Castor	2%
Groundnut	4%
Sesame	3%
Total of "Oil seeds"	10%
Cereals	8%
Vegetables	2%

Source: Wassan (2015a)

Annexure D. Earning per acre by type of cultivation

	Block plantations	Agroforestry	Only agriculture
Total earnings (Rs)	7,346,900	18,861,367	1,202,210
Total area (acres)	349	715	54
Earnings per acre (Rs)	21,051	26,370	22,263

Source: Indian Agribusiness Systems Private Limited (2015)

Annexure E. Investments made by Households from Wood Harvest Incomes

Investments	% of households
Improving housing facility	43%
Land development and irrigation infrastructure	61%
Agriculture and livestock	57%
Accessories	37%
Recreation/ consumption	66%
Gold	8%
Education	38%
Health	56%
Loan re-payment	6%
Savings	8%
Other	62%

Livestock Resource Management: Recent Trends, Future Prospects

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1. Introduction

Livestock farming systems inhabit about 30 per cent of the world's terrestrial area and is a significant global asset with a value of at least USD1.4 trillion. Livestock farming and associated market chains employ atleast 1.3 billion people worldwide and contributes directly to the livelihoods and food security of 600 million poor smallholder farmers in the developing world. Livestock products contribute 17% to kilocalorie consumption and 33% to protein consumption globally. However, there is a long gap in terms of energy and protein consumption from livestock products between developing and developed countries. In developing countries, livestock is one of the fastest growing agricultural subsectors. Its contribution to the total agricultural GDP is already 33% and is showing signs of further increase. This growth is a consequence of rapidly increasing demand for livestock products. Increase demand for livestock products is multifactorial and includes population growth, urbanization and increasing incomes in developing countries. Much of this growth was concentrated in countries that experienced rapid economic growth, particularly in East Asia.

Livestock is an important sub-sector of the agriculture of Indian economy, supporting livelihood and food security for rural households, supporting agriculture in the form of critical inputs, supplementing incomes, offering employment opportunities, and finally being a dependable "bank on hooves" in times of need. India is blessed with a rich biodiversity of livestock resources evolved over a long time in varying agro-climatic conditions and production systems. They provide milk, meat, egg, fibre, wool, leather, draught power and organic fertilizers to agriculture and employment to rural masses as well as many stakeholders engaged in management and improvement of these resources.

2. Livestock Resources

Analysis of global livestock population indicates an increase in the population of major five livestock species *i.e.* cattle, sheep, chickens, goats and pigs (FAOSTAT 2014). During the period 2005 to 2014, chicken population showed highest increase (23.8%), followed by goat (14%), pig (11%), sheep (8.4%) and cattle (6.8%). The world's cattle population amounted to about 1.39 billion in 2005 has now reached almost1.5 billion in 2014. India tops the list of country with highest cattle population followed by Brazil and China. Asia accounts for one-third, Latin America accounts for 27%, Africa for 17%, Europe and the Caucasus for 9 percent, North America for 7%, the Near and Middle East for 4 percent and the Southwest Pacific for 3% of the total cattle population. The pattern of regional distribution has not changed greatly since 2005. Asia and Africa have increased their shares of the world total, while the shares of Latin America and the Caribbean, North America, and Europe and the Caucasus have declined.

The world's sheep population reached almost1.2 billion in 2014. China has the largest sheep inventory with 16% of world's sheep population. Asia accounts for 37%, Africa for 22%, Europe and the Caucasus for 14%, the Near and Middle East for 10, the Southwest Pacific for 9%, Latin America and the Caribbean for 7% and North America for 1 of the total sheep population. Regional distribution of sheep population has taken a dramatic change since 2005 in that there has been a sharp decline (25% in absolute in terms) in the sheep population of Southwest Pacific region that has accounted for share of the total falling by 4%, globally. In contrast, shares of Africa and Asia has increased in world sheep population with Africa's sheep population having risen by 19 percent in absolute terms.

The world's goat population reached approximately 1billion in 2014. Goats are more popular and are widely distributed in developing regions than they can be found in developed regions. Asia shares more than half (56%) of world's goat population with highest numbers in China and India. Africa has shown a major increase in goat population and with the Near and Middle East account for the vast majority (7%) of the world's goats. There are also significant populations in Latin America and the Caribbean (3%) and in Europe and the Caucasus (3%). The world's pig population reached near1 billion in 2014. Asia accounts for 60% of the world total, with China alone accounting for 49% of world's pig population. Europe and the Caucasus accounts for 19%, Latin America and the Caribbean for 9%, North America for 8% and Africa for 4%. From a relatively low starting point, Africa's pig population has increased by 37% since 2005.

Owing to vast demand for poultry meat, the world's chicken population has increased and reached morethan 21.3 billion in 2014. Asia, with largest poultry population in China, has more than half the total (53%) of world's poultry. Latin America and the Caribbean accounts for 15%, of the total; Europe and the Caucasus for 11%; North America for 10%; Africa for 7 and the Near and Middle East for 3%. Since 2005, the chicken population has increased in all regions except North America. Asia has increased its share of the total world population, while the shares of Europe and the Caucasus and North America have declined.

India has vast resource of livestock and poultry, with breeds of almost all the mammalian and avian species domesticated in Asia and itharbours a good number of indigenous breeds of livestock and poultry. Till 2012, National Bureau of Animal Genetic Resources (NBAGR), Karnal has registered 37 breeds of cattle, 13breeds of buffalo, 23 breeds of goat, 39 breeds of sheep, 6 breeds of horses and ponies, 8 breeds of camel, 15 chicken breeds, 2 pig breeds and one donkey breed in the country. As per recent statistics of FAO (FAOSTAT 2014), there are about 297 million bovines, 63 million sheep, 135.2 million goats and about 10 million pigs in the country. The species wise population of animals in Livestock and Poultry population during the last three Censuses is given in table 1. A comparative analysis for last decade (2005-2014) indicates that cattle population has registered a negative growth rate (-2.6%), while buffalo population have grown (8.3%), making total bovid population almost static over the period. Most impressive growth has been in the poultry (36%), with a driver for strong demand for poultry meat grew fastest. Contrary to world's trend, trend in both pig and sheep population have declined (-18.48 and 5 %, respectively).

3. Livestock Production System

There are three broad types of poor livestock producers: pastoralists and herders, smallholders and breeders, and urban dwellers. However, these are not distinct classes, but segments of a continuum that changes and reshapes according to prevailing agro-ecological conditions and related livelihood systems.

Pastoral herders. Pastoral farmers are also known as graziers and could be of both nomadic and sedentary types. Sedentary pastoral farming is common in Argentina, Brazil, Australia, UK, Ireland, New Zealand and Canada. Livelihoods of the mobile pastoralists are characterised by a critical dependence on a vulnerable natural resource base and extreme marginal conditions, which hamper their access to roads, markets and services. Patterns of mobility vary from pure nomadism (opportunistic, no fixed base), to various forms of transhumance (set migratory routes on seasonal basis)to levels of agro-pastoralism (attachment to crop production).

Smallholding livestock producers: They are farmers who depend greatly upon livestock for their livelihoods. They are often involved in small-scale farming systems where livestock plays a central role as a source of food, income and critical inputs for agricultural production (such as draught power and fertilising manure). In densely populated areas where land is a limiting factor synergies between the crop and the livestock sectors are increasingly sought by poor households to increase overall productivity and income through labour investments.

Peri-urban livestock-keepers: They are often either the better-off or the poorest groups or households from the previous two classes, who live in the fringes of urbanare as in order to better access labour, income and services to cope with their limited access to productive resources. Migration of these groups to peri-urban environments is caused by natural as well as socio-political factors such asdrought, epidemics, stratification and conflict.

In India, different production systems are in existence in different regions of the country. These production systems are characterised by specific socioeconomic structure of the society including caste, religion and social status. Many are driven by various cological considerations. The migratory system of livestock raising for sheep, goats and cattle is an age-old tradition. For example, Gujjar and Bakarwal communities, who rear buffalo and goats are nomadic tribes based in Pir Panjal and Himalayan mountain of India. Their system of keeping livestock involves movement across states and countries. However, livestock resources in India are undergoing unprecedented changes due to introduction of new technologies. Major changes in livestock production have occurred during the past few decades due to introduction of several new technologies, e.g. control of diseases like rinder pest, artificial insemination, embryo transfer, and associated technologies (genomics, cloning and trans-genesis). Nonetheless, smallholding livestock producers still contributes (>50%) to the livestock production system in the country.

4. Livestock Sector Trends

Livestock sector is expanding, intensifying and scaling-up, as a result of drivers from both the demand and the supply sides. Demand side drivers were particularly strong in developing countries, where consumption of animal source food grew fastest. Consumption of meat, milk and eggs rose steadily in a number of developing countries as a result of growth in the human population and rising purchasing power. Growth rates were highest for poultry meat and pork, averaging 4.7% and 2.6% per year, respectively, between 1981 and 2007, with consumption growth in China and India making an important contribution. Projections suggest that global meat and milk consumption will continue increasing until 2030 and beyond, although growth rates are expected to be slower than those in the past. Global growth of meat and milk consumption is projected to be 1.6 and 1.3% per year, respectively, in the 2007–2030 period. There will be regional differences in these trends, with growth coming mainly from developing countries. In South Asia, meat consumption is predicted to grow faster than before, predominantly through increased consumption of chicken meat in India.

The poultry sector has been the most buoyant part of the livestock sector in the past few decades and this is likely to continue. Per capita demand for poultry meat is projected to increase by 271% in South Asia, 116 percent in Eastern Europe and Central Asia, 97% in the Middle East and North Africa and 91 percent in East Asia and the Pacific during the 2000 to 2030 period. Evolution of per capita demand for poultry in India is striking, with a predicted increase of 577% between 2000 and 2030. Milk consumption has grown more slowly than meat consumption, except in South Asia. Over the period 1991 to 2007, global milk consumption grew by 1.6% per year, mainly due to a surge in demand for milk in China and India. In India, per capita demand for milk is expected to increase by 57% between 2007 and 2030.

5. The Indian Scenario

Livestock production and agriculture are intrinsically linked in India, each being dependent on the other, and both crucial for overall food security. According to estimates of the Central Statistics Office (CSO), the Gross Value Added from livestock sector at current prices was about Rs. 4,06,035 crores during 2013-14, which is about 21.58% of the Gross Value Added from total agriculture. The livestock Sector is contributing about 3.88% of total Gross Value added of the Country at current prices and about 3.92% at constant prices (2011-12). The Livestock Sector was expanded by 5.5% during 2013-14 against the total agriculture.

Milk production: India continues to be the largest producer of milk in world. Several measures have been initiated by the Government to increase the productivity of livestock, which has resulted in increasing the milk production significantly from the level of 102.6 million tonnes at the end of the Tenth Plan (2006-07) to 127.9 million tonnes at the end of the Eleventh Plan (2011-12). Milk production during 2012-13 and 2013-14 is 132.4 million tonnes and 137.7 million tonnes respectively with an annual growth rate of 3.54% and 3.97% respectively. The per capita availability of milk is around 307 grams per day in 2013-14.

Egg production: Poultry production in India has taken a quantum leap in the last four decades, emerging from an unscientific farming practice to commercial production system with state-of-the-art technological interventions. Egg production at the end of the Tenth Plan (2006- 07) was 50.66 billion numbers as compared to 66.45 billion at the end of the Eleventh Plan (2011-12). Currently the total Poultry population in our country is 729.21 million numbers (as per 19th Livestock Census) and egg production is around 74.75 billion numbers during 2013- 14. The current per capita availability (2013-14) of egg is around 61 eggs per year. The poultry meat production is estimated to be 2.69 million metric tonnes. Exports of poultry products are currently at around R566 crore in 2013-14 as per Agricultural and Processed Food Products Export Development Authority (APEDA).

Wool production: Wool production declined marginally at the end of Eleventh Five Year Plan (2011-12) to 44.7 million kg from 45.1 million kg in the end of Tenth Five Year Plan (2006- 07). Wool production in the beginning of Twelfth Plan (2012-13) is 46.1 million Kgs which has been further increased to 47.9 million Kgs in 2013-14. The Annual growth rate for production of wool is 4.03% in 2013-14.

Meat production: The Meat production has registered a healthy growth from 2.3 million tonnes at the end of Tenth Five Year Plan (2006- 07) to 5.5 million tonnes at the end of the Eleventh Five Year Plan (2011-12). Meat production in the beginning of Twelfth Plan (2012-13) was 5.9 million tonnes which has been further increased to 6.2 million tonnes in 2013-14.

6. Livestock Development: Needs and Challenges

The major global challenge for the twenty-first century is to sustainably feed a growing population that is expected to reach 9 billion by 2050: the so-called “2050 challenge to our global food system”. Further increase in production is needed. At the same time, the ecological footprint of food production needs to be reduced and the quantity and quality of natural resources, including biodiversity, need to be sustained. There is a need to reduce waste, increase efficiency in the use of water, feed and energy and reduce greenhouse gas emissions and the pollution of land, air and water. Economic, social and environmental trends in the livestock sector continue to pose many challenges to the sustainable management of livestock resources. Rapid growth in demand for animal products has beena major driver of change in the livestock sector in recent decades, particularly in some develop in gregions, and the associated changes in livestock production systems have had a major effecton livestock resource management and often posed a threat to diversity. Traditional production systems that harbour diverse genetic resources have been marginalized and a narrow range of international trans-boundary breeds have become more widely used. Economic and market-related factors are frequently highlighted by stakeholders as threats to livestock resources. Shifts in market demand or increasing competition may mean that particular breeds can no longer be raised profitably. Shifts of this kind are part of social and economic change, and there are always likely to be some breeds that are at risk of falling out of use and declining towards extinction. However, there may be measures that can be taken to reduce economic threats, either by “valorizing” individual at-risk breeds via marketing initiatives, genetic improvement or the identification of new roles, or by more general policy measures such as eliminating support measures that create favourable economic conditions for breed replacement. Climate change is placing increasing pressure on the livestock sector, especially on production systems that depend heavily on the state of the local ecosystems. Livestock are recognized as contributors to climate change, but also as an entry point for climate change mitigation. Grazing systems in arid and semi-arid areas are likely to be particularly severely affected, but mixed farming systems will also need to adapt. Given the major roles of small-scale livestock keepers and pastoralists in maintaining livestock resource diversity, factors that undermine the sustainability of smallholder and pastoralist production systems constitute significant threats to livestock resources. These threats may include both market-related factors (e.g. competition from large-scale producers or exclusion from markets because of difficulties in meeting the specific requirements of retailers and consumers) and problems related to the degradation of (or lack of access to) natural resources. Balancing different objectives is unlikely to be easy. However, there may be scope for synergies in efforts to promote livestock resource management, livelihood and environmental objectives. Effective management of gene flow and effective use of imported genetics involve all the main elements of livestock resource management: characterization of breeds and production environments to ensure that they are well matched; well-planned breeding strategies; monitoring of outcomes in terms of productivity and genetic diversity; measures to promote the sustainable use and conservation of breeds that may be put at risk of extinction; and appropriate policies and legal frameworks.

Maintenance and management of this valuable vast diversity has become a major challenge for India, as most of these breeds are low producers, facing genetic dilution due to many factors like increasing mechanization of agriculture, over emphasis on some high producing breeds, market forces and many unforeseen factors in different parts of the country. Therefore, there is a need for every country to develop their plans for conservation and sustainable utilization of vastly distributed farms animal breeds by utilizing available technologies for their management. Further, shrinkage in grazing land and unavailability of breeding males of known genetic merit are resulting into dilution and depletion of animal genetic resources. Indian Council of Agricultural Research has constituted a National Advisory Board to develop the guidelines for Management of Genetic Resources which also includes a chapter on guidelines for management of Animal Genetic Resources. Likewise, India is in process to develop National Plan of Action for animal genetic resources which may be useful for the state animal husbandry agencies for developing strategies and programmes for management of animal genetic resources in their respective states. The National Livestock Mission (NLM) has commenced from 2014-15. The Mission is designed to cover all the activities required to ensure quantitative and qualitative improvement in livestock production systems and capacity building of all stakeholders. The Mission will cover everything germane to improvement of livestock productivity and support projects and initiatives required for that purpose subject. This Mission is formulated with the objective of sustainable development of livestock sector, focusing on improving availability of quality feed and fodder. NLM has 4 submissions *i.e.*: The Sub-Mission on Fodder and Feed Development to address the problems of scarcity of animal feed resources, in order to give a push to the livestock sector making it a competitive enterprise for India, and also to harness its export potential. Under Sub-Mission on Livestock Development, there are provisions for productivity enhancement, entrepreneurship development and employment generation, strengthening of infrastructure of state farms with respect to modernization, automation and biosecurity, conservation of threatened breeds, minor livestock development, rural slaughter houses, fallen animals and livestock insurance. Sub-Mission on Pig Development is provided in North-Eastern Region for all round development of piggery in the region. Sub-Mission on Skill Development, Technology Transfer and Extension is aimed at boosting the extension machinery at field level for livestock activities. The emergence of new technologies and practices require linkages between stakeholders and this sub-mission will enable a wider outreach to the farmers.

7. Conclusion

It is thought that humankind's association with domesticated animals goes back to around 10000BC, a history just about as long as our association with domesticated plants. The global trend indicates a necessity driven flux of livestock sector that may well undergo radical change in the future. However, the key fact remains that contribution of small and marginal farmers is still critical to the wellbeing of millions, possibly billions, of people in the country. Government policies, strategic and applied research have made significant and proactive development for them, nevertheless, emphasis is amply worthy for extension personnel for instigating the message of skill development and technology transfer to the farmers.

Climate Change and Its Impacts on Fisheries

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1. Introduction

Climate change is a change in the statistical distribution of weather patterns which lasts for an extended period of time (ranging from decades to millions of years). It has unequivocally been considered as one of the most serious threats to sustainable development with possible adverse impacts on natural resources, thereby affecting food security, human health and economic activities. Factors that can shape climate include variations in solar radiation, variations in the earth's orbit, mountain-building, continental drift, changes in greenhouse gas concentrations and certain anthropogenic activities. The most notable and significant changes associated with climate change are the gradual rise of global mean temperatures and a gradual increase in atmospheric greenhouse gases.

2. Impacts of Climate Change

Intergovernmental Panel on Climate Change (IPCC, 2014) reported that global surface temperature increased about 0.74±0.18°C (1.33±0.32°F) during the past 100 years and global surface temperature will probably rise a further 1.1 to 6.4°C (2.0 to 11.5°F) during the end of 21st century. The year 2014 was declared as the warmest year across global land and ocean surfaces since 1880. Most models on global climate change indicate that snow pack is likely to decline on many mountain ranges in the west, which would bring adverse impact on fish populations, hydropower and water availability for agricultural, industrial and residential use. Further, partial loss of ice sheets on polar land could imply meters of sea level rise, which further bring major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands. Such changes are projected to occur over millennial time scales, but more rapid sea level rise on century time scales cannot be excluded. Current models of climate change predict a rise in sea surface temperatures of between 2°C and 5°C by the year 2100 (IPCC, 2001; Done *et al.*, 2003). The average sea-level rise over the past two decades has been recorded 3.2 millimeters per year. Levels of CO_2 in the atmosphere climbed to 396 parts per million in 2013 which is 142% higher than the levels in the atmosphere in the 1800s. Climate change will have impact on global biodiversity. Alien species would expand into regions in which they previously could not survive and reproduce. Climate change has been implicated in mass mortalities of many species.

In India, studies conducted on impact of climate change reported that sub surface temperature increased by 0.2-0.3°C along the Indian coast from 1961 to 2005. Similar pattern of warming was evident in the Bay of Bengal too also predicted that the annual average sea surface temperature in the Indian seas would increase by 2 to 3.5°C by 2099 (Vivekanand *et al.*, 2009 a, b). The global warming resulted in increase in sub surface temperature of the Arabian sea, which is associated with increase in the development of most intense cyclones. Concurrent with these events, there are progressively warmers winters, decreased monsoon rainfall and an increase in the phytoplankton biomass. According to, the historic sea level rise for Cochin is estimated to have been 2 cm in the last one century and it is projected that it may rise @5cm $year^{-1}$ in the coming decades. Considering this, it is possible that the sea level may rise by 25-30 cm in 50 years (Das and Radhakrishna, 1993; Dinesh Kumar 2000; Emery and Aubrey,1989).

3. Status of Fisheries

Fish is an important part of the human diet and provides about 20% of animal protein intake, globally. On one hand it serves as a health food for the affluent world owing to the fish oils rich in polyunsaturated fatty acids (PUFAs), on the other hand fish is a health food owing to its proteins, oils, vitamins and minerals and the benefits associated with the consumption of small indigenous fishes for the people in the other extreme of the nutrition scale. Fisheries and aquaculture contribute significantly to food security and livelihoods. Globally, 158 million tonnes (MT) fish is produced both from capture (91.3 MT) and culture (66.6 MT) resources and out of this 136.2 MT is used for human consumption (FAO, 2014). Global fish production has grown steadily with food fish supply increasing at an average annual rate of 3.2 percent, outpacing world population growth at 1.6% with an apparent per capita fish consumption of 19.2 kg. Fish provides essential nutrition for 3 billion people and at least 50% of animal protein and minerals to 400 million people from the poorest countries. Over 500 million people in developing countries depend, directly or indirectly, on fisheries and aquaculture for their livelihoods.

In India too fisheries sector occupies a very important place in the socio-economic development of the country. It has been recognized as a powerful income and employment generator as it stimulates growth of a number of subsidiary industries, and is a source of cheap and nutritious food besides being a foreign exchange earner. Most importantly, it is the source of livelihood for a large section of economically backward population of the country. The fisheries resources of the country comprises both marine [Exclusive Economic Zone (EEZ) of 2.02 million km^2, a continental shelf area of 530000 km^2 and a coast line of 8118 km] and Inland (45000 km of rivers, 3.0 million ha of reservoirs) resources. India is the third largest producer of Inland fish (after China and Bangladesh) and second largest producer of farmed fish (after China) in the world, contributing to 5.68% of global fish production. The total fish production during 2013-14 (provisional) is at 9.58 million metric tonnes with a contribution of 6.14 million metric tonnes from inland sector and 3.44 million metric tonnes from marine sector. The historical scenario of Indian fisheries reveals a paradigm shift from marine dominated fisheries to Inland dominated fisheries. In 1990-91 contribution from marine sector was 60% which declined to 35.90% in 2013-14. Further, within an Inland sector, there is a shift from capture fisheries to aquaculture. Freshwater aquaculture with a share of 34% in Inland fisheries in mid-eighties, has increased to about 80% in recent years. During 2013-14 the volume of fish and fish products exported was 983756 tonnes worth Rs.30213 crores. The fishery sector accounts for 0.83 percent of total GDP and 4.75% of the Agriculture sector's GDP at current price for the year 2012-13 (Govt. of India, 2014). In India, fish is consumed by 56% population (@ 14.44 kg capita^{-1} yr^{-1}) and provide livelihood as well as employment to over 14 million people (75% engaged in Inland fisheries and 25% in marine fisheries).

4. Impacts of Climate Change on Fisheries

Key areas related to climate change having impact of fisheries and aquaculture include rise in sea level and sea temperature, sea surface salinity (acidification), wind patterns, seasonality and seasonal pattern, rainfall, natural disasters, waves and currents, tidal action, mud flow and turbidly, shoreline change (erosion and sedimentation), the frequency and severity of extreme events and associated ecological changes etc. Though precise consequences cannot yet be forecast, climate change has both direct and indirect impacts on fisheries and aquaculture. It is modifying distribution (biodiversity) and productivity of aquatic species and both direct and indirect impacts include impacts on targeted populations' range and productivity, habitats and food webs as well as impacts on fishery and aquaculture costs and productivity and fishing community livelihoods and safety.

Changes in distribution of fish and plankton are particularly striking because they are more rapid than the changes occurring in terrestrial fauna and flora. The effects of increasing temperature on marine and freshwater ecosystems are already evident, with rapid pole ward shifts in distributions of fish and plankton in regions, where temperature change has been rapid. Further changes in distribution and productivity are expected due to continuing warming and freshening. Some of the changes are expected to have positive consequences for fish production, but in other cases reproductive capacity is reduced and stocks become vulnerable to levels of fishing that had previously been sustainable. If small sized, low value fish species with rapid turnover of generations are able to cope up with changing climate, they may replace large sized high value species, which are already showing declining trend due to fishing and other non-climatic factors. Such distributional changes would lead to novel mixes of organisms in the region, leaving species to adjust to new prey, predators, parasites, diseases and competitors and result in considerable changes in ecosystem structure and function.

Impact on total fish production: Climate change, in particular, rising temperatures and decline in rainfall, can have both direct and indirect effects on fish production. Fish feeding, migration and breeding behavior will be directly affected and changes in their physical environments will indirectly affect survival, growth and reproduction. In addition, the species and ecosystems that fish rely on, will be affected with uncertain impacts on fishery catch potential. The rising ocean acidity makes it more difficult for marine organisms such as shrimps, oysters, or corals to form their shells (calcification). Further, zooplankton, that forms the base of the marine food chain also have calcium shells. Thus the entire marine food web is being altered and there are 'cracks in the food chain'. Changing rainfall patterns and water scarcity is impacting on river and lake fisheries and aquaculture production. As a result, the distribution, productivity and species composition of global fish productionis changing, generating complex and inter-related impacts on oceans, estuaries, coral reefs, mangroves and sea grass beds that provide habitats and nursery areas for fish.

Impact on fish biodiversity: With increased global temperature and decline in rainfall, the spatial distribution of fish stocks might change due to the migration of fishes from one region to another in search of suitable conditions. Climate change will have major consequences for population dynamics of freshwater biota via changes in transport processes that influence dispersals and recruitment.. Fish species will probably shift their distributions as warmer-water species and colder-water species are both expected to move pole wards.

Impact on fishing communities: Coastal and fishing populations and countries dependent on fisheries are particularly vulnerable to climate change particularly due to rise in sea level. The effect of sea level rise means that coastal fishing communities are in the front line of climate change. Low-lying countries such as the Maldives and Tuvalu are particularly vulnerable and entire communities may become the first climate refugees. Fishing communities in Bangladesh are subject not only to sea-level rise, but also flooding and increased typhoons**.**

5. Impacts of Climate Change on Indian Fisheries

In recent years climate is showing perceptible changes in the Indian subcontinent, where the average temperature is on the rise over the last few decades. In India, observed changes include an increase in air temperature, regional monsoon variation, frequent droughts and regional increase in severe storm incidences in coastal states and Himalayan glacier recession. Coastal fisheries sector is one of the most vulnerable sectors as far as impacts of climate change are concerned. Marine fishing communities mostly reside within 2-3 hundred meters of the coastline and are the most vulnerable group of people with respect to storms and cyclones, rogue waves and of course rare events such as the tsunami. Fish species in the south India exhibited distributional shifts (latitude and depth) in response to a temperature increase and that the response of pelagic species is stronger than that of demersal species, corroborating a number of recent studies of changes in fish assemblages. From analysis of 30 years' time series data on river Ganga and water bodies in the plains, Vass *et al*. (2009) reported an increase in annual mean minimum water temperature in the upper cold-water stretch of the river (Haridwar) by 1.5°C (from 13°C during 1970-86 to 14.5°C during 1987-2003) and by 0.2- 1.6°C in the aquaculture farms in the lower stretches in the Gangetic plains. This change in temperature clime has resulted in a perceptible biogeographically distribution of the Gangetic fish fauna. A number of fish species which were never reported in the upper stretch of the river and were predominantly available in the lower and middle stretches in the 1950s (Menon, 1954) have now been recorded from the upper cold-water region. The predator-prey ratio in the middle stretch of the river has been reported to be declined from 1:4.2 to 1:1.4 in the last three decades. Fish production has been shown to have a distinct change in the last two decades where the contribution from IMCs has decreased from 41.4% to 8.3% and that from catfishes and miscellaneous species increased (Vass *et al*., 2009; Mohanty and Mohanty, 2009). In West Bengal, the average minimum and maximum temperatures has increased in the range of 0.1-0.9°C over the last few decades throughout the state. The average rainfall has decreased and monsoon is also delayed; consequently, the climate change impact is being felt on the temperature of the inland water bodies and on the breeding behaviour of fishes. In recent years the phenomenon of Indian Major Carp maturing and spawning as early as March is observed, making it possible to breed them twice a year. Thus, there is an extended breeding activity in Indian Major Carps recorded as compared to a couple of decades ago. The climate change resulted in change in species composition of phytoplankton at higher temperature, extension of distributional boundary of small pelagic, extension of depth of occurrence and phenological changes. The Indian coral reefs have experienced 29 widespread bleaching events since 1989 due to increase in sub surface temperature. Vivekanandan *et al*. (2009b) projected the vulnerability of corals in the Indian seas. Other factors such as increasing acidity of sea water would affect formation of exoskeleton of the reefs and scientists are of the opinion that if the acidification continues as it is now, all the coral reefs would be dead within 50 years. Saud *et al.* (2014) the effect of climate change in the mountain regions of the Brahmaputra Basin coupled with siltation and shifting of river course may be indirect but significant in the scenario of the capture fishery dynamics of the Brahmaputra river system. The distribution and yield of fish stocks are observed to be affected owing to the process such as habitat damage, disruption to precipitation, changes in river course etc in the last three decades.

6. Strategies to Overcome the Impact of Climate Change on Fisheries (Adaptation and Mitigation)

The impacts of climate change can be addressed through adaptation and mitigation. Climate change has occurred throughout the history and natural system has developed a capacity to adapt, which help to mitigate the future changes.

Adaptation: Adaptations means considering in advance what changes may occur and taking those changes into account for further planning. Several international agencies, including the World Bank and the Food and Agriculture Organization have programs to help countries and communities adapt to global warming. Although the fisheries sector is relatively a minor contributor to carbon dioxide emissions, nevertheless the fishing boats have to reduce the emissions by using fuel efficient engines, adhering to fuel emission norms and adopting suitable methods, such as use of sails for harnessing wind power and thereby reducing fossil fuel consumption. The reducing overcapacity in fishing fleets and rebuilding fish stocks can both improve resilience to climate change and increase economic returns from marine capture fisheries by US$50 billion per year, while also reducing GHG emissions by fishing fleets. Consequently removal of subsidies on fuel for fishing can have a double benefit by reducing emissions and overfishing. Investment in sustainable aquaculture can buffer water use in agriculture while producing food and diversifying economic activities. Algal biofuels also show potential as algae can produce 15-300 times more oil per acre than conventional crops, such as rapeseed, soybeans, or jatropha and marine algae do not require scarce freshwater. Programs such as the GEF-funded Coral Reef Targeted Research provide advice on building resilience and conserving coral reef ecosystems, while six Pacific countries recently gave a formal undertaking to protect the reefs in a biodiversity hotspot – the Coral Triangle.

Mitigation: Mitigation means reducing the rate of climate change. The oceans have removed 50% of the anthropogenic CO_2, so the oceans have absorbed much of the impact of climate change. As warmer waters absorb less CO_2, so rise in ocean temperature will release back some dissolved CO_2 into the atmosphere. Healthy ocean and coastal ecosystems are necessary to continue the vital role of the ocean carbon sinks. The current level of GHG emissions means that ocean acidity will continue to increase and aquatic ecosystems will continue to degrade and change (Seiz, 2007). Warming also reduces nutrient levels in the mesopelagic zone (about 200 to 1000 m deep). This in turn limits the growth of diatoms in favour of smaller phytoplankton that are poorer biological pumps of carbon. This inhibits the ability of the ocean ecosystems to sequester carbon as the oceans warm. Climate change and climate variability have occurred throughout history and natural systems have developed a capacity to adapt, which will help them to mitigate the impact of future changes. However, two factors will limit this adaptive capacity in future i.e., the rate of future climate change is predicted to be more rapid than previous natural changes, and the resilience of species and systems is being compromised by concurrent pressures, including fishing, loss of biodiversity (including genetic diversity), habitat destruction, pollution, introduced and invasive species and pathogens. Some activities generate both mitigation and adaptation benefits, for example, the restoration of mangrove forests can protect shorelines from erosion and provide breeding grounds for fish while also sequestering carbon.

7. Conclusion

The global warming might include a slowdown or complete breakdown of the thermohaline circulation. Oceans and coastal ecosystems play an important role in the global carbon cycle. Healthy ocean ecosystems are essential for the mitigation of climate change. Coral reefs provide habitat for millions of fish species and with climate change it can provoke these reefs to die. Well designed and reliable monitoring of fish stock and marine ecosystem is essential in order to detect changes and give advance warning of alterations of its structure and functioning. Climate change is an additional pressure on top of the many which fish stocks already experience. The impact of climate change must be evaluated in the context of other anthropogenic pressures (fishing pressure, loss of habitat, pollution, disturbance, introduced species), which often have much greater and more immediate effect.

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Natural Resource Management for Ecological Sustainability of Islands

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1. Introduction

Natural resources are vital for the survival of human race, but its endowment and proper utilization will decide the level of economic development within the ecosystem boundaries. The proper management refers to the sustainable utilization of natural resources such as land, water, soil, plants and animals, with in the ecosystem boundaries to improve the quality of life for both present and future generations. However, natural resource management problems don't have straight forward solutions. It involves ecological cycles, hydrological cycles, climate, animals, plants and human interactions. Therefore, understanding ecological natural of the agriculture is vital to enhance the productivity and provide sustainable livelihood to the people.

The management of soil and water resources, the most important natural resource, with appropriate technology is the key for providing livelihood and sustaining the economic activity in an island condition with limited land area, inadequate fresh water storage, intricate production system, and limited choice for crop combinations. Thus appropriate production technology for island conditions and its management strategy based on the ecological principles for field level adoption are very essential for sustainable livelihood security.

On the other hand, there have been observed changes in surface temperature, rainfall, evaporation and extreme events since the beginning of the 20th century. Analyses of global precipitation pattern show variations and some notable trends in recent decades. Few studies have shown a rising trend in precipitation over the middle and high latitudes of northern hemisphere. There are also many studies related to precipitation trend and pattern over India. In these Islands about 95 percent of the total annual rainfall of 3100 mm is received during May-December but deficit is experienced during January-April. The study of climatic pattern highlighted decreasing trend in rainfall and rainy days in post-monsoon season. Therefore, the emphasis should be on the sustainability of production system within the dynamic boundaries of ecological nature of the agriculture and allied areas.

2. Physical Settings

The Andaman and Nicobar Islands, India are situated as a dissected chain in arcuate fashion oriented in North to South in the Bay of Bengal off the Eastern Coast of India and extended between 6^0 and 14^0 North Latitudes, and 92^0 and 94^0 East Longitudes covering a geographical area of 82 km^2. These islands form two major groups, popularly known as Andaman Group or the Northern Group of Islands and Nicobar Group or the Southern Group of Islands (Fig. 1). The Andaman and Nicobar Islands are located 1200 km east of main land India in the Bay of Bengal between 6-14^0 N latitude and 92-94^0 E longitude. The Nicobar group of Islands are situated in the South-east of the Bay of Bengal between 6° - 10° N latitude and between 92° - 94° E longitude and separated from the Andaman group by 10° channel.

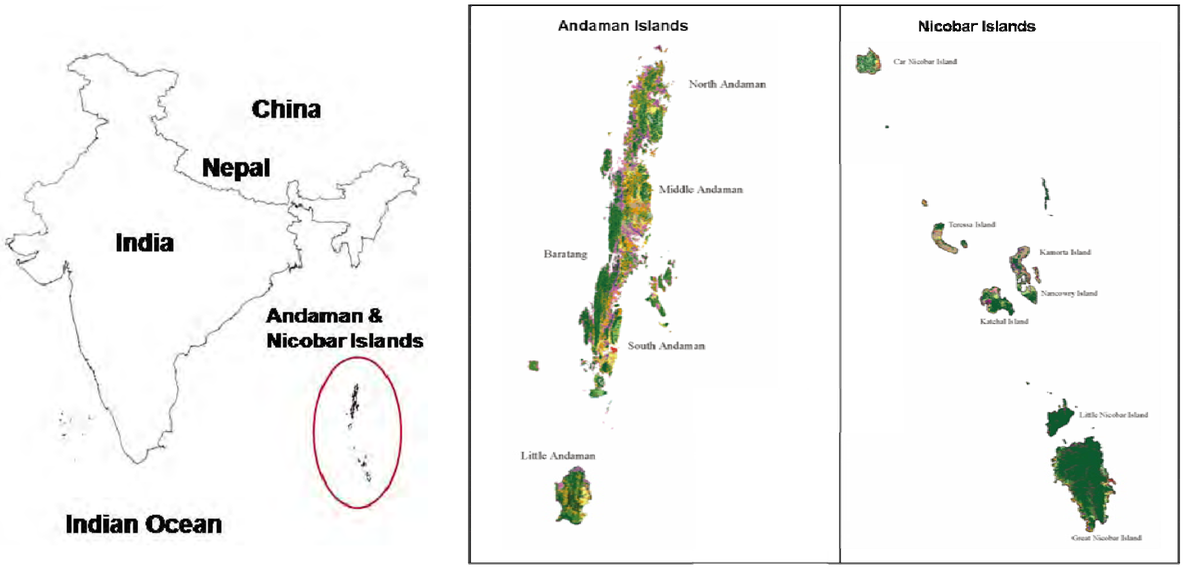


Fig.1: Location of Andaman and Nicobar Islands

3. Agro-climatic Conditions

The Islands experience humid tropical climate with total annual rainfall ranging from 2900 - 3100 mm. The mean maximum and minimum temperature are 30.2° C and 23.0° C, respectively. Major share of rainfall is received during May to December while dry period extends from January to April (Fig 2). The excess rainfall during monsoon season results in water logging of the coastal and valley areas for more than six months because of which only rice is grown. The Islands have undulating topography, characterized by hills and longitudinal valley areas. The major land forms are longitudinal hills, hill slopes, mid hill valley and coastal plains. Agriculture, plantations, mangroves, and forests are the major land use/cover of these islands. Though the Islands experience heavy rainfall during monsoon season, dry condition prevails for three months during January to March resulting in water scarcity. The analysis of climate data indicates that on an average the total annual rainfall remains same, but number of rainy days is decreasing. In addition the length of dry spell is increasing during dry season. In addition, the impact climate change and extreme events on the agricultural production system is expected to affect the tribals particularly the coastal communities very severely.

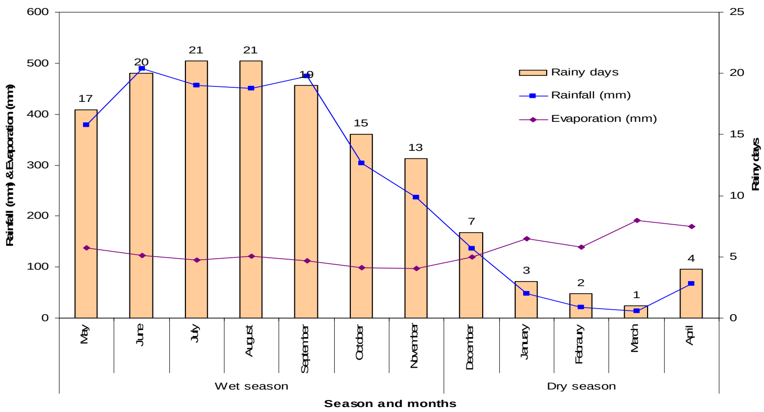
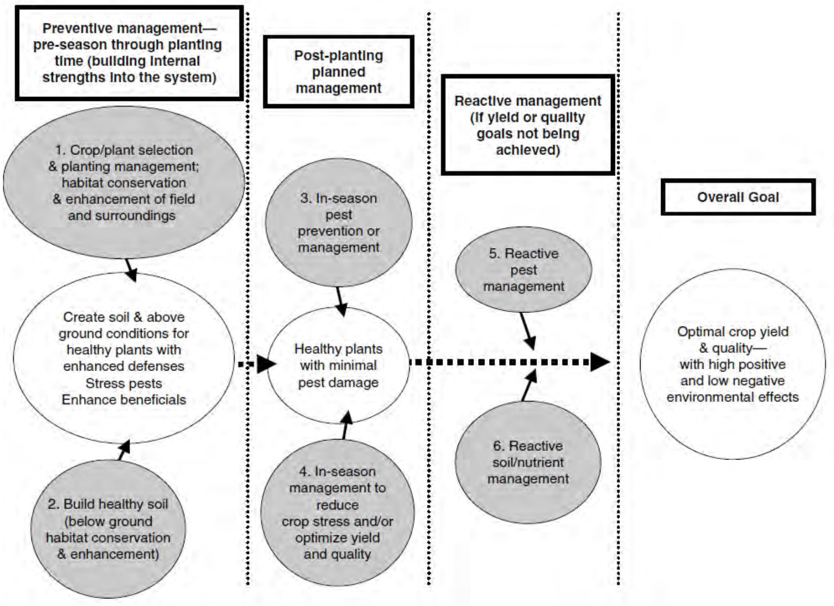


Fig. 2: Climatic parameters of Andaman and Nicobar Islands

4. Ecological Principles

The sustainable development of island agriculture largely depends on the ecological management alternatively, it depends ecological sustainability of the technologies being implemented or promoted to enhance the agricultural production. This includes proper understanding and management of island ecosystem components such as biotic, abiotic and attributes. An ecological approach to agriculture involves designing the strengths of natural ecosystem into agroecosystems to increase the productivity and efficient management. Natural ecosystems exhibit certain strengths or characteristics. These include efficiency, diversity, self-sufficiency, self-regulation and resiliency. The details are depicted in Fig. 3.

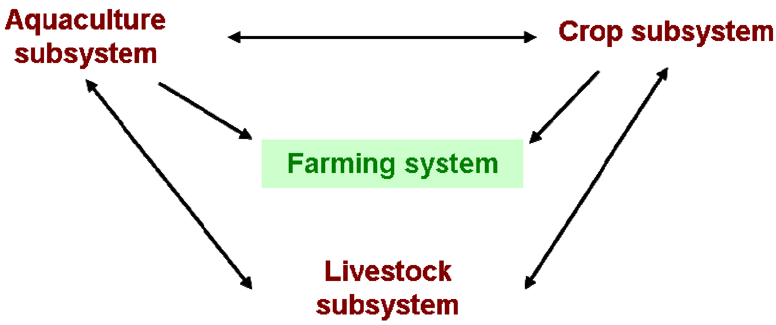


Source: Fred Magdoff, 2007, Renewable Agriculture and Food Systems: 22(2); 109–117

Fig. 3: Ecological framework for agricultural production

5. Technologies for Sustainable Agricultural Production

Integrated farming system: Integrated Farming System promises to enhance food, nutritional, livelihood and income of farmers apart from reducing risk of total failure of crops in monocropped areas due to weather vagaries and or biotic factors such as pest and diseases. The integration of various components provides helps in efficient recycling of products and by-products of one component into another component.



This in turn reduces the cost of cultivation resulting in increased farm production. Under this approach though the cropped area cannot be increased, cropping intensity can be increased by multiple land use through integration of crops, livestock and aquaculture and other production activities. Integrated farming systems, therefore assume greater importance for sound management of farm resources to enhance farm productivity which will reduce environmental degradation and improve the quality of life of resource poor farmers and to maintain agricultural sustainability. The aim of integrated farming system can be achieved by:

- Efficient recycling of farm and animal wastes
- Minimizing the nutrient losses
- Maximizing the nutrient self sufficiency
- Adopting efficient cropping system and crop rotation
- Complementary combination of farm enterprises

Some of the suitable IFS models Andaman and Nicobar Islands are given below;

(a) Hilly uplands: The hills having more than 25% slope, where plantation crops like coconut and arecanut are dominant with few fruit trees like jackfruit, guava, and sapota in the homestead gardens. The soils are poorly fertile and subject to soil erosion. Under such condition plantation based farming systems involving crop + dairy+ backyard poultry found to increase the production and productivity of the farm. Growing of spices including black pepper, clove as intercrop in plantation is the best possible option for such areas. By integrated approach the net farm income increased to Rs.3.9 lakhs/ha/year as compared to plantations alone. There was an additional employment of 163 man days/ha/year.

(b) Medium uplands/mid slopes: In the middle portion i.e medium upland areas plantations are intercropped with banana and pineapple. They have a slope of 10- 15 %, soils are coarse, medium depth with less nutrient and water retention. Soil erosion and low nutrient status are the major problems. Here upland rice, followed by pulses, vegetables, flowers and sugarcane is cultivated. At the end of the slope unmanaged fishponds are also present. Backyard poultry, cattle and goat rearing is common. Little modification of the existing cropping system and integration of components like dairy + poultry + fish or dairy + goat + poultry + fish along with crops gave an additional net income of about Rs.1.0 lakh and employment generation of 198 man days ha^{-1} yr^{-1}.

Table 1: Performance of different IFS models in Andaman Islands

System	Gross income (Rs ha^{-1})	Expenditure (Rs ha^{-1})	Net return (Rs ha^{-1})	Employment generated (man days)
(a) Hilly uplands				
Plantation + buffalo + poultry	4,74,440	83,732	3,90,708	528
Existing system	3,72,560	46,152	3,26,408	365
Additional benefit	1,01,880	37,580	64,300	163
(b) Mid slope or medium uplands				
Crop + cattle + poultry + fish	5,52,017	1,57,850	3,94,167	438
Existing system	4,00,107	1,05,758	2,94,349	240
Additional benefit	1,51,910	52,092	99818	198
(c) Low lying valley or coastal plains				
Crop + cattle + poultry +fish	2,64,904	99,944	1,64,960	259
Existing	99,549	41,789	57,760	58
Additional benefit	1,65,355	58,155	1,07,200	201

(c) Low-lying valley areas/coastal plains: In low-lying valley areas rice cultivation alone is possible due to water logging for more than 6 months. Long duration paddy is the only crop grown during rainy season. Soils are deep and fertile, however water logging during monsoon is the main problem in these areas. Backyard poultry and cattle rearing are common. Fish culture is also present. In these areas modifications of existing cropping system with short duration rice followed by pulses or vegetables and integration with cattle, poultry and fish resulted in an additional net farm income of Rs.1.07 lakhs and employment generation of 201 mandays /ha /year.

(d) Mangrove based IFS towards the seafront of the coast: Mangroves contribute to the natural productivity and also act as a bio-shield against natural disasters protecting the island coastline from storm surges and cyclones. A mangrove-based integrated agro-aqua farming system model will be an ideal option to enhance the livelihood security of the coastal communities. A mangrove based aquaculture model suitable for island condition was developed and successfully implemented (Dam Roy *et al*., 2009). The model has two ponds with provision for water exchange as per tide level and a mangrove nursery bordering the ponds. The ponds were stocked with mullet - *Mughil cephalus* (300 Nos), Scat - *Scatophagus argus* (150 Nos), Tilapia -*Oreochromis mossambica (*200 Nos) and Tiger Prawn - *Penaeus monodon* (200 Nos) under polyculture system. Vegetables and fruits were raised on the bunds. A duckshed (for 10 birds) was provided on the bund with a provision to wash off the duck waste directly into the ponds. *Azolla* cultivated in the FRP tank on the bund also served as a source of fish and duck feed. In mangrove nursery seedlings of *Bruguiera gymnorrhiza, Rhizophora apiculata* and *Acanthus ilicifolius* were raised for planting in vacant spaces to strengthen the shield against the erosion action and increase the mangrove density. The ponds received the organic wastes from the duckshed and the nutrient rich mangrove water during high tide and no supplementary feed was provided to the fishes. The integrated farming system model provides additional income to the farmers apart from meeting the nutritional requirements.

(e) Homestead based integrated farming system for Nicobar Islands: Considering the remoteness, dietary intake, limited land availability and lack of market for the perishable produce, a small scale homestead based integrated farming system comprising home garden (400m^2), backyard poultry (20 no's), goatary (2 no's) and composting were developed for improving nutritional security of the tribal household besides increasing the farm production and employment generation. The frequency of consumption of meat, poultry, egg, fruits and vegetables by the farm family increased to the extent of 71 to 380 % after the intervention. The vegetables including greens, fruits and egg consumption increased significantly due to onfarm productionand there was a reduction in intake of tubers indicating a change in dietary pattern more towards balanced nutrition. A total of 95 man days were generated by the system viz., 52 man days in home garden, 40 man days in livestock rearing and 3 man days in composting spread throughout the year.

6. Bio-diversity: Biological diversity, or biodiversity, denotes the variety of life on Earth. Functionally, it is the combination of life forms and their interactions with one another, and with the physical environment that has made Earth habitable for humans. The services provided by healthy, biodiverse ecosystems are the foundation for human well-being. However, the ecosystem services are in decline, as reported by the Millennium Ecosystem Assessment. These include the provision of fresh water, marine fishery production, the number and quality of places of spiritual and religious value, the ability of the atmosphere to cleanse itself of pollutants, natural hazard regulation, pollination, and the capacity of agricultural ecosystems to provide pest control.

Biodiversity loss disrupts ecosystem functions, making ecosystems more vulnerable to shocks and disturbances, less resilient, and less able to supply humans with needed services. The damage to coastal communities and the consequences of biodiversity loss and ecosystem disruption are often harshest for the rural poor, who depend most immediately upon local ecosystem services for their livelihoods and who are often the least able to access or afford substitutes when these become degraded. A&N Islands are the hot spot of biodiversity and different stakeholders should join hands and make strenuous efforts to conserve them which will provide the island communities the adaptive capabilities to perceived climate change.

- A&N islands are rich is biodiversity of plantation crops, fruits, vegetables, tubers, medicinal plants. It also centres of origin for some of the crops as well. Documentation and conservation of them are essential to improve the ecosystem services. Efforts are required to develop technologies to harness the benefits out of it to provide livelihood and ensure food security of the island population.
- The Nicobar Islands are known for their indigenous animals such as Nicobari fowl, pig and Teresa goat which are well adapted to the local conditions and known to be tolerant to some of the diseases prevalent in the mainland.
- Mangroves are one of the sources of income and food for most of the tribals. Mangroves occurring in these islands are mostly fringing the creeks, backwater and muddy shores. Along the creeks, the width ranges from 0.5 to 1 km. This salt-tolerant community is found on rocky shores exposed to tidal action and

sometimes is also found growing in tidal mudflat. In Andaman and Nicobar Islands 966 km^2 is under mangrove vegetation, of which 929 km^2 in Andaman islands and only 37 km2 in Nicobar group of Islands.

- The island microbial resources are still to be explored to harness the benefits such as biocontrol of pest and diseases, nutrient mobilization and plant growth promotion. Proper understanding of its role in the ecosystem may pave the way to develop some of the climate resilient technologies for enhancing crop production.

7. Organic farming: Organic farming techniques has ample scope to improve and sustain the agricultural production through multi-storeyed cropping and intercropping by effectively utilizing the vertical and horizontal unutilized spaces available between the plantation rows. Some of the suitable multi-storeyed cropping systems suitable for island conditions are given in Table 6 (Gangwar and Singh, 2011). The fertilizer requirement can be met through organic means by effective recycling of the plantation and other plant and animal wastes within the garden. In arecanut plantations approximately 60 per cent of the light is intercepted by an adult areca palm. By growing intercrop, the level of light interception could be increased to about 95 per cent. Intercropping also leads to increased availability of organic matter for recycling.

In many situations, the adaptation of state-of-the-art organic farming offers considerable potential for yield increase and yield stability. By following suitable organic management practices, 6318 Mg of spices can be produced which is 149% increase over the existing production. Similarly organic practices have the potential to improve the yield of coconut production by 32%, fruits 21% and cashewnut 17%. The production of pulses, root crops, and vegetables can also be increased by organic management practices and most of its potential can be realized by linking it with the local market and tourism sector (Velmurugan *et al*., 2014).

8. Agroforestry models and MPT's: The cultivable fodder area is insufficient to meet the requirements of existing cattle population of the Islands. In the small holder farming system prevalent in these Islands, the production of forage and fodder is often a sideline activity and not being practiced by the Island farmers as a routine. The population growth accompanied by the improvement in the general living standards in Bay Islands have pushed up the demand of dairy products which has further widened the gap between the demand and supply of fodder and feed resources in the Islands. The non-availability of feeds and fodder is the major challenge to sustain the livestock activity during the dry season. Due to heavy rains for about eight months, green fodder cultivation is difficult. Similarly, cereals, which can be used as source of feed is also not possible because these are major food for human also.

There is plenty of scope for increasing productivity of fodder tree and fodder legumes by growing together in the IFS system with appropriate silvicultural management. Alley cropping, also known as hedge row intercropping, involves managing rows of closely planted (within row) woody plants with annual crops planted in alleys in between hedges. Fodder trees and hedges can also be planted as live fence to protect the farm from stray animals or other biotic influences. In Andaman and Nicobar Islands suitable multipurpose tree (MPT's) can be integrated as a component of farming system by way of

- Alley farming with livestock, the hedgerows of trees are managed to provide high-quality fodder for sheep, goat, and / or cattle.,
- The MPT's can also be integrated into farming system by way of utilizing the border space as boundary planting
- In block planting high value fodder tree species depending on the need and locations are grown as a separate block

9. Problem soils and stress tolerant crops: Land degradation will remain an important issue to be addressed in coastal and island ecosystem for the 21st century because of its adverse impact on agronomic productivity, the environment, and its effect on food security and the quality of life. The problems are aggravated by natural events such as tsunamis. Soil resource assessment carried out by CIARI have identified waterlogging, acidity, salinity and low nutrient reserve as the major soil factors causing land degradation in different soil series of Andaman Islands. Soil acidity was a common constraint in all the series except Rangachang, because of hot and humid climate favouring intensive weathering and leaching of the basic cations.

The cultivated land available before 2004 tsunami was 50,000 ha which was shrunk by 14% due to land degradation imposed by tsunami and after effects. Analysis of land degradation showed that significant increase in area under coastal erosion (22.4%) followed by salinity with water logging (14.4%) forced the abandonment of agriculture in low lying coastal areas of Andaman. The vulnerability assessment showed that 11% of the reported area of 6895 km^2 and 8-12% of agricultural area are directly exposed to tsunami due to topography and proximity to sea.

Table 2: Biotic and abiotic stress tolerant crops and their varieties for island conditions

Name of the crop	Varieties	Specific features
Rice	BTS-24, CARI Dhan-5; CSR 23, 36; Vytilla 4, 5; TRY-1, CO 43	Salt tolerant cultivars
	CARI Dhan-6, 7	Bacterial leaf blight tolerant
Red gram	CIARI Arhar	highly drought and heat resistant
Coconut	CARI Annapurna, Surya & Chandan	Salt and drought tolerant cultivars
Tuber crops	Cassava (H-226, Sree Visakham, Sree Vijaya), Elephant foot yam & Greater Yam (Yamini)	Withstands high rainfall and abiotic stress
	Sweet Potato (Pusa safed, Sree Bhadra, CIP-440038)	Salinity tolerant
	Swamp taro, Colocasia (Sree Pallaviand, Sree Kirana)	Waterlogged condition
Tomato	Pusa Ruby, Pusa Rohini,	Salt tolerant cultivars
Brinjal	CARI Brinjal 1	Bacterial wilt resistant
	Pusa Uphar	Salt tolerant cultivar
Chilli	Suryamukhi, Pusa Jwala	Salt tolerant cultivars
Broad Dhaniya (*Eryngium foetidum*)	CARI Broad Dhaniya	Suitable for shaded conditions
Poi (*Basella rubra*)	CARI Poi selection	Withstand water stress
Noni (*Morinda citrifolia*)	CARI Rakshak	Comes up well in salinity affected soils
Sorghum	CO-4	highly drought-resistant, suitable to improve fodder production

Such conditions coupled with evolving climate change scenarios necessitate the need for salinity tolerant crops in the coastal areas and such other suitable crops which provide higher yield in the degraded soils. As mentioned in the earlier section, these crops should be integrated into IFS models suitable for degraded soils of these islands. CIARI has introduced CSR-27, 36, CARI Dhan-5,6 rice varieties for these areas, and the performance are encouraging.

10. Adaptation strategies: Some of the adaptation strategies appropriate for island condition are;

- Rain water harvesting and its efficient use : lined ponds, tank cum ring well, and check dams
- Land degradation management and water harvesting – broad bed and furrow system, rice-fish system, farm pond with broader dykes, ridges and furrow
- Use of salt and water logging tolerant rice varieties
- Utilization of improved native breeds of livestock
- Multi storey cropping under coconut plantations
- Proper soil and water conservation measures
- Suitable IFS models for different physiographic conditions / islands
- Agricultural diversification

11. The way forward: With increasing population and the need to ensure livelihood security, it is imperative to evolve a suitable strategy for augmenting production through on farm and off farm activities. By integrating different agricultural activities based on the resource endowment and constraints of different locations, it is possible to improve the farm production as well as employment opportunities of the individual farm households within the ecological boundaries of the island. This will reduce the external dependence of islands for livelihood and instill climate resilient.

12. Conclusion

The practice of ecological agriculture involves adopting the strengths of natural ecosystems into agro-ecosystems to enhance the agricultural production by utilizing the available natural resources. The overall strategies include using practices that (a) maximization of resource use for higher farm production through IFS (b) grow genetically superior plants with good abiotic stress tolerance (c) plant protection through ecological manipulation and (c) enhancing populations of beneficial organisms and nutrient recycling. These are accomplished by enhanced habitat management both above ground and in the soil. These measures not only facilitate management of natural resources of the island but also ensure the diversification of agricultural activity resulting in higher productivity and livelihood security.

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Micro-irrigation Technology for Efficient Water and Nutrient Management

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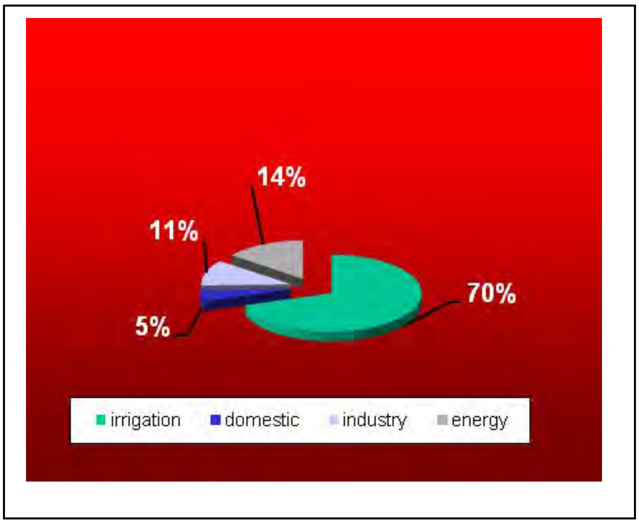
1. Introduction

Globally, 3240^3 m km fresh water is being utilized, out of this 69% is being used in agriculture sector, 8% in domestic, 23% in industrial and other sectors. In India around 88% water is being used in agriculture sector, which covers around 80 m ha area under irrigation (Fig. 1 & 2). Due to the liberalisation of industrial policies and other developmental activities, the demand for water in industrial and domestic sectors is increasing day by day, which forces to reduce the percentage area under irrigation. Expected annual water demand by various sectors in the year 2025 is given in Fig.1. The current irrigated area of around 38% of total cultivated area. The growing demand from the population calls for more efforts to enhance agricultural production activity covering cereal, millets, oilseeds and horticultural crops (Alam and Kumar, 2001).

Sustainable development of land and water resources is very important for a country like India which shares 16% of the global population with only 2.4% of land and 4% of water resources. Efforts were therefore made to develop irrigation potential during the Plan periods. However, simultaneously efforts were not made to utilise irrigation water more efficiently. The conventional system of irrigation employing different methods like flooding, furrow, border irrigation revolved around the concept of replenishing the moisture level to full Field Capacity (FC) only after depletion by 50% to 60% of FC. The system did not permit the restricting of irrigation only to meet the requirement of the root zone, thus leading to excessive percolation and other losses. It, therefore, resulted in problems like water logging, soil salinity and even drought like conditions in tail ends of the system. These conditions have created the low productivity levels of 2-3 t ha^{-1} in irrigated agriculture against 4-6 tonnes/ha at research levels. Also, the overall efficiency of the system ranged between 25%-40%. To meet the food security, income and nutritional needs of the projected population in 2010 the food production in the country will have to be almost doubled. Thus, judicious use of irrigation water is more important to enhance total production and area under irrigated agriculture (Chauhan, 2002). It can be achieved by introducing advance method of irrigation like micro-irrigation coupled with other improved water management practices (Jain, 2001).



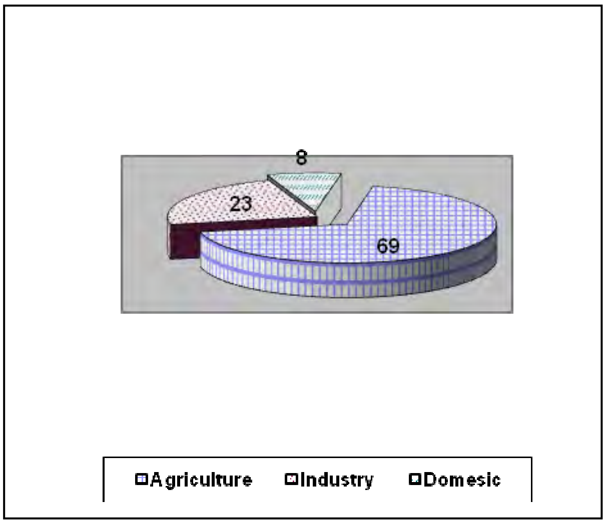


Fig. 1: Expected annual water demand in different sectors Fig. 2. Share of water useby the year 2025

There has been a great deal of intensive and serious thought about the limited availability of earth's fresh water resources and management since the 1992 International Conference on Water and the Environment in Dublin and the June 1992 United Nations Conference on Environment and Development in Rio de Janerio. This has brought out worldwide reforms in the water sector. The Agenda 21 of the Conference says: "Sustainability of food production increasingly depends on sound and efficient water use and conservation practices consisting primarily of irrigation development and management with respect agriculture, livestock water supply, inland fisheries and agro forestry. Achieving food security is a high priority in many countries including India, and agriculture must not only provide food for rising population, but also save water for other uses. The challenge is to develop and supply water saving technology and management methods and, through capacity building enable farming communities to adopt new approaches in irrigated agriculture".

2. Micro-irrigation System

Micro-irrigation system is irrigation system with high frequency application of water in and around the root zone of plant system. The micro-irrigation system consists of a network of pipes along with a suitable emitting device. Micro irrigation is based on the fundamental concept of irrigating only the root zone of the crop rather than the entire land surface, as done during surface irrigation. Micro irrigation system is known to be able to achieve high water use efficiency, and also results in improved crop yield (Patel and Rajput, 2003a). In traditional type of surface irrigation, huge amount of water is lost through seepage and conveyance of water from the source to field. This loss can be avoided to a greater extent by adopting micro irrigation. In conventional irrigation methods, the plants are stressed for a good part of irrigation interval from the desirable water regime of field capacity of root zone (Sivanappan et al., 1980). On the other hand, micro irrigation system allows frequent application of small quantities of water, which ultimately provides a nearly constant low-tension soil water condition in the major portion of the root zone.

Keeping these factors in view, major emphasis has been laid, since the VIII Plan, on improving water use efficiency by promoting micro irrigation in the country. The total cropped area suitable for micro irrigation in the country is to the tune of 27 million ha. (Table.1). This technology has been prevalent in developed countries like USA, Israel etc. Micro irrigation has high water use efficiency and can save water up to 70% as compared to conventional methods. Moreover, effective use of micro irrigation system can make even `water scarce areas bloom. Horticultural crops in particular benefit the most from micro irrigation and with this facility can be cultivated profitably marginal productive lands (Singh, 2001). Micro irrigation not only makes such lands productive but also environmentally beneficial it can help in assisting soil erosion and other types of degradation. The efforts of GOI in promotion of micro irrigation have resulted in bringing about three lakh ha under micro irrigation (Table 1). It is estimated that in all, about 4.5 lakh ha has been covered under micro irrigation, which includes the 3.5 lakh ha covered under GOI schemes (Fig. 3).

3. Comparison of micro-irrigation system over conventional systems of irrigation: Micro irrigation system has surely has a number of advantages over the conventional irrigation methods like border, check basin, furrow or surge irrigation. The following table shows some of the important points of difference between two methods of irrigation.

Performance indicator	Conventional irrigation Methods	Micro irrigation method
Water saving	Wasteful of water, losses occur due to percolation, runoff and evaporation	40-100% of water can be saved over flood method. Runoff and deep percolation losses are nil or negligible
Water use efficiency	30-50% because losses are very high	90-95%
Saving in labour	Labour engaged per irrigation is higher than Micro	Labour required only to start or stop the system
Reduced weeds problem	Weeds infestation is very high	Less wetting of soil, weeds infestation is very less or almost nil
Use of saline water	Concentration of salts increases and adversely affects the plant growth. Saline water cannot be used for irrigation	Frequent irrigation keeps the salt concentration within root zone soil below harmful level
Diseases and pest problems	High	Relatively less because of less atmospheric humidity
Suitability under physical soil constraints	Deep percolation is more in light soil and with limited soil depths. Runoff loss is more in heavy soil.	Suitable under various soil physical constraints as flow rate can be controlled.
Water control	Inadequate	Very precise, high and easy
Efficiency of fertilizer use	Efficiency is low because of heavy losses due to leaching and runoff	Very high due to reduced loss of nutrients through leaching and runoff water
Soil erosion	Soil erosion is high because of large stream sizes used for irrigation.	Partial and control the wetting of soil surface eliminates any possibility of soil erosion
Increase in crop yield	Non-uniformity of available moisture reduced the crop yield	Frequent watering eliminates moisture stress and yield can be increased up to 20-100% as compared to flood

4. Fertigation

Fertilizer application through the MI system i.e. fertigation is the most advanced and efficient practice of fertilization. Fertigation combines the two main factors in plant growth and development, water and nutrients. The right combination of water and nutrients is the key for high yield and quality of produce. Fertigation is the most efficient method of fertilizer application, as it ensures application of the fertilizers directly to the plant roots (Rajput & Patel, 2002).In fertigation, fertilizer application is made in small and frequent doses that fit within scheduled irrigation intervals matching the plant water use to avoid leaching. Significant savings in the use of fertilizers and increase in yield (Table 1) have been reported by different research workers (Anonymous, 2001; Hayness, 1988; Patel and Rajput, 2003b).

5. Points needs to consider for efficient fertigation: All chemicals applied through irrigation system must avoid corrosion, softening of plastic pipe and tubing, or clogging any component of the system. It must be safe for field use, must increase or at least not decrease crop yield, must be soluble or emulisifiable in water, and it must not react adversely to salts or other chemicals in the irrigation water. In addition, the chemicals or fertilizers must be distributed uniformly throughout the field. Uniformity of distribution requires efficient mixing, uniform water application and knowledge of the flow characteristics of water and fertilizer in the distribution lines (Rajput and Patel, 2003 & 2004). To avoid clogging, chemicals are applied through micro irrigation systems to dissolve the deposits in Micro lines.

Table 1: Savings in fertilizer and increase in crop yield under fertigation as compared to conventional method of fertilizer application

Crop	Saving in fertilizer, %	Increase in yield, %
Okra	40	18
Onion	40	16
Grapes	20	37
Broccoli	40	10
Banana	20	11
Castor	60	32
Cotton	30	20
Potato	40	30
Sapota	20	74
Tomato	40	33
Sugarcane	50	40

i. Fertilizers solubility: An essential pre-requisite for the granular fertilizer use in fertigation is its complete dissolution in the irrigation water. Examples of highly soluble fertilizers appropriate for their use in fertigation are: ammonium nitrate, potassium chloride, potassium nitrate, urea, ammonium monophosphate and potassium monophosphate (Kessel, 2001). The solubility of fertilizers depends on the temperature (Table 2).

Table 2: Fertilizers solubility and temperatures (g/100 g water)

Temperature	Fertilizers				
	KCl (Muriate of Potash)	K_2SO_4	KNO_3	NH_4NO_3	Urea
10°C	31	9	21	158	84
20°C	34	11	31	195	105
30°C	37	13	46	242	133

ii. Mobility of fertilizers in soil: The ability of a fertilizer to dissolve in water does not always give a good indication of the potential for the fertilizer or its components to move through the soil. Table 3 gives a general guide to the mobility of fertilizer (McNab *et. al.*, 1995) components in soil. Another point to remember is that although one may apply a fertilizer of lower mobility (i.e. ammonium), it will be naturally broken down in the soil to form nitrate, which is very mobile. As a result, care should be taken during irrigation to minimize leaching of mobile nutrients.

Table 3: Mobility of different fertilizers in soil

Fertilizers	Mobility
UUrea	Good
NNitrate	Good
AAmmonium	Low
PPotassium	Low
PPhosphate	Low

iii. Fertilizers compatibility

Mixing the solutions of two or more than two water soluble fertilizers can sometimes result in the formation of a precipitate. Such cases indicate that these fertilizers are not mutually compatible, and special attention has to be paid to avoid mixing them in one tank. Their solutions should be prepared in two separate tanks. It is clear from Table 4 (Montag, 1997) that neither phosphoric- nor sulphatic fertilizers can be mixed with calcium fertilizers in the same tank.

Table 4: Compatibility chart among different fertilizers

Fertilizers	*Urea*	*Ammonium Nitrate*	*Ammonium Sulphate*	*Calcium Nitrate*	*Mono Ammonium Phosphate*	*Mono Potassium Phosphate*	*Potassium Nitrate*
Urea		*C*	*C*	*C*	*C*	*C*	*C*
Ammonium Nitrate	*C*		*C*	*C*	*C*	*C*	*C*
Ammonium Sulphate	*C*	*C*		*LC*	*C*	*C*	*LC*
Calcium Nitrate	*C*	*C*	*LC*		*NC*	*NC*	*C*
Mono Ammonium Phosphate	*C*	*C*	*C*	*NC*		*C*	*C*
Mono Potassium Phosphate	*C*	*C*	*C*	*NC*	*C*		*C*
Potassium Nitrate	*C*	*C*	*L*	*C*	*C*	*C*	

C- Compatible, NC = Not Compatible LC = Limited compatible

iv. Fertilizer injection devices: Pressurized irrigation methods require fertilizer injector for injection of fertilizers, into the irrigation water. There are two concepts on the basis of which the fertilizer injectors are designed. The total amount of fertilizers applied in both the cases should be equal since the requirement of nutrients of plant is independent to the injection device and method of fertilization.

Proportional concept is characterized by constant concentration of the fertilizer solution **(**Montag, 1999) in irrigation water throughout the irrigation duration (Fig. 5). Fertilizer injection devices such as venturi pump and fertilizer injection pump operate on this principle. The main advantage of this concept is that it enables a delivery of constant concentration during the entire irrigation duration.

Quantitative or non-proportional concept is characterized by change in the concentration of fertilizers in irrigation water. Concentration of fertilizer decreases gradually with the irrigation duration (Fig. 6). Fertilizer tank is one such device that works on this principle (Montag, 1999).

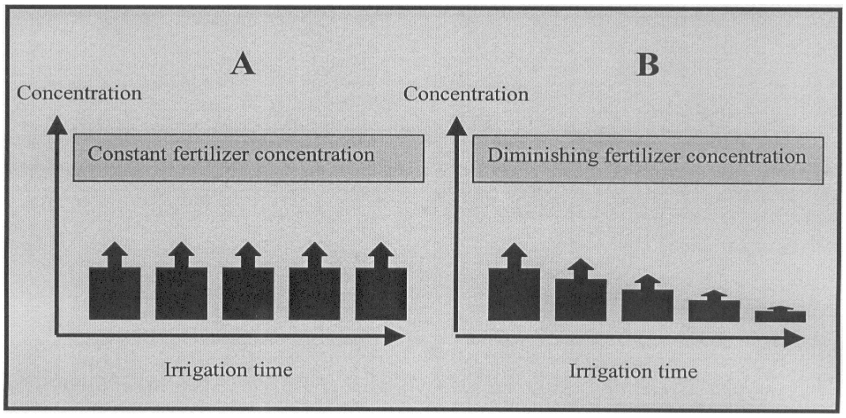


Fig. (5) Proportional and (6) Quantitative type fertilizer injectors

Fertilizer tank method (by-pass system): This method employs a tank into which the fertilizer solution is filled. The tank is connected to the main irrigation line by means of a by-pass so that a part of the irrigation water flows through the fertilizer tank and dilutes the fertilizer solution (Fig. 3).

Venturi pump: Venturi consists of a converging section, a throat and a diverging section. When the flowing water passes through the constricted throat section, its velocity increases and the pressure reduces, creating a suction effect. Due to suction, liquid fertilizer enters into the Micro system through a tube from the fertilizer storage tank connected to the throat. To start the venturi system the desired pressure difference across the venturi is created by using pressure regulating valves to enable the flow of fertilizer into the Micro system (Fig.3). The rate of flow is regulated by means of the valves. The venturi system works because of differential pressure in the system (usually 20 %) (Snyder & Thomas, 1994) from one side of the device to the other**.** Injection rate depends on the pressure difference and pressure fluctuations in the system change the injection rate.

Fertilizer injection pump: In this method a pump is used to draw the fertilizer stock solution from a storage tank and inject it under pressure into the irrigation system. Injection rates can be easily set to create a desirable mixing ratio. The solution is normally pumped from an un-pressurized reservoir, and the choice of pump type used is dependent on the power source (Fig. 5).

Fig. 3. Fertilizer tank

Fig.4. Venturi pump

Fig. 5. Fertilizer injection pump

Table 5: Suggestive schedule of fertigation for vegetable crops (Bar-Yosef, 1991)

Crop	*Stages of crop*												Total, nutrients, (kg ha^{-1})		
	Transplant to 6 leaf, (kg ha^{-1})			6 leaf to fruit set (kg ha^{-1})			Fruit set to fruit development (kg ha^{-1})			Fruit set to ripening, (kg ha^{-1})					
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Potato	44	32	16	26	26	58	130	87	196	-	-	-	200	145	270
Tomato	55	98	58	35	17	35	30	15	45	30	15	172	150	145	310
Capsicum	55	122	58	35	17	35	30	15	45	30	15	172	150	170	310
Onion	60	107	60	32	33	32	31	15	171	32	32	32	155	185	295
Red cabbage	32	32	32	35	18	35	33	15	173	-	-	-	100	65	240
Carrot	55	120	120	30	15	171	30	15	171	-	-		115	150	400
Lettuce	55	122	122	35	18	35	-	-	-	-	-		90	140	90
Cucumber	55	121	121	35	17	35	35	17	35	-	-		125	155	125
Water melon	110	10	10	25	25	25	30	15	75	-	-		165	50	120
Melon	15	15	5	30	15	45	35	18	80	35	17	55	115	65	195

6. Constraints in Fertigation

In India, growth of adoption of micro irrigation system has taken place during last decade and mostly horticultural farmers are adopting this technology to save irrigation water and enhancing the water-use efficiency. Although, fertigation offers numerous advantages but it is not being used widely due to the reasons given below:

- There is lack of research and developmental information in respect of its rate of application, amount applied and frequency adopted. However, research efforts are being focused on this aspect but there is a lack of information in respect of varied agro-climatic conditions and crops.
- In India, there is a subsidy policy for normal NPK fertilizers in specified grades. However, for fertigation the requirement of fertilizer is in different grades and it should be 100 per cent water soluble for its effective application. The fertigation material is either not available in desired form or available at higher price, than the conventional fertilizer.
- Once the fertigation practice is being followed along with Micro irrigation system causes higher clogging. The farmers must be trained to adopt fertigation along with other chemigation technique.

7. Recommendations to Promote Micro-irrigation and Fertigation

The unbalanced growth of micro irrigation limiting mainly to the Southern Peninsular States is yet another area of concern. Some of the reasons for the uneven development in the Micro irrigation are:

- Inadequate awareness about the advantages of micro irrigation.
- Lack of trained manpower.
- Inadequate credit facilities for the farmer.
- The availability of the system and its spares are not uniform in the country.
- The distribution network at rural areas have inadequate facilities in terms of
  - material availability and technical know-how.
- Industrial growth of micro irrigation system in India favors the widespread
  - use but industry needs discipline for quality and providing services to
  - safeguard the technology.
- Micro irrigation research in India has received attention but integration among

- different programs are lacking. Through effective integration and linkages
- more useful information could be generated and duplication could be avoided.
- There is a need to strengthen the information system on micro irrigation,
- which should be user's friendly and guide to farmers.
- There is also a need to attract more investment for capital formation and
- technology should be designed to have shift from subsidy-driven mode to
- farmer-driven mode.

8. Conclusion

Sustainable development of land and water resources is very important for a country like India which shares 16% of the global population with only 2.4% of land and 4% of water resources and judicious use of irrigation water is more important to enhance total production and area under irrigated agriculture. It can be achieved by introducing advance method of irrigation like micro-irrigation coupled with other improved fertilizer application practices like fertigation. Micro-irrigation system is irrigation system with high frequency application of water in and around the root zone of plant system. Micro irrigation system is known to be able to achieve high water use efficiency, and also results in improved crop yield. Fertilizer application through the micro irrigation system i.e. fertigation is the most advanced and efficient practice of fertilization. With micro irrigation 40-100% of water can be saved over flood method and 90-95 % water use efficiency can be achieved. Significant savings in the use of fertilizers (20 to 50%) and 20-70 % increase in yield can be achieved through fertigation.

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Strategy for Optimization of Higher Productivity and Quality in Field Crops Through Micronutrients

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1. Introduction

Micronutrients or Trace elements are essential for plant growth & development but it is needed in very small quantities in the plant system. It includes Fe, Cu, Cl, Mn, B, Ni, Zn & Mo. The accumulation of these micronutrients by plants generally follows the order of Mn>Fe>Zn>B>Cu>Mo. This order may change among plant species and growth conditions (e.g.; flooded rice). Zinc deficiency is the most ubiquitous micronutrient problem throughout the world affecting many crops including the staples maize, rice and wheat which reduces not only grain yield but also nutritional grain quality (Graham and Welch, 1996). Copper deficiency is important in some parts of the world, such as Europe and Australia where cereals are most affected. Micronutrient constitutes in total less than 1% of dry weight of most plants. Micronutrient availability is greatly influenced by soil pH. As pH increases from 4-7. Zn, Fe, Mn & B decreases in solubility & availability while Mo increases in solubility & availability (Jacobsen, 2009). Incidence of micronutrient deficiencies in crops has increased markedly in recent years due to intensive cropping, loss of top soil by erosion, losses of micronutrients through leaching, liming of acid soils, decreased proportions of farmyard manure compared with chemical fertilizers, increased purity of chemical fertilizers, and use of marginal lands for crop production. Micronutrient deficiency problems are also aggravated by high demand of modern crop cultivars (Bell, 2006). Plant factors such as root and root hair morphology (length, density, surface area), root induced changes (secretion of H^+, OH^-, $HCO3^-$), root exudation of organic acids (citric, malic, tartaric, oxalic, phenolic), sugars, and non-proteinogenic amino acids (phytosiderophores), secretion of enzymes (phosphatases), plant demand, plant species/ cultivars, and microbial associations (enhanced CO2 production, rhizobia, mycorrhizae, rhizobacteria) have profound influences on plant ability to absorb and utilize micronutrients from soil (Clark and Zeto, 2000). Water shortages are another problem, as access to groundwater has diminished in several areas. It showed that a small amount of nutrients, particularly Zn, Fe, and Mn applied by foliar spraying increases significantly the yield of crops (Sarkar *et al*., 2007).

The micronutrients that practicing agronomists and crop production people can reasonably do something about are zinc (Zn), iron (Fe), manganese (Mn), boron (B), chlorine (Cl), copper (Cu), and molybdenum (Mo). Zinc is likely the most common micronutrient that is in short supply. Iron is perhaps the most difficult to make available because it is needed in relatively large amounts and soil chemical processes sometimes quickly make it unavailable. Knowing how an element functions in the plant and some of its associated soil chemical interactions helps diagnose problems and prescribe solutions.

Table 1: Concentration of micronutrients in plants on dry weight basis

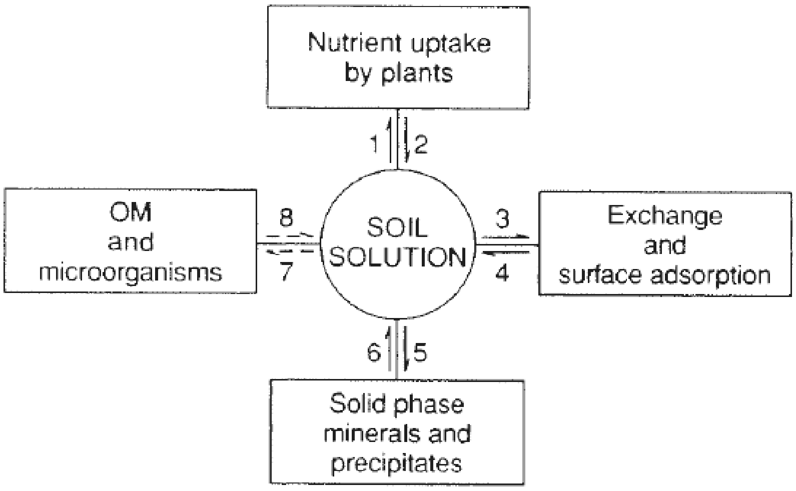
Element	Symbol	Form	Range of concentration (ppm)	Adequate concentration (ppm)
Boron	B	H_3BO_3	0.2-800	20
Chlorine	Cl	Cl^-	10-80,000	100
Copper	Cu	Cu^+,Cu^{2+}	2-50	6
Molybdenum	Mo	MoO_4^{2-}	0.10-10	0.10
Manganese	Mn	Mn^{2+}	10-600	50
Iron	Fe	$Fe^{3+,}$ Fe^{2+}	20-600	100
Zinc	Zn	Zn^{2+}	10-250	20

Source: Lohry (2007)

2. Importance of micronutrients in crop production: Increases quality & yield because most micronutrients act as cofactors in various enzymes taking part in the various metabolic activities of the plant like protein metabolism, carbohydrate metabolism, photosynthetic rate etc. therefore there will be increase in protein content, TSS and other quality parameters which results improving the quality and other micronutrients like iron, it is important for chlorophyll formation, photosynthesis will also increase and thus increase in yield.In legumes, it influences N_2-fixation because micronutrients like Fe and Mo is an important constituent of Nitrogenous enzymes, which helps in leghaemoglobin formation (O_2 scavenger).Major economic impact of micronutrient concentrations in a farming operation is through the increased efficiency of macronutrient fertilizer use.

3. Causes of micronutrient deficiencies: Intensive cropping, High demand of modern crop cultivars, Losses of top soil by erosion, Losses of micronutrients through leaching, Use of marginal lands for crop production, and the factors affecting availability of micronutrients are Soil pH, organic matter, Temperature, Moisture,

Dynamics of Micronutrients in Soils



1= absorption, 2= exudation, 3= adsorption, 4= desorption, 5= precipitation, 6= dissolution, 7= immobilization, 8= mineralization.

All these processes interact to control concentration of micronutrients in soils. Plants take nutrients from soil solution and absorb them through roots. Some exudates are secreted from plant roots which move into the soil solution. The various nutrient ions present in soil solution gets adsorbed on some minerals and also nutrient exchange takes place between these minerals and soil solution. As the environment of the soil changes, the nutrient from soil solutions gets precipitated. The precipitation also gets dissoluted into the soil solution**.** Various micro-organisms get convert organic into inorganic residues i.e. mineralization thus soluble form of nutrients gets available and also from soil solution, inorganic nutrients gets converted into organic i.e. taken by microbes which serve as organic source.

4. Management Tools to Help with Decision Making

Take soil and plant tissue samples from the affected and unaffected areas within the same field for a complete comparative analysis. This service is available from most soil testing laboratories. Call the laboratory for sampling details for a complete comparative test.

Keep good field records: know which fields had previous problems with micronutrients; soil test annually; and monitor each crop for symptoms. The amount of micronutrients varies with crop. Micronutrients are expensive in comparison to macronutrients, so site-specific management makes economic sense.

5. Role and Deficiency Symptoms of Micro-nutrients

Zinc: Zinc has been the micronutrient most often needed by western crops. It is common for Citrus crops to be given foliar zinc treatments one or more times per year. Other tree crops, grapes, beans, onions, tomatoes, cotton, rice, and corn have generally required zinc fertilization.

Unlike other metal ions such as copper, iron, and manganese, zinc is a divalent cation (Zn^{++}) that does not undergo valence changes and therefore has no redox activity in plants. High concentrations of other divalent cations such as Ca^{++} inhibit zinc uptake somewhat. Zinc acts either as a metal component of enzymes or as a functional, structural, or regulatory cofactor of a large number of enzymes. More than 80 zinc-containing proteins have been reported. The rate of protein synthesis and the protein content of zinc-deficient plants are drastically reduced. The accumulation of amino acids and amides in these plants demonstrates the importance of zinc for protein synthesis. Zinc is an essential component of RNA polymerase and if the zinc is removed, the enzyme is inactivated. Zinc is also a constituent of ribosomes and is essential for their structural integrity. The decrease in protein content of zinc-deficient plants is also the result of enhanced rates of RNA degradation. Higher rates of RNase activity are a typical feature of zinc deficiency (Rehm, 2010).

6. Symptoms of zinc deficiency in plants include, Decrease in stem length and shortening of internodes, rosetting of terminal leaves, reduced fruit bud formation. Mottled leaves, interveinal chlorosis. Sometimes, a red Spot-like discoloration (caused by anthocyanins) on the leaves often occurs. Symptoms of chlorosis and necrosis on older leaves of zinc-deficient plants are most likely the result of phosphorus toxicity, Dieback of twigs after the first year, Striping or banding on corn leaves (Jain, 2007).

Table 2: Residual effect of zinc and boron on yield of French bean

Treatment	No. of pods plant^{-1}	Pod length (cm)	Pod yield (q ha^{-1})
Control (RDF)	10.33	7.33	62.5997
Zn6 kg ha^{-1}	14.66	8.66	69.368
Zn12 kg ha^{-1}	15.33	9.00	77.1685
Zn18 kg ha^{-1}	19.33	11.13	90.7881
Zn6 kg ha^{-1}+B4 kg ha^{-1}	17.66	10.33	78.8178
Zn12 kg ha^{-1}+B4 kg ha^{-1}	23.33	11.83	95.3658
Zn18 kg ha^{-1}+B4 kg ha^{-1}	25.66	12.8	98.7155
SEm±	0.33	0.32	2.90
CD (p=0.05)	0.76	0.721	6.32

Source: Hamsa *et al*. (2012)

In rice-French bean cropping system, micronutrients were applied on rice and then there residual effect was studied on French bean.Pod yield, Pod length and number of pods/ plants are highest obtained from Zn18kg ha^{-1} + B4kg ha^{-1}because due to increase in starch production, protein production and increase in activity of certain enzymes such as ribosomes, acid phosphatases etc. in leaves and pods of residues of Zinc and Boron and interaction of residues of Zn and boron along with RFD (Table 2).

Iron: Iron (Fe) is required for the formation of chlorophyll in plant cells. It serves as an activator for biochemical processes such as respiration, photosynthesis and symbiotic nitrogen fixation. (Reddy, 2004) Iron deficiency can be induced by high levels of manganese or high lime content in soils. Iron is taken up by plants as ferrous (Fe^{2+}) or ferric (Fe^{3+}) ions. The function of iron in plants depends on the ready transitions between its two oxidation states in solution. Plants store iron as ferritin, a protein that encapsulates ferric iron. Under aerobic soil conditions, iron is largely insoluble as a constituent of oxides and hydroxides. Ferric iron tends to be tied up in organic chelates. Hence, the concentration of free iron in the soil solution is exceedingly low in many soils. Plants have mechanisms to mobilize iron and make it available for absorption by their roots. Some of these mechanisms are not specific to absorption of iron. Roots extrude protons and thereby lower the pH of the rhizosphere: the lower the pH, the higher the solubility and availability of iron. Roots also release organic acids into the soil. That has a dual effect on the availability of iron: it lowers the external pH and the acids may form soluble complexes with iron. There are two mechanisms specific to iron absorption. The first (characteristic of dicots and non-graminaceous monocots) acidifies the rhizosphere by extruding protons. Ferric iron is reduced to ferrous iron by an inducible Fe^{3+}reductase enzyme at the plasma membrane. The reduced iron is transported across the membrane by Fe^{2+} specific ion transport system. The second mechanism (characteristic of corn, barley, and oat) involves the extrusion of siderophores (Greek meaning “iron carriers”) by the roots. No reduction to ferrous iron takes place. Crops often affected by iron deficiency are corn, sorghum, certain soybean varieties, turf, and certain tree crops and ornamentals (Cannolly, 2002).

7. Symptoms of iron deficiency include interveinal chlorosis of young leaves. Veins remain green except in severe cases, Twig dieback, in severe cases, death of entire limbs or plants (Jain, 2007).

Manganese: Manganese serves as an activator for enzymes in growth processes. It assists iron in chlorophyll formation. It is part of the system where water is split and oxygen gas is liberated. The splitting of water is an oxidation, namely $2\ H_2O \rightarrow O_2 + 4\ H^+ + 4\ e^-$. The other protein in which manganese is an integral constituent is the manganese-containing superoxide dismutase. This enzyme is widespread in aerobic organisms. The function of this enzyme is to provide protection from free oxygen radicals formed when O_2 receives a single electron. Superoxide dismutases convert this highly toxic free radical into hydrogen peroxide (H_2O_2) which is subsequently broken down to water (Millaleo, 2010).

8. Symptoms of manganese deficiency include

Interveinal chlorosis of young leaves. Gradation of pale green coloration with darker color next to veins. No sharp distinction between veins and Interveinal areas as with iron deficiency. Development of gray specks (oats), interveinal white streaks (wheat), or interveinal brown spots and streaks in barley (Jain, 2007).

Boron: Boron functions in plants in differentiation of meristem cells. The general consensus is that its major function has to do with the structure of the cell wall and the substances associated with it. It is necessary for sugar translocation and helps in pollen grain germination. It is present in soil solutions with a pH less than 8 mainly as un- disassociated boric acid ($B(OH)_3$), the principle form taken up by roots, and disassociates to $B(OH)_4^-$ only at higher pH values (Gupta, 1993).

Boron deficiency is a widespread nutritional disorder. Under high rainfall conditions boron is readily leached from soils as $B(OH)_3$. Boron availability decreases with increasing soil pH, particularly in calcareous soils and soils with high clay content. Availability also sharply decreases under drought conditions, probably because of both a decrease in boron mobility by mass flow to the roots and polymerization of boric acid. Symptoms of boron deficiency in the shoots are noticeable at the terminal buds or youngest leaves, which become discolored and may die. Internodes are shorter, giving the plants a bushy or rosette appearance.

Chlorine: Chlorine is a strange mineral nutrient. Its normal concentration in plants is more typical of a macronutrient and yet the chlorine requirement for growth is more like a micronutrient. Chlorine is ubiquitous in nature and it occurs in aqueous solutions as chloride (Cl^-). Evidence indicates that it is highly mobile and its main higher plant functions relate to charge compensation and osmo-regulation. Because chlorine is usually supplied to plants from various sources (soil reserves, rain, fertilizer and air pollution) there is much more concern about toxic levels than about deficiency. Nonetheless, a few cases have been noted of positive responses to the application of chloride as a fertilizer for wheat.

Symptoms of chlorine deficiency include: A blue-green shiny appearance of young leaves, Wilting, followed by chlorosis, Excessive branching of lateral roots, Bronzing of leaves and Chlorosis and necrosis in tomatoes and barley (Jain, 2007).

Copper: Copper is present in plants in complex form. Like other potentially toxic heavy metals, copper in excess is bound to phytochelatins (Greek meaning "plant claws") and sulphur containing peptides. Copper in solution is present as cuprous (Cu^+) and cupric (Cu^{++}). Cuprous copper is readily oxidized to cupric and so cuprous copper is only found in complex forms. Cuprous complexes are usually colourless, whereas, the cupric complexes are often blue or brown. Copper is an activator of several enzyme systems in plants and functions in electron transport and energy capture by oxidative proteins and enzymes. It may play a role in vitamin A production (Rehm, 2009).

Symptoms of copper deficiency include: Leaves may be chlorotic or deep blue-green with margins rolled up, the bark of trees is often rough and blistered, and gum may exude from fissures in the bark, Young shoots die back.

Table 3: Effect of graded levels of copper application on the grain yield attributes straw yield and harvest index of wheat

Cu applied (mg kg^{-1})	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})	1000-grain weight (g)	Harvest index (%)
0	3.88	6.92	32.58	35.92
0.5	4.48	6.64	35.02	40.29
1.0	4.64	6.68	38.62	40.99
1.5	6.32	6.92	41.35	47.73
2.0	4.44	6.44	35.85	40.81
2.5	3.80	5.84	33.93	39.42
SE(d)±	0.98	-	1.54	2.39
CD(p=0.05)	2.06	NS	3.24	5.03

Source : Kumar *et al*. (2009)

Kumar *et al*. (2009) showed that the Copper application has significant effect on grain yield and harvest index but not on straw yield this may be due to fact that low copper favours the production of more number of tillers (Table 3). There was increase in grain yield attribute and harvest index with the increase in copper application up to their level of 1.5mg kg^{-1} and then decreases afterwards reason being that excessive copper reduces Fe translocation**.**

Molybdenum: Although molybdenum is a metal, it occurs in aqueous solution mainly as molybdate anion. Molybdate seems to be relatively mobile in plants and higher concentrations can be found in roots than leaves when supplies are limited. Molybdenum deficiency is widespread in legumes and certain other plant species grown in acid mineral soils with a large content of reactive iron oxide hydrates. Liming may increase molybdenum availability to the point where luxury consumption occurs. This may be dangerous to ruminant livestock, which are very sensitive to excessive concentrations of molybdenum. Plants generally have a wide range of acceptable molybdenum concentrations. High, but nontoxic, molybdenum concentration in seeds ensures proper seedling growth and higher final grain yield. There is an inverse relationship between seed molybdenum content and yield response to added molybdenum fertilizer. Uptake rate of molybdenum is extremely low in the first 4 weeks after germination. Thus, the molybdenum requirement has to be met by retranslocation from the seed.

Symptoms of molybdenum deficiency include Interveinal chlorosis. Veins remain green producing a mottled appearance, Stunting and lack of vigor. This is similar to nitrogen deficiency due to the key role of molybdenum in nitrogen utilization by plants.

Table 4. Number of tillers, number of grains, 1000-grain weight and grain yield of wheat as affected by different micronutrients

Treatments	Tillers (m^{-2})	Grains ($spike^{-1}$)	1000- grain weight (g)	Grain yield ($t\ ha^{-1}$)
Zn @ 5 kg ha^{-1}	206.0	44.25	40.54	3.15
Zn @ 10 kg ha^{-1}	220.8	37.75	43.22	3.15
Zn @ 15 kg ha^{-1}	195.5	45.75	41.56	3.20
Cu @ 6 kg ha^{-1}	226.5	41.00	41.68	3.38
Cu @ 8 kg ha^{-1}	249.0	39.75	41.56	3.62
Cu @ 10 kg ha^{-1}	190.0	43.00	44.02	3.05
Fe @ 8 kg ha^{-1}	190.0	42.00	42.24	2.86
Fe @ 12 kg ha^{-1}	210.8	40.25	44.02	3.24
Fe@ 16 kg ha^{-1}	201.8	44.25	42.66	3.26
Mn @ 8 kg ha^{-1}	229.8	43.00	41.31	3.60
Mn @ 12 kg ha^{-1}	190.3	44.25	43.00	3.06
Mn @16 kg ha^{-1}	218.5	39.25	42.80	3.14
B @ 1 kg ha^{-1}	195.5	45.25	41.39	3.15
B @ 2 kg ha^{-1}	212.0	46.50	42.58	3.67
B @ 3 kg ha^{-1}	201.0	43.25	43.06	3.19
Zn+Cu+Fe+Mn+B @ 5+6+8+8+1 kg ha^{-1}	194.0	46.00	43.65	3.30
Zn+Cu+Fe+Mn+B @ 10+8+12+12+2 kg ha^{-1}	216.3	43.50	39.67	3.29
Zn+Cu+Fe+Mn+B @ 15+10+16+16+3 kg ha^{-1}	190.0	41.00	44.64	2.96
LSD (p=0.05)	14.36	3.13	1.19	0.18

Source: Nadim *et al*. (2011)

Grains/spike and grain yield are highest obtained from B @ 2 kg ha^{-1} because boron is responsible for the translocation of food materials in plants and B@ 2kg ha^{-1} is optimum and thus it helps in more grain yield (Table 4).

9. Factors associated with supply and acquisition

Sufficient concentrations and available forms of micronutrients must be at or near root surfaces to meet plant acquisition needs. Nutrient supplies to plants are governed by such factors as concentrations inside plants and in soil solution, supply and chemistry at root surfaces or in the rhizophere, and interactions of one nutrient with another At any given time, concentrations of nutrients in the solution immediately adjacent to roots appear to be one of the best measures for assessing absorbtion potential, although plant and rhizosphere factors may influence the rates of absorption (Frageria *et al*., 1997).

1) Deficiencies and toxicities: Micronutrient deficiencies and toxicities are widespread and have been documented in various soils throughout world. The deficiency of essential micronutrients induces abnormal pigmentation, size and shape of plant tissues, reduces leaf photosynthetic rates, and leads to various detrimental conditions (Masoni *et al*; 1996) Specific deficiency symptoms appear on all plant parts but discoloration of leaves is most commonly observed. Deficiency and toxicity symptoms may be confused with drought, disease, insect and other damage so correct diagnosis may be difficult without experience. Critical concentration ranges of micronutrients in soil for important field crops (Table5). Some description of deficiency (already discussed in previous) & toxicity symptoms associated with many crop plants in Table 6 has been provided.

Table 5: Critical micronutrient concentration (mg kg^{-1}) in soil for some field crops

Element	Crops	Extracting solution	Critical concentration	
			Range	Mean
B	Alfalfa, sugarbeet	Hot water	0.1-2	0.8
Cl	Wheat, Barley, Oats	Water	>22	
		0.01M $Ca(No_3)_2$		
		0.05M K_2So_4		
		CaO		
Cu	Maize and small grains	NH_4HCO_3-DTPA	0.12-2.5	0.8
		Mehlich-1	0.1-10	3
Fe	Sorghum and soyabean	NH_4HCO_3-DTPA	2.5-5	4.8
	Sorghum	DTPA-TEA		4.5
Mn	Soyabean,	Mehlich-1	4-8	7
	Small grains	NH_4HCO_3-DTPA	1-2	1.4
				3
				3.9
Mo	Forages, Legumes	NH_4-oxilate	0.1-0.3	
Zn	Beans, Maize	NH_4HCO_3-DTPA	0.25-2	0.8
	Rice,Sorghum	Mehlich-1	0.5-3	1.1
	Maize	0.1M HCl	2-10	5
	Maize			0.86
	Rice			1

Table 6. General description of mineral toxicity symptoms on plants

B	:	High B may induce some interveinal necrosis, and severe cases turn leaf margins straw colour (dead) with distinct boundaries between dead and green tissue. Roots appear relatively normal.
Cl	:	High Cl results in burning leaf tips or margins, reduced lead size, sometimes yellowing, resembles K deficiency, and root tips die.
Cu	:	High Cu may induce Fe deficiency (chlorosis). Light colored leaves with red streaks along margins. Plants become stunted with reduced branching and roots are often short or barbed (like wire). Laterals may be dense and compact.
Fe	:	Excess Fe is a common problem for plants grown in flooded acidic soil. May induce P, K and Zn deficiencies. Bronze or blackish-straw colored leaves extending from margins to midrib. Roots may be dark red and slimy.
Mn	:	Excess Mn may cause leaves to be dark green with extensive reddish-purple specks before turning bronze yellow, especially interveinal tissue. Uneven distribution of chlorophyll. Margins and leaf tips turn brown and die. Sometimes Fe deficiency appears, and main roots become stunted with increased number and density of laterals.
Mo	:	Excess Mo induces symptoms similar to P deficiency (red bands along leaf margins), and roots often have no abnormal symptoms.
Zn	:	Excess Zn may enhance Fe deficiency. Leaves become light colored with uniform necrotic lesions in interveinal tissue, sometimes damping off near tips. Roots may be dense or compact and may resemble bared wire.
Ni	:	High Ni results in white interveinal banding alternating with green semi-chlorotic areas with irregular oblique streaking,dark green veins and brown patches. Yellowing of leaves may resemble Fe or Mn deficiency.
Co	:	Pale green leaves with pale longitudinal stripes.

Source: Clark and Baligar (2000)

2) Supply and uptake

Micronutrient uptake by roots depends on nutrient concentrations at root surfaces, root absorption capacity, and plant demand. Micronutrient acquisition includes dynamic processes in which mineral nutrients must be continuously replenished in soil solution from the soil solid phase and transported to roots as uptake proceeds. Mineral nutrient transport to roots, absorption by roots and translocation from roots to shoots occur simultaneously, which means that rate changes of one process will ultimately influence other processes involved in uptake (Frageria, 1997). In soil systems mineral nutrients move to plant roots by mass flow, diffusion, and root interception.

3) Oxidation and reduction

Oxidation –Reduction reactions occur when electrons are transferred from a donor to an acceptor. The donor loses electrons to increase in oxidation number, and the acceptor gains electrons to decrease in oxidation number. Redox reactions with various forms of Mn (Mn^{2+} and Mn^{4+}), Fe ($Fe^{2+}$and Fe^{3+}), and Cu (Cu^{+} and Cu^{2+}) are common in soils (Lindsay,1979). Redox reactions in soils can also be influenced by organic metabolites produced by roots and microorganisms.

4) Rhizosphere

The rhizosphere is defined as the zone of soil immediately adjacent to plant roots in which the kinds, numbers, and/or activities of microorganisms differ from those of the bulk soil. This zone usually contains fungi, bacteria, root and microorganism secretions, sloughed off or dead materials from microorganisms and roots, and chemical properties that are markedly different from the bulk soil. The chemistry of the rhizosphere has pronounced effects on the availability of micronutrients. An example of rhizosphere activity is mycorrhizae. Mycorrhizae associated with crop plants are primarily arbuscular mycorrhizal fungi (AMF).

5) Interactions with other elements

The understanding of micronutrient interactions between and among the various mineral nutrients is important for balancing nutrient supplies to plants, improving growth and yields of plants, and eliminating deficiencies and toxicities imposed on plants (Table 7 & 8). Mineral interactions are generally measured in terms of growth responses and changes in mineral nutrient concentrations in plants.

Table 7: Crop and soil conditions under which micronutrient deficiencies may occur

Micronutrient	Soil	Crop
Boron	Sandy soils or highly weathered soil slow in organic matter	Alfalfa and clover
Copper	Acid peats or mucks with pH <5.3 and black sands	Wheat, oats, corn
Manganese	Peats and mucks with pH > 5.8, black sands and lakebed/depressional soils with pH > 6.2	Soybeans, Wheat, Oats, Sugarbeet, Corn
Zinc	Peats, mucks and mineral soils with pH > 6.5	Corn and Soybeans
Molybdenum	Acid prairie soils	Soybeans

Source: Kelling (2005)

Table 8. Micronutrient sources commonly for correcting micronutrient deficiencies in plants

Micro-nutrients	Common fertilizer sources
B	Sodium tetraborate (14-20%B), Solubor(20%B), Liquid boron (10%B), Boric acid (17% B)
Fe	Ferrous ammonium sulfate(14%Fe),Ferrous ammonium phosphate (29%Fe)
Zn	Zinc sulfate (23-36%Zn), Zinc ammonium complex (10%Zn), Zinc oxide (50-80%Zn), Zinc chelate (9-14%Zn)
Cu	Copper sulfate(13-35%Cu),Copper oxide(75-89%Cu)
Cl	Potassium chloride (47%Cl), Sodium chloride (60% Cl), Ammonium chloride (66%Cl), Calcium chloride (64%Cl), Magnesium chloride (74%Cl)
Mn	Manganese sulfate (23-25%Mn), Manganese oxide (41-68%Mn)
Mo	Ammonium molybdate (54%Mo), Sodium molybdate (39%Mo), Molybdenum trioxide (66%Mo), Molybdic acid(53%Mo)
Ni	Nickle chloride (25%Ni), Nickle nitrate (20%Ni), Nickle oxide (79%Ni)

Source: Singh (2004)

10. Method of Application

The best method of micronutrient application depends on the element and when the deficiency is being addressed (Table 9).

Table 9: Methods of correcting micronutrient deficiencies

Micro-nutrients	Soil application	Foliar application
B	0.75-7 kg Borax/ha	0.1-0.25%B solution
Cl	20-50kgKCl/ha	Unknown
Cu	1-20kg $CuSO_4$/ha(every 5-10 years)	0.1-0.2% solution $CuSO_4.5H_2O$ or 0.1-4kg Cu/ha as $CuCl_2.2H_2O$, $CuSO_4.5H_2O$ or CuO
Fe	30-100kg $FeSO_4$ or FeEDDHA/ha (need annual treatment of 0-10 kg/ha)	2% $FeSO_4.7H_2O$ or 0.02-0.05%FeEDTA solution (several sprays needed)
Mn	5-50kg $MnSO_4$/ha	0.1% $MnSO_4$ H_2O solution or 3-6kgMn/ha
Mo	0.01-1kg ammonium molybdate or lime to pH 6.5	0.07-0.1% Na or ammonium molybdate (100gMo/ha)
Zn	0.5-35kg $ZnSO_4$ or ZnEDTA/ha	0.1-0.5% $ZnSO_47H_2O$ solution (0.17-1.5 kg/ha)

Source: Baligar and Jones (1997)

11. Future Strategies of Research

Screening and/or breeding of micronutrient efficient crops and their cultivars should be done on a priority basis, and more importantly, nutrient efficient crop rotations should be recommended to farmers of the State, particularly those on deficient soils. Systematic studies to monitor micronutrient deficiencies in different crop rotations and soils should be carried out using GIS. The entire state may be covered once in 2 to 3 years and repeat survey should be done after 4 to 5 years to monitor the trends. In addition, critical limits for main crops of the State should be refined for different soils. Limited information is available on emerging deficiencies of B and Cu in the State and on the response of different crops to application of Cu and B in deficient soils. More field experiments should be initiated to generate information on response, critical limits and their efficient management under field conditions (Sadana *et al.*, 2010).

12. Conclusion

World over micronutrients are gaining much importance not only for their role in sustaining higher crop yield but such increased nutritional deficiency in soil, seed and/or feed, is more affected animal and human health. Micronutrients are required relatively in smaller quantities (<100 ppm). These include: B, Fe, Zn, Cl, Mn, Mo & Ni whenever, the supply of one or more of these elements is inadequate, yields will be reduced and the quality of crop is impaired, but crop species, cultivars vary considerably in their susceptibility to deficiencies. Micronutrients may be minor in terms of the amounts needed by the crop, but they can be major in terms of their impact on crop growth (Zayed *et al.*, 2011). Micronutrients often act as co-factors in enzyme systems and participate in redox reactions, in addition to having several other vital functions in plants. Micronutrients are vital for plant growth and human health. Soil and foliar applications are the most prevalent methods of micronutrient addition but the cost involved and difficulty in obtaining high quality micronutrient fertilizers are major concerns with these in developing countries. Micronutrients are essential to plant growth, yet are required in much smaller amounts than macronutrients. Studies of the roles of nutrients in plants have involved several diagnostic criteria that address the accumulation of nutrients and their roles in plants. These criteria include visual diagnosis, plant analysis, biochemical tests, and soil tests. Factors such as soil pH, organic matter, temperature, moisture & light are important in determining the availability of micronutrient (Fageria *et al.*, 2001). If micro nutrient deficiency will occur, some fertilizer sources will correct them e.g; in case of boron, fertilizer source is sodium tetraborate (14-20% B), in case of Zn, fertilizer source is Zinc sulfate (23-36% Zn) &

Zn-chelate (9-14% Zn) and in case of iron, fertilizer source is ferrous ammonium sulfate (14% Fe) & ferrous ammonium phosphate (29% Fe), (Hansch, 2009). Methods of correcting micronutrient deficiencies for field crops can be either by soil application or foliar application, but foliar application is more efficient than soil application because it is quickly taken up by the plants (Fageria *et al.*, 2001). Micronutrients are required in very small quantities by the plant for their function. To manage micronutrient deficiencies, spraying of suitable chemicals at recommended levels by foliar application will alleviate the deficiency which in turn improves crop yield.

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New Chemistry and Insect Pest Management

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1. Introduction

Agriculture plays a vital role in India's economy. Over 58 per cent of the rural households depend on agriculture as their principal means of livelihood. Over the recent past, multiple factors have worked together to facilitate growth in the agriculture sector in India. Agricultural production in India increased dramatically during the last four decades due to newer technologies like high yielding crop varieties, chemical fertilizers and pesticides, as well as expansion of cropped arealeading to food self-sufficiency through. India's population has been growing at an annual rate of 1.8 percent, and is expected to touch 1.3 billion marks by 2020 and would require an additional food grain of about 2 million tonnes a year. The increase in the food production in the future must come from the land already under cultivation with adoption of new technology without any time lack. The second green revolution will focus on maximizing the benefits of the first phase and minimizing or elimination of its drawbacks. India has achieved self-sufficiency in food grain production, concerns of food security will remain as ever, due to decline in area under cultivation with limited scope to bring additional land under cultivation and degradation of natural resources. The agricultural production technology has started showing signs of fatigue due to multiple factors. The climate change will also have impact on uncertainty in productivity. This requires the diffusion of new technologies that produce sufficient food and protect the environment and human health. Insect pests, diseases and weeds inflict enormous losses to the potential agricultural production. Anecdotal evidences also indicate rise in the losses, despite increasing use of chemical pesticides. There is a rising public concern about the potential adverse effects of chemical pesticides on the human health, environment and biodiversity. These negative externalities, though, cannot be eliminated altogether; their intensity can be minimized through development, of new safe molecules.

2. Potential and Emerging Pests

Insect pests attack the crop from sowing to maturity. With passage of time the number of sprays on different crops increased due to development of resistance to insects, cropping pattern and appearance of secondary and minor pests, loss of biodiversity and simplification of crop ecosystem. Pest problems will become more serious due to climate change (Table 1). The rise in temperature will help the pests to complete more generations and extension to new areas.

3. Losses Due to Insect Pests

Insect pests, diseases and weeds are the major constraints limiting agricultural productivity growth. It is estimated that herbivorous insects eat about 26 percent of the potential food production. The percent loss due to pests increased from in green revolution era to after era of green revolution an increase by 2.5 per cent inspite of advancement in technology.. The estimated losses due to pests are Rs 90,000 crores.

4. Pesticide Scenario

The total installed capacity of technical grade pesticides is approximately 140,000 tpa. Out of the 237 pesticides or combinations are registered in the country, including 83 insecticides, 56 fungicides,40 herbicides and10 growth promoters. Combination products insecticide, fungicides and herbicides registered are 12, 10 and 8, respectively. More than 85 technical grade pesticides are manufactured in India. Cotton, rice and wheat growers account for almost 70 per cent of pesticide consumption. There are 125 technical grade producer units and 800 formulators units

The pesticide demand is close to 90,000 MT per annum. India's pesticide industry is the largest in Asia and the twelfth largest in world with annual market of Rs. 40260 million (including exports) covering agriculture, horticulture, part of public health and household, etc. The consumption is very low 0.381 kg in India against 16.56 kg in Republic of Korea. The cropped area under pesticide umbrella was 137.00 million ha in seventh plan.

5. Insecticides and Pest Management

Many new groups of insecticides with different modes of action are being developed and introduced for crop protection. The insecticides based on mode of action are classified by IRAC in 28 groups. A number of novel insecticides with unique mode of action were registered during the late 1990s and early 2000s for insect control and played an dominant role in insect pests integrated pest management due to constraints in adoption of cultural practices, lack of varieties resistance to insect pests and non availability of effective bio agents. In fact, IPM Is referred as the judicious use of insecticides. New insecticide class and ingredients introduced after 1995 are referred as new chemistry.

Groups for "Old" Classes & Active Ingredients (pre-1995): includes four classes: Carbamates, organophosphates, Organochlorines and Pyrethroids.

New chemistry: They belong to different groups and have different mode of action and are given in Table 1

Table 1: Classification of newer insecticides

S.No.	Class of the insecticides	Name of the insecticides
1.	Neonicotinoids	Imidacloprid, Acetamiprid, Thiacloprid, Thiamethoxam, Clothianidin, Dinotefuran,
2.	Phenyl pyrazoles	Fipronil
3.	Oxadiazines	Indoxacarb
4.	Pyrrole	Chlorfenapyr
5.	Pyridine Azomethines	Pymetrozine
6.	Diamide	Flubendiamide, Chlorantriniliprole
7.	Pyridine carboxamid	Flonicamid
8.	Tetronic Acid Derivatives	Spiromesifen
10.	Tetramic Acid Derivative	Spirotetramat
11.	Bacterial Fermentation Products	Spinosyns,
12.	Dichloropropenyl Ethers	Pyridalyl
13.	Benzoylphenyl urea	Novaluron, Buprofezin

Table 2. List of insect pests likely to become serious due to changes in ecosystems and habitats

Insect pest	Scientific name
American bollworm	*Helicoverpa armigera* (Hubner)
Whitefly	*Bemisia tabaci* (Gennadius)
Brown planthopper	*Nilaparvata lugens* (Stal)
Green leafhopper	*Nephotettix* spp.
Serpentine leaf miner	*Liriomyza trifolii* (Burgess)
Fruit fly	*Bactrocera* spp.
Mealy bugs	Several species
Thrips	Several species
Wheat aphid	*Macrosiphum miscanthi* (Takahashi)
Pink stem borer	*Sesamia inferens* (Walker)
Gall midge	*Orseolia oryzae* (Wood-Mason)
Gall midge	Several species
Diamond back moth	*Plutella xylostella* (Linnaeus)
Hoppers	Several species
Pyrilla	*Pyrilla perpusilla* (Walker)
Polyphagous pests like termites, white grubs, hairy caterpillars and tobacco caterpillar	Several species

6. Advantages of New Insecticides

- *Lower Mammalian Toxicity*:- It allows for short re-entry and pre-harvest intervals, allowing the insecticides to be easily incorporated into pest control programs.
- Less Resurgence problem
- Short restricted entry intervals (REIs)
- Environmental protection
- *Pest management-Selectivity*:- greater selectivity to target specific species, so they are less likely to harm natural enemies.

7. Newer Insecticides and Pest Management

Neonicotinoids: Neonicotinoids are the most effective insecticides for the control of sucking insect pests such as aphids, white flies, leaf and plant hoppers, thrips, and some micro lepidoptera and a number of coleopteran pests. Their broad spectrum of efficacy, together with systemic and translaminar action, pronounced residual activity and a unique mode of action, make the neonicotinoids the most rapidly expanding insecticidal class since the launch of the first compound, imidacloprid, by Bayer Crop Science in 1991. Six additional neonicotinoid insecticides were launched: nitenpyram (Sumitomo Chemical Takeda Agro Company, 1995), acetamiprid (Nippon Soda, 1995), thiamethoxam (Novartis, 1998), thiacloprid (Bayer Crop Science, 2000), clothianidin (Sumitomo Chemical Takeda Agro Company, Bayer Crop Science, 2000) and dinotefuran (Mitsui Chemicals, 2002). They act on the central nervous system of insects. Their action causes excitation of the nerves and eventual paralysis, which leads to death. Because they bind at a specific site (the postsynaptic nicotinic acetylcholine receptor), they are not cross-resistant to the carbamate, organophosphate, or synthetic pyrethroid insecticides, which was an impetus for their development.

Imidacloprid: Imidacloprid is a systemic neonicotinoid insecticide and upon the nervous system, causing blockage of postsynaptic acetylcholine receptors. Because of the systemic mode of action and low toxicity to humans, imidacloprid has become a popular insecticide worldwide for use in ornamentals, field crops and vegetables and is registered in approximately 120 countries and is used on over 140 different agricultural crops. In the field, imidacloprid used as a seed treatment, is linked to alteration in foraging, recruitment, and mortality of honey bee, *Apis mellifera* (L.).

Acetamiprid: Acetamiprid is a systemic neonicotinoid insecticide developed by M/s Nippon Soda Co. Ltd., for use against sucking insects, such as jassid, planthoppers, aphids and whiteflies, on leafy vegetables, cole crops, citrus, cotton, ornamentals, and fruiting vegetables. It acts on the central nervous system causing irreversible blocking of the postsynaptic nicotinergic acetylcholine receptors Acetamiprid degrades rapidly and poses low risks to the environment

Thiacloprid: Thiacloprid is a neonicotinoid insecticide with systemic properties It has activity not only against sucking insects such as aphids, whiteflies, and some jassids but is also active against weevils, leafminers, and *Cydia pornonella* in apples and various species of beetles. On the basis of its high insecticidal activity with a favourable ecological profile and safety to bees, it is particularly useful in horticulture as well as in modern crop protection systems. Like other chloronicotinyl insecticides, thiacloprid acts selectively on the insect nervous system as an agonist of the nicotinic acetylcholine receptor (nAChR).

Thiamethoxam: Thiamethoxam is a novel neonicotinoid belonging to sub class of thianicotinyl compounds and it represents the first example of second generation neonicotinoids with a unique structure and outstanding insecticidal activity introduced by Novartis. This is a systemic insecticide for soil and foliar applications and control a variety of pests such as aphid, whiteflies, thrips, beteles, leaf hopper, bugs and borers in fruiting, corn, tuberous vegetables, cotton and fruits. Thiamethoxam’s chemical structure is slightly different than the other neonicotinoid insecticides, making it the most water soluble of this family. Because of its greater water solubility, it moves readily in plant tissue The compound shows contact as well as exceptional systemic activity.

Clothianidin: Clothianidin is a novel, highly effective systemic and contact insecticide exhibiting low mammalian toxicity. Clothianidin is active on hemipteran pest species in particular, such as aphids, leafhoppers and planthoppers, and also on many coleopteran and some lepidopteran pest species with a low application. Like other neonicotinoid insecticides, clothianidin also acts as an agonist at the nicotinic acetylcholine receptors (nAChR) located in the central nervous system at much lower concentration in insects than in.

Dinotefuran: Dinotefuran is a new neonicotinoid developed by Mitsui Chemicals and has a characteristic tetrahydro-3-furylmethyl group instead of the aromatic heterocyclic ring that was previously considered indispensable for insecticidal activity of neonicotinoids. It has excellent insecticidal properties and offers excellent control of a wide variety of pests in many kinds of crops. particularly hemiptera, lepidoptera, coleoptera, diptera, dictyoptera and thysanoptera. Dinotefuran acts through contact and ingestion and results in the cessation of feeding within several hours of contact and death shortly after. Dinotefuran was granted Organophosphorus Alternative and Reduced Risk Status by the EPA. Dinotefuran is water-soluble and has excellent systemic and translaminar action in many plants.

8. Phenyl Pyrazole

Fipronil : Fipronil is a phenyl pyrazole insecticide first synthesized by M/S Rhône Poulenc Ag Company (now Bayer Crop Science) introduced for use in 1993. It has contact, systemic and ingestion activity. Fipronil is applied at low doses, is effective against a wide range of crop pests, notably rice(stem borer),sugarcane (early shoot borer, termite),cole crops (diamond back moth, chilli (thrips)and cotton (thrips). Fipronil is effective against insects that are resistant to other chemical such as pyrethroids, organophosphates and carbamates. Fipronil act by interfering with the passage of chloride ions through the γ-aminobutyric acid regulated chloride channel, thereby disrupting central nervous system activity and causing death. This causes the over-excitation of the muscles and nerves of infected insects, causing them to death. It belongs to toxic category of pesticides.

9. Oxadiazines

Indoxacarb: Indoxacarb is the first commercialized insecticide of the oxadizine and is a mixture of R & S isomer in the ratio of 25:75. The active isomer is S-isomer. This insecticide has a novel mode of action and acts by inhibiting sodium ion entry into nerve cells, resulting in paralysis and subsequent death of pests. It acts primarily as a stomach poison as well as by contact action. Indoxacarb is effective against lepidopteran pests of rice, cotton, soybean, chickpea, cabbage and pigeon pea and is considered a reduced risk pesticide with low mammalian toxicity and a benign profile for avian and aquatic toxicity as compared to that of conventional insecticides.

10. Pyrrole

Chlorfenapyr: Chlorfenapyr is the first commercial pesticide to be derived from a class of microbially-produced compounds known as halogenated pyrroles and was synthesized in 1988 from a naturally-produced chlorinated pyrrole, Chlorfenapyr is a 'proinsecticide', i.e., it requires activation through metabolism. The parent compound is converted to a metabolite, which functions as an uncoupler of oxidative phosphorylation at mitochondria. It has broad spectrum activity against many species of coleoptera, lepidoptera, acarina and thysanoptera. It is mainly a stomach toxicant, but has some contact activity. Chlorfenapyr works by disrupting the production of adenosine triphosphate. resulting in disruption of production of ATP, cellular death, and ultimately mortality.

11. Pyridine Azomethine

Pymetrozine: Pymetrozine a novel pyridine azomethine insecticide, is highly specific against sucking insect pests. Its unique mode of action is not yet entirely understood, but it affects the nerves controlling the salivary pump and causes immediate and irreversible cessation of feeding due to an obstruction of stylet penetration, followed by starvation and insect death. The compound is a powerful toxicant against aphids [*Aphis gossypii* Glover and *Myzus persicae* (Sulzer)], whiteflies (*Bemesia. tabaci* and *Trialeurodes vaporariorum)* and brown planthopper [*Nilaparvata lugens* (Stal)]. Pymetrozine has systemic and translaminar activities and can be used as drench or foliar application. The compound appears to have great promise in IPM programmes due to its high degree of selectivity, low mammalian toxicity, and safety to birds, fish and non target arthropods.

12. Diamides

Flubendiamide: Flubendiamide belongs to phthalic acid diamide developed by Bayer Crop Science, Germany in collaboration with Nihon Nohyaku Co. Ltd., Tokyo, Japan and introduced in many countries during 2005-2007. It has a novel biochemical action as it affects calcium ion balance irrespective of sodium or potassium ion balance, which causes contraction of insect skeletal muscle. Flubendiamide is mainly effective for controlling lepidopteron pests including resistant strain in pulses, rice, cotton, corn, grapes, other fruits and vegetables. It very effective against lepidopterous pests including *Helicoverpa spp, Spodoptera spp, Plutella spp, Trichoplusia spp* and *Hyrotis spp*.

Chlorantraniliprole: Chlorantraniliprole, belongs to a new chemical class, the anthranilic diamides, and has a novel mode of action as an activator of insect ryanodine receptors, causing rapid muscle disfunction and paralysis. This insecticide is effective against lepidopteran pests as well as against selected species in the orders coleoptera, diptera and hemiptera. Chlorantraniliprole is classified as a reduced-risk pesticide. The key biological attributes of chlorantraniliprole are its selectivity profile towards non-target organisms and its long-lasting activity against target pest species particularly in term of the speed to cause cessation of feeding.

13. Pyridine carboxamid

Flonicamid: Flonicamid, a novel compound with a unique mode of action, has contact activity and is upwardly systemic. Flonicamid effectively manages populations of aphids, thrips, leafhoppers, plant bugs and other sucking insects on cereal, cotton, potatoes, pome fruit and vegetables. It has no negative impact on beneficial insects or natural enemies. This compound acts as an antifeedant and a behavioral modifier resulting in insect mortality from starvation within 5 to 7 days after exposure. Flonicamid inhibits aphid feeding by inhibition of stylet penetration to the plant tissue. The feeding disruption appears to be related to the neurological effect of flonicamid, resulting in death from starvation. Thus the insecticidal properties of flonicamid are similar to those of pymetrozine.

14. Tetronic Acids Derivative

Spiromesifen: Spiromesifen is a novel insecticide/acaricide belonging to the new chemical class of spirocyclic phenyl-substituted tetronic acids, recently introduced by Bayer Crop Science, Spiromesifen is especially active against whiteflies (*Bemisia spp*. and *Trialeurodes spp*.) and spider mite (*Tetranychus spp*). It has new mode of action that leads to the inhibition of the fat synthesis in the target pest and acts as lipid biosynthesis inhibitor. Spiromesifen has a low toxicity to honeybees and bumblebees and extremely effective against pyriproxyfen and neonicotinoid resistant Q-type whiteflies. Therefore it is an excellent resistance management tool in combination/rotation strategies. Spiromesifen is considered as harmless (category 1) to parasitoid *Eretmocerus mundus* Mercet.

15. Tetramic Acid Derivative

Spirotetramat: Spirotetramat, a novel insecticide belonging to chemical class of ketoenols is a tetramic acid derivative. It interfere with lipid biosynthesis, leading to death of juvenile within two to ten days after application. It is effective against a wide spectrum of sucking insects including wolly and green apple aphid, san jose scale, pear psylla, scale on peach and grape mealy bug and grape phylloxera etc. It is systemic in action, xylem and phloem mobile, allowing acropetal and basipetal translocation in the plant. After foliar application spirotetramat penetrates through the leaf cuticle and is translocated as spirotetramat-enol via xylem and phloem, up to growing shoots and down to roots. This two-way systemicity (phloem and xylem transport) ensures the control of hidden and soil living sucking pests after foliar application and protects new shoots.

16. Bacterial Fermentation Product

Spinosad: Spinosad is active on various insect pests, especially lepidopteran, thysanopterans, dipterans and termites. It acts by depolarizing insect neurons involving acetylcholine and GABA receptors. Spinosad is classified as reduced-risk product due to its unique mode of action, coupled with high degree of activity against targeted pests, low toxicity to mammals, fish, birds, wildlife and human beings, and of course, beneficial arthropods and may be used as an alternative to conventional insecticides in integrated pest management program. Due to its safety profile and biosynthesis during fermentation of *S. spinosa*, spinosad has been classified as bioinsecticide. Spinosad is registered in many countries for controlling lepidopteran and dipteran pests in fruit trees, ornamental plants, field- and vegetable crops. Spinosad exhibits wide margins of safety to many beneficial insects.

Emamectin benzoate: `Emamectin benzoate is a novel non-systemic insecticideand is derived from a natural fermentation product, avermectin $B_{1.}$ It is highly toxic to a broad range of lepidoptera pest species at very low concentration and penetrates leaf tissues by translaminar movement. It is neuroactive- affects ion transfer through cell membranes (chloride channel activator). The avermectins act by disrupting nerve impulses by a unique mode of action. It paralyses the lepidoptera larvae, which stop feeding within hours of ingestion, and die 2-4 days. Avermectin B1 (abamectin) is nother semi-synthetic avermectin derived from fermentation of avermectin B1. Emamectin benzoate against the American bollworm, *Helicoverpa armigera and* lepidoptera pest species in vegetable and fruit crops

Milbemycins: It is isolated from soil bacteria, *Streptomyceshygrosscopius* and is *e*ffective against mites and aphids.

Diabroctins: It is isolated from bacteria, *Baccilussubtilis* and *Bacilluscereus* and is effective against Colorado potato beetle

17. Dichloropropenyl Ethers

Pyridalyl: Pyridalyl is the only member of class propyl ether and effective against various lepidopterous and thysanopterous pests on cotton and vegetables, without phytotoxicity. Pyridalyl has outstanding insecticidal efficacy toward lepidopterous pests, including the diamondback moth, *Plutella xylostella*, *Helicoverpa armigera* and the tobacco cutworm, as well as against *Tysanopteran* insects, including *Thrips palmi*. Thisnovel insecticide invented and developed by Sumitomo Chemical Co., Ltd. in 1998. Pridalyl is environmentally friendly insecticide that is suitable for use in IPM systems, as it possesses a high level of safety for humans, animals and fish; and it has minimal impact upon natural pest predators, such as parasitic wasps, pirate bugs (*Orius strigicollis*), lacewing, ladybugs, predatory mites and spiders, as well as on pollinating insects, such as the honey bee and the bumble bee.

18. Benzoylphenyl urea

Novaluron: Novaluron is an insecticide of the benzoylphenyl urea class of insect-growth regulators (IGR). It is a relatively new chitin synthesis inhibitor, that inhibits the chitin formation on larvae of various insects (lepidoptera, coleoptera, homoptera and diptera). It has a potent insecticidal activity against several important foliage feeding insect pests. Novaluron is powerful suppressor of lepidopteran larvae such as *Spodoptera littoralis* and *Helicoverpa armigera* (Hübner) (by ingestion) and of cotton whitefly larvae *Bemisia tabaci* (Gennadius) (by contact). This insecticde is far more active in suppressing developing stages of the leafminer *Liriomyza huidobrensis* (Blanchard)

Buprofezin: Buprofezin belongs to class thiadiazin and is good insect growth regulator effective against the nymph stages of whitefly, scales, mealybugs, planthoppers, and leafhoppers by inhibiting chitin biosynthesis, suppressing oviposition of adults, and reducing viability of eggs. Buprofezin suppresses embryogenesis and progeny formation of *B. tabaci*. Non-systemic insecticide with contact and stomach action, and repellent properties and gives rapid knockdown and long residual activity.

19. Pyridine

Pyriproxyfen: It is a pyridine based pesticide which is found to be effective against a variety of arthropods and was introduced to the US in 1996 to protect cotton crops against whitefly. Pyriproxyfen is a juvenile hormone analogue, preventing larvae from developing into adulthood and thus rendering them unable to reproduce. It prevents them from maturing into reproductive adults and cause morphological abnormalities and disrupts the normal development of immature stages of insects, leading to sterility or death.

20. Carbazate miticides

Bifenazate: It is neuroactive but exact MOA is unknown and **e**ffective against spider mites in fruiting vegetables, cucurbits.

21. Diacylhydrazines

Methoxyfenozide (Intrepid): Intrepid is a member of the general class of chemicals diacylhydrazines and are commonly known as MAC's (molt accelerating compounds). Insects affected by this material begin to molt (shed their skin) and cannot complete this cycle. Intrepid must be eaten to be effective. It is probably most effective against young larvae. The two other insecticide of this group is tebufenozide and halofenozide. It can be used on crops likeapple, pear, berries, cole crops, leafy & fruiting vegetables, ornamental herbaceous plants, shrubs. It is effective against leaf rollers, webworms, armyworms, cabbageworms, diamondback moth

22. Conclusion

Insecticides are critical input for reducing damage due to pests Insecticide resistance, indiscriminate use, poor decision by user, improper spray technology and delay in technical flow of knowledge are the critical problem for management of pests. Major impetuses for the adoption of these chemistries include human health and environmental concerns. Newer insecticides have lower mammalian toxicity, much safer for natural enemies, less residual toxicity, environmental protection, less resistance and resurgence problems and pest management-selectivity. These insecticides are more suitable for controlling pests under various IPM programmes. Failure of insecticides during last decade due to lack of insecticide resistance management resulted in collapse of insecticide as key component pest management. New chemistry is not cost effective and use of under dosages may aggravate the resistance management. Moreover, the use of new chemistry is without any resistance management strategy from scientific instituting and industry. The failure of imidacloprid is one example where dosages have gone up three times. In spite of good chemistry for management of whitefly on cotton, insecticide fail to provide effective control. The Insecticide Act also fail to address this problem. The pesticide industry with extensive network must address the issue on priority.

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Integrated Pest Management: an analysis of Challenges and future Strategies

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1. Introduction

A spouse indicated the marriage partner, he or she called “our wife or our husband”, not “my wife or my husband,” Closing gaps in crop yield while enhancing sustainability is among the greatest challenges for achieving food security. Ecological intensification, the improvement of crop yield through ecosystem services provided by biodiversity, may be a sustainable pathway. However, data supporting such an approach are missing, especially for two billion smallholders, many of which are undernourished. It is beyond doubt that Integrated Pest Management is the powerful tool in the hands of farming community engaged in sustainable agriculture. In one hand, it has played a crucial role in enhancing the yield potential in the sustainable way to meet out the burgeoning population demand and on the other to keep the natural resources (land and water) and environment safe for the future farming generations to come. But, the scenario has been different in many developing countries having small area to feed or support the rapidly growing population, where IPM has started some 20 years late rather than developed countries and could not keep the essence of IPM intact in achieving the mandate of an IPM programme. Chemical pesticides have been set as the last resort in IPM practices, but farmers still applying the pesticides as the first resort for getting quick results. At the same time, pesticides proved to be more dangerous due to their indiscriminate and excessive use, contaminating food (milk, honey, cereals, vegetables, and fruits) and the environment (ground water, soil, etc.), resulting in pest resistance, pest resurgence, loss of beneficial fauna, pesticide poisoning and frequent localizedpest outbreaks (Abrol and Shankar, 2014). We have travelled a long way of five decades since the inception of economic threshold level by Stern et al. in 1959 and at this juncture we have to redefine and analyze the challenges and strategies of IPM particularly in developing countries to boost the safe and sustainable food production. Growing population pressure has hastened environmental degradation and depletion of essential natural resources (UNFPA 2008). Nearly 1 billion people in the world are undernourished or suffer from chronic diseases as a result of food insecurity due to population growth, climate change, and urban development (FAO 2010). In the next 50 years, the global population is expected to reach 9 billion, doubling the demand for food, feed, and crop (FAO 2009). According to World Health Organization (WHO), more than 20,000 unintentional deaths and 3 million poisonings occur due to misuse of pesticides in the Third World every year (Lowel 1998). Available estimates reveal that global pesticide use has increased 50-fold since 1950, and 2.5 million tonnes of agricultural pesticides are now used each year worldwide (Tyler, 2002). No doubt pesticides are credited to have saved millions of lives by controlling diseases, such as malaria and yellow fever which are insect borne; however, their use causes a variety of adverse health effects and environmental pollution as described above. Alternate pest control methods and the restricted use of pesticides can minimize the risk of pesticide usage (Soundararajan, 2012). Pesticides can prove to be the most effective instruments in crop protection and if correctly used, their effect is fast and complete, which makes them applicable against nearly every pest (Oomen and Bouma, 2003). However, the introduction of high inputs of agro-chemicals during the Green Revolution era have proved to be more dangerous due to their overuse, which resulted in the deterioration of soil and plant health, pesticide contamination of food and the environment, and pesticide resistance and pest outbreaks. Consequently, the need arose for IPM strategies to produce safe food and reduce the negative externalities caused by pesticides (Kogan, 1998; Wilson and Tisdell, 2001; Abrol and Shankar, 2012; Shankar and Abrol, 2012a). In the near future, these challenges are expected to worsen further if measures are not taken to address them.

2. Scenario of IPM in India

In India, Integrated Pest management has mostly remained as an academic exercise, and could not be able to leave THE long term impressions in terms of its implementation and adoption among the farming community. It is the matter of grave concern that farmers are not willingly coming forward to adopt the IPM technology due to lack of proper knowledge. World-wide integrated pest management (IPM) is the accepted policy decision for pest management. However, in reality this often becomes “integrated pesticide management”. The strategy of IPM and its implementation and evaluation has always struggled with interpretation and true progress (Peshin and Pimentel, 2014).There are several challenges in successful implementation and adoption of Integrated Pest management programme which include-

3. Scenario of Pesticide Pressure or Integrated pesticide management

Worldwide, about 4 million tons of pesticides per year are used although their distribution is uneven in different countries (FAOSTAT 2010). Despite the fact that the consumption of pesticides in India is still very low, about 0.5 kg/ha of pesticides against 6.60 and 12.0 kg/ha in Korea and Japan, respectively, there has been a widespread contamination of food commodities with pesticide residues, basically due to non-judicious use of pesticides. In India, 51% of food commodities are contaminated with pesticide residues and out of these, 20% have pesticides residues above the maximum residue level values on a worldwide basis (Gupta, 2004). Among the various pesticides used in India, 40% of all the pesticides used belong to organo-chlroine class of chemical pesticides [FAO, 2005; Gupta, 2004]. The other major category is organophosphate pesticides. Regarding the usage of technical pesticides, insecticides account for 80% of total pesticide used in the country, followed by herbicides and fungicides. Globally herbicides are the leading category followed by insecticides and fungicides. In India, the share of herbicides is insignificant [MAFF, 1999-2000]. Lack of training in pesticide use, ignorance about potential dangers to health and environment, poor literacy, inappropriate mixing and application methods, repeated and excessive dosage of pesticides application are some related factors relevant to pesticide usage and safety measures in India (Abhilash and Singh, 2009).

Although pesticides are generally profitable in agriculture, their use does not always decrease crop losses. For example, despite the more than 10-fold increase in insecticide (organochlorines, organophosphates, and carbamates) use in the United States from 1945 to 2000, total crop losses from insect damage have nearly doubled from 7 to 13% (Pimentel *et al.*, 1991). Still farming community is using the excessive and indiscriminate use of pesticides. Pesticides continue to play the key role in arthropod pest management. However, some key species (*Heliothis armigera* Hubner, *Plutella xylostella* L.) are developing high levels of insecticide resistance and with the human and environmental health concerns related to pesticide use, cultural techniques are increasingly being used. The combination of genetic resistance, hygiene, and monitoring of crops for threshold levels of infestation, allows the most economic and effective use of chemical controls with the result that economic yields can be maximized.

4. Environmental Degradation/Losses

Extensive and indiscriminate usage of chemical pesticides has resulted in environmental degradation, adverse effects on human health and other organisms, eradication of beneficial insects and the development of resurgence and resistant to pesticides in insects pests.

Reliance on single control tactics have resulted in environmental degradation, contamination of food products, problems of residues and resistance in target species, there by seriously impairing the sustainability (Vega *et al.*, 2009; Miller *et al*., 2010). It is therefore essential to devise a sound management system that is based on ecological principles resulting in sustainable agricultural production without disturbing the balance of nature (Overton, 1996; Lewis *et al*., 1997; Kennedy and Sutton, 2000).

5. Lack of Proper Taxonomy of Pests and Biocontrol Agents

Identification or proper diagnosis is the pre-requisite in the IPM programme. We often talk of biodiversity loss, but unless we have a detailed account of the existing species, the loss cannot be pinpointed. Numerous examples can be cited where wrong classification has led to misinterpretations. Taxonomy plays an important role in the management of pests and weeds. To illustrate this point, *Salvinia molesta* (kariba weed), native of Brazil, is an aquatic fern and one of the world’s worst weeds. The environmental damage caused by it has been enormous. It chokes lakes, reservoirs, slow-moving rivers, irrigation systems, rice paddies, fishponds, etc. with continuous metre-thick mats of dense vegetation. In addition to rendering the water useless for normal use, its presence can lead to the breeding of mosquitoes. Initially, the weed was identified as *Salvinia auriculata*. A weevil, *Cyrtobagouss ingularis*, from Trinidad was used in Africa to control it, but the effort failed. Later, this weed was identified as *S. molesta*, whose growth in Queensland was controlled by *Cyrtobagous* from Brazil. It is evident from these examples as to how effective control or mitigation measures could be implemented[2]. Similarly, identification of an effective biological control agent for Azolla depended on expert taxonomic work. Floating water fern/fairy fern (*Azolla filiculoides*) has for years been a highly effective invasive species in South Africa, creating problems in inland waterways. The weevil, *Stenopelmus rufinasus* was found effective in cleaning up sites heavily infested with *Azolla*within months. Proactive taxonomy of biotypes of whiteflies, *Siphonius phillyreae* and *Bemisia tabaci* causing viral epidemic in crops in Argentina allowed effective implementation of biological control programmes via natural enemies such as *Encarsia hispidia*, *E. protransvena* and *E. transvena*[3].

In spite of its importance as an inevitable field for all types of research, taxonomy faces many challenges and remains a neglected subject. There is no national repository centre, museum, or maintenance of taxonomic collections. Many museums have no curators and several universities have no faculty positions for taxonomists. A demand for taxonomy is on the rise in the wake of the global biodiversity crisis. There is a need to promote scientific identification and documentation requires immediate attention. Due to lack of infrastructure at academic institutions and a well-structured research programme, seldom are students willing to pursue taxonomy. There are a handful of job openings for taxonomists and pay scale is low. Further, inadequate funding in taxonomy largely diverts students to studying phylogeny. It is also difficult to publish in the field as there are only a few journals dedicated to taxonomy research. The miniscule journals however do not accept large revisionary work or monographs. This calls for building a network among institutions and organizations involved in taxonomic collections. It is high time that the national institutes and funding agencies encourage taxonomic work and provide financial assistance to strengthen the knowledge base in taxonomy (Abrol, 2014).

6. Problems in Pest Management in Context of Climate Change

Climate change no longer is a matter of opinion or speculation. Of concern now is the assessment of the extent of the changes and their potential impacts. Climate change, food insecurity, and energy demand are major concerns for modern agriculture and their impact is increasing rapidly. The last decade has seen new developments in food production: the genetic engineering of organisms and the organic chemical-free agriculture. Biotechnology and release of genetically modifiedorganisms (GMOs), such as engineered soybean, colza, maize, and tomatoes, didpromise a solution to food security needs and nutritional problems (Khush, 2002). According to the main private biotechnology companies (Aventis, Monsanto, Novartis, Zeneca, etc.), these GMOs may be resistant to insect pests, molds, frost, dry conditions, etc., and could revolutionize agriculture (Pingali and Traxler, 2002). For example, soybean and other plants were modified to be tolerant to glyphosate, a common herbicide used to fight weeds allowing for much higher crop yields. However, because the weeds become increasingly resistant to this herbicide, the use of these genetically modified (GM) plants renders the farmers dependent on the use of more and more glyphosate.

7. Lack of Information and Communication Technology (ICT) in IPM

Practically, IPM is concerned with most constitutional levels of agroecosystems, from populations and communities down to individual viruses or genotypes, and genomes and genes, as well as up to the levels of landscape and global ecosystems. In fact, IPM practices are involved in a complex course responding to climatic change, soil dynamics, vegetation evolution and human activities.

ICT is any technology that enables communication and the electronic capture, processing and transmission of information. Radio, television and print media are vital in many developing countries. Over the last decade, 'new' ICTs, such as mobile phones and Internet-associated applications such as Voice over Internet Protocol (VoIP), have become available to growing numbers worldwide. Developing countries face challenges when harnessing the potential of ICT for economic development (Michelle and Fong, 2009).The potential of ICT for the speedy dissemination of information to farmers needs to be realized (Meera *et al.*, 2004). Integrated pest management (IPM) practices have to solve many problems of sensitivity and intractability in the sustainable development of agriculture.ICT has proved to be a powerful tool in pest forecasting as a prop to giving priority to prevention, as pest forecasting involves data acquisition, processing and information dissemination. ICT can also be very helpful in terms of enforcing IPM (Shen *et al.*, 2012).

8. IPM Implementation and adoption

In the 1970s and 1980s, the first IPM program under the Operational Research Project (ORP) focused on pilot programs using a prescriptive approach to demonstrate IPM practices in cotton and ricecrops in a cluster of villages in seven states. The government of India adopted IPM as the main strategy for plant protection in 1985. In the early 1990s, the farmer field school (FFS) model was adopted to implement IPM by educating farmers and extension workers. Between 1990 (before many adhoc IPM programs began) and 2002 (when Bt cotton was introduced) pesticide use (a.i.) by weight decreased by 35 %, mainly because hexachloro-cyclohexane, accounting for 30 % of the total pesticides, was banned in 1997 and low-dosage pesticides were introduced. Only about 2–4 % of the total cultivated area, including only 5 % of the farmers, however, is covered under IPM programs, so whether IPM has reduced overall pesticide use in Indian agriculture is debatable. Although the introduction of Bt cotton has reduced insecticide use in cotton by almost 50 %, mass pesticide use in Indian agriculture overall has increased by 9 % since 2002 (Peshin *et al.*, 2014).

Bt crops are compatible with IPM strategies but Bt crops alone are not sustainable. Over reliance on transgenic crops has already led to the weed and insect resistance which may lead farmers into a transgenic-cum-pesticide treadmill. Experiences with implementation of pesticide action plans and IPM programs around the world confirm that reduction in pesticide use by mass is not the robustindicator to measure success of IPM. Low volume pesticides propelled the pesticide use reduction in many countries. The pesticide treatment frequency index and the environmental impact quotient are better evaluation indicators tomeasure the impact of IPM programs.What experiences with IPM technology and IPM extension that are documented in this book can be bracketed successful and viable? In many instances IPM technologies developed at the research level have not been effectively scaled upto industry-wide practice because of the lack of a well conceived and evaluated extension process. Different extension approaches are needed in different situationsfor greater adoption of IPM by the farmers. IPM practices in most cases are testedfor success at pilot scale but fail to factor in the constraints, mainly the IPM attributes, for replication in large scale (Peshin and Pimentel, 2014).

Some of the strategies which need to be adopted to make the IPM programme successful include:

9. Ecological Pest Management Programme

The aim of this new approach is to shift management strategies so that they have less reliance on chemicals and more on the biology of pestsand their interactions with crops. Thus, ecologically-based IPM combining all approaches – physical, cultural, chemical and biological – is the only option for sustaining productivity and maintaining the health of ecosystems (Kennedy and Sutton, 2000). Most of the IPM inventories like cultural, mechanical, biological, plant resistance and biotechnological approaches are basically compatible and supportive tactics in the IPM strategy. Hence, strengthening of IPM infrastructure, especially for surveillance and forecasting the outbreak of localized insect pests and diseases and mass multiplication of bio-control agents for filed use, should be given adequate attention and priority. IPM programmes need to be designed in a way to manage pests on the one hand and ensure the build-up of beneficial organisms on the other (Kennedy and Sutton, 2000).

10. Bio-intensive Pest Management Programme

BIPM is the recent trend to reduce the pesticide pressure and to enhance thefarmers' interest to fetch higher remuneration for their produce. Consumers Union of the United States Department of Agriculture defines biointensive IPM as, "A systems approach to pest management based on understanding of pest ecology. It begins with steps to accurately diagnose the nature and source ofpest problems, and then relies on a range of preventive tactics and biological controlsto keep pest populations within acceptable limits. Reduced-risk pesticides are usedif other tactics have not been adequately effective, as a last resort, and with care tominimize risks."

BIPM also opensnew horizons to opt for a better choice, as biological control and use of bio rationalproducts, which are less toxic and only affect the target pest. It also includes biopesticides derived from microbials, parasitoids, predators, botanicals and all conventional non-chemical methods of pest management. It refers to the more dynamicand ecologically informed approach to IPM that considers the farm as a vital partof an agro-ecosystem. BIPM approach is a biological form of agriculture in which asmall area is intensively cultivated, using natural ingredients to rebuild and revitalizethe soil health. Initially, it is more labor intensive than conventional approaches, therefore, it is better suited to the small farm areas. It lays emphasis on the useof predominantly indigenous or region specific cultivars, crop diversity, good soilhealth and water conditions which results in little or no pest problem (Kaul *et al.*, 2009)

11. Ensuring Availability of Biological Control Agents and IPM Devices

Efforts shall also be made to ensure the timely availability of Biological control agents on demand to farmers to help them adopt IPM in the true spirit by encouraging the private sector, Governmentorganizations, central and state agricultural universities in providing such support services. Government must have to strengthen the programme through some new policy to establish more number of regional biocontrol laboratories, encourage the use of bio-pesticides and bio-control agents and safer and efficacious quality IPM devices or products for the farming community.

12. Habitat Manipulation or Ecological Engineering

It is evident that the crop diversification tends to increase natural enemy abundance and diversity, providing a system more resilient to pest population increase. Overall farming diversity within the agroecosystem may also affect biological control by natural enemies, due in part to a wider range of flowering plants that provide nectar (carbohydrate) and pollen (protein) resources to insects during more times of the growing season.Thus, pestoutbreaks tend to be less common in polycultures than in monocultures (Andow, 1991). The response of beneficial insect populations to habitat manipulation depends upon their ability to use or exploit one or more of the plant components of the agro-ecosystem (Altieri and Nicholls, 2004). Flowering plant strips adjacent to fields help support beneficial insect biodiversity in agricultural landscapes (Baggen and Gurr, 1998; Carreck and Williams, 2002; Fiedler and Landis, 2007a, 2007b; Tuell *et al.*, 2008). Much of the testing of flowering plants hasbeen done with non-native annual or biennial flowering species, although these often bloomin one growing season requiring annual sowing.A well-designed flowering border adjacent to a crop field will provide necessaryresources and alternative food source for natural enemies during periods when crop pestand crop flower numbers are low, thus maintaining high populations of natural enemiessupported by the provision of nutrients throughout the season (Landis *et al.*, 2000).

13. Farmers Demonstration through Community Participation for Enhancing the Adoption of IPM

The dangers of acute pesticide poisoning are well known to Indian farmers, but the need is to highlight the chronic exposure which can cause many neurological diseases. The current need is to address the awareness for long term moderate exposure. Further, Indian farmers are lagging behind in the use of new application technologies for pesticides spraying. The crux of the problem is that though, the technology is available in the country and is being used by few progressive farmers, majority of them are not in a position to implement these new technologies either due to lack of awareness or means. The farmers need to be educated by the crop protection industry since they are the main end-users of the products. This realization leads to development of indigenous technology as required by the farmers (Pina and Forcada 2004;Falconer and Hodge, 2000). Farmers in their quests to controlling pests and increasing yields ignore the problems of health and environment hazard.

14. Avoidance and Excessive Use of Pesticides

Currently, the pesticides are being used on 25% of the cultivated area and, the consumption of pesticide is showing a slight declining trend, probably due to shift of farmers toward biopesticides, natural plant sources and other alternative methods. Despite such a large consumption of pesticides, it is estimated that crop losses vary between 10–30% due to pests alone. In monetary terms, these losses amount to Rs. 290,000 million per year (Agnihotri, 1999). It has been observed that their long-term, low-dose exposure are increasingly linked to human health effects such as immune-suppression, hormone disruption, diminished intelligence, reproductive abnormalities, and cancer. In this light, problems of pesticide safety, regulation of pesticide use, use of biotechnology, and biopesticides, and use of pesticides obtained from natural plant sources such as neem extracts are some of the future strategies for minimizing human exposure to pesticides.

15. Rational Use of New Interventions and Biotechnological Approaches

New technological interventions such as transgenics and the offing of biorational compounds may become the more suitable choice for the farming community for maintaining the balance in an agro-ecosystem for sustainable agriculture. These new interventions may prove to be environmentally safe, economically sound and socially viable in a long run.

Major technological advances in biochemistry, molecular biology, genetics and biotechnology have facilitated in designing plants with improved resistance to insect pests. The potential of genetic transformation technology has been widely recognized over the last two decades. Recent advances in molecular biology, plant tissue culture and genetic engineering have clearly demonstrated the possibility of incorporating foreign genes for desired characters while preserving theexisting traits of improved genotypes. Bt is a Gram positive, aerobic, sporulating bacterium that synthesizes crystalline proteins during sporulation. These crystalline (Cry) proteins are highly insecticidal at very low concentrations to lepidopterans, coleopterans, dipterans, lice, mites and nematodes, and are non-toxic to mammals and other organisms.

By using biotechnological approaches, it has become possible to use Bt more effectively and rationally by introducing the insecticidal crystal proteins (ICPs) of Bt into crop plants. The crystal toxins are classified on the basis of amino acid sequence homology. The first transgenic tobacco plants using cry genes were developed against tobacco hornworm in 1987. The commercialization of Bt transgenic crops started in 1996 with the introduction of bollworm-resistant cotton (Bollgard) carrying the Bt toxin gene in the USA, while Bt cotton was commercialized in India in 2002. Plants possess a wide array of defense proteins including the PIs and lectins induced in response to insect attack.

16. Organic Way to Get Safer and Remunerative Foods/Organic Farming

The principal essence of organic food production aims to encourage and enhance biological cycles within farming systems to maintain and increase long time fertility of soil, to minimize different forms of pollution caused by synthetic chemicals (fertilizers and pesticides) and to produce food of high quality in sufficient quantity. It has been reported that more than 75% of consumers are very concerned regarding pesticides residues in food. All these issues have a direct bearing on the marketing of the products (Hallman *et al*., 2003).However, this process is costly, quite labor intensive, and in some cases ineffective (Abhilash and Singh, 2009).

Sikkim became the 1^{st} state in India to gone organic which portrays the sound picture of state to promote the pesticide free agri-Horticultureproduce and simultaneously agri-tourism to provide job opportunities to the rural masses. Organic scenario will definitely assist in maintaining the balance of an ecosystem, promotion for safe and residue free produce and thereby fetching the enhanced remuneration from their organic certified produce.

17. Conclusion

Keeping the above facts in mind, it is imperative to properly educate farmers for judicious use of pesticides. Other alternatives such as use of biotechnology, use of biopesticides, and use of pesticides obtained from natural products such as neem, pongamia oil, etc. should be encouraged. Secondly, Government should have to frame policy to propagate and strengthen the adoption of IPM to the farmers through demonstration of IPM technologies which will not only ensure the production of safe food but also reduce economic losses resulting through contamination of food degradation of environment, ecosystem, and indirect losses to the human health.

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Integrated Pest Management: Development and Implementation

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1. Introduction

One of the greatest challenges of the 21st century is the need to feed a growing population while improving the productive capacity of agricultural ecosystems, and the health and integrity of surrounding environments. In an effort to produce increasing amounts of food, agriculture threatens to destroy the very resources at its base: healthy soils, water and a stable climate. Intensification of production has led to increased use of inputs, particularly fertilizers, antibiotics and pesticides. According to FAO (2015) global pesticide use increased by 53% from 1993 to 2010. Pest challenges to food and ecological health include weeds, insect, mite, nematode and wildlife pests, plus animal and plant diseases, all causing substantial economic loss despite more than 1.5 million metric tons of pesticides applied worldwide each year. Crop losses from pests have not decreased as a result of increased pesticide use. Repeated application of pesticides, selects for resistance on the part of the pest. This resistance leads to the increased application of pesticides and to the collapse of the agricultural systems characterized by highly resistant pests, with no natural enemies left to control them. Development and spread of pest populations resistant to pesticides perpetuates a treadmill of need for new pesticide products and increased pesticide use. Pesticides have been found to cause acute and chronic human health problems, contamination of groundwater, contamination of surface water, atmospheric contamination, and negative effects on non-target organisms. Although developing countries account for a relatively small portion of total pesticide used each year, they have the highest rates of pesticide poisoning of humans. Integrated Pest Management (IPM) can address this vital challenge.

Integrated Pest Management, focuses on the management of pests, relying on knowledge of biology to make tactical decisions, taking into account the external risks to health and environment. IPM has many published definitions; most include using natural or ecologically sound principles or techniques, preventing pests from reaching economically damaging levels, and using multiple chemical, biological and cultural tactics, including host-plant resistance.

IPM is widely defined as a science-based decision-making process that identifies and reduces risks from pests and pest management related strategies. IPM coordinates the use of pest biology, environmental information, and available technology to prevent unacceptable levels of pest damage by the most economical means, while minimizing risk to people, property, resources, and the environment. IPM provides an effective strategy for managing pests in all arenas from developed agricultural, residential, and public lands to natural and wilderness areas. IPM provides an effective, all encompassing, low-risk approach to protect resources and people from pests (USDA NIFA 2013).

IPM integrates multiple management tactics in ways that usually allow production systems to move away from traditional, chemically based management to ecologically sound strategies. When chemicals are applied, the applications are guided using economic and treatment thresholds based on monitoring pest and beneficial organisms, and environmental conditions. IPM practices are crop and region-specific, and are intended to result in effective, timely and affordable pest control while also reducing use of and/or risks of pesticides to health and the environment. IPM can address any pest complex including insects, diseases, weeds, vertebrates and others, and can be adapted to any production goals including conventional, sustainable and organic.

2. History of IPM

Pests cause substantial crop losses throughout the world. Historically, farmers had to manage this problem to secure their basic subsistence needs. As a response, farmers have practiced and developed cultural and mechanical pest control based on trial and error. Over time, these practices have become a part of their production management system. One of the first documented examples of farmer awareness of biological control is the manipulation and placing the nests of predatory ants, *Oecophylla smaragdina* Fabricius by Chinese citrus growers in mandarin orange trees to control leaf feeding insect and used bamboo bridges to help the ants cross between trees. Pest management practices began to change in the 1800's. From the late 1800's to 1940's, the main insecticidal compounds used were oils, soaps and resins, plant-derived poisons and inorganic compounds. The first known chemical control dates back 2,500 years. The chemical age began in the 1940s with the discovery of DDT (insecticide), ferbam (fungicide), and 2, 4-D (herbicide). In 1940s and 1950s, pesticides were thought to be the final word in pest control and their introduction contributed substantially to raising agricultural productivity in many regions of the world. Since then, pesticides have become an integral component of many intensive agricultural systems. At that time, the growing concerns and deleterious effects caused by pesticides to the environment, human health, and wildlife were pointed out by Rachel Carson through her book *Silent Spring* in 1962.

Concerns about the negative effects of pesticides led to research and promotion of alternative pest control practices - Integrated Pest Control or simply IPC. This new concept called Integrated Pest Control (IPC) and later Integrated Pest Management (IPM) was stimulated by symposia organized by the Food and Agriculture Organization of the United Nations (FAO) in 1966 and the International Organization for Biological Control (IOBC) in 1967. In India, Pradhan introduced the concept of IPM during 1980s, who first proposed the IPC utilizing the combination of different methods of pest control. Later the concepts of Economic threshold level (ETL) and Economic injury level (EIL) came into shape to take up decisive control measures replaced the term control with management. IPM made a paradigm shift in the philosophy of pest control, away from pest eradication towards pest management. Instead of single tactic control, emphasis was placed on the use of a combination of available tactics, such as pesticides were to be applied as in integrated control, but these had to be compatible with control tactics for all classes of pests. Other tactics, such as host-plant resistance and cultural manipulations, became part of the IPM arsenal. Consequently, a more integrated approach to pest control was advocated to consider the ecological factors such as natural mortality, which may keep pest populations below economic damage levels. IPM added the multidisciplinary element, involving entomologists, plant pathologists, nematologists, and weed scientists.

3. Key Benefits ofIPM

- Reduces reliance on singletactics; improves resilience of production systems.
- Can reduce pesticideuse, residues, pestdamage, production costs and risks, and health and environmental impacts.
- Flexibility to create newapproaches, address anypest complex, and be implemented at different levels and adapted to any production goals.

4. Key Limitations

- Benefitsandabilityare highlydependenton the extentto whichavailable IPM tacticsareadopted,and limited bylackofunderstanding.

Pre-requisites of integrated pest management include:

- Collection of base line data through survey and surveillance
- Proper and accurate identification of major pests
- Disease and pest forecasting
- Field monitoring and scouting of pest population
- Proper record keepings

5. Tactics of IPM

Tactics commonly adopted for the control of pests are classified into curative and preventive methods. These methods include cultural, mechanical and physical, chemotherapeutic, regulatory, biological, plant resistance and genetic to check the increase in pest population.

6. Implementation of IPM

In spite of the efforts, there is little evidence that IPM (as originally intended) has been implemented to any significant extent worldwide. This apparent failure can be due to IPM being time consuming and complicated; farmers cannot be expected to carry out the integration of multiple, suppressive tactics for all classes of pests. Also, pesticides can be a cheap insurance policy when there is a possibility of losing an entire crop. World Bank in 2005 issued a report concluding that IPM adoption remained relatively low in most of the developing world, and that there was no convincing evidence for changes in pesticide use in targeted crops such as rice or cotton in Asia. According to estimates by the Consumers Union, true IPM is probably being practiced on only 4 to 8 percent of the U.S. crop acreage. Globally, the percentage is probably even lower. Adoption of IPM in India remains restricted to hardly two per cent of the area treated with plant protection inputs. The structure of agrochemical market also suggests a similar level of adoption. In India, share of bio-pesticides is only two per cent of the agrochemical market.

For assessing the level of IPM implementation, the US Department of Agriculture (USDA) in 1993 launched the National IPM Initiative with the goal of having 75% of crop area under IPM by the year 2000. To measure the level of adoption, USDA put forth the PAMS concept, the acronym for prevention, avoidance, monitoring and suppression. A farmer was required to apply at least three of the four PAMS components; monitoring of pests and their natural enemies/antagonists being optional. However, the problem with this approach was that there was little or no commitment to integration of pest management tactics as envisioned by the founders of IPM. Simply combining different management tactics does not constitute IPM. Studies have shown antagonistic relationships between genetically resistant crop cultivars and biological control agents of insect pests. As such, combining different tactics arbitrarily may actually aggravate pest problems or produce undesired effects. MeasuringIPM implementation is further complicated by the fact that there are over 65 definitions of IPM, so any one can find a definition that fits what they are doing. Another measure for IPM implementation is reduction in pesticide use. In the recent years, the consumption of pesticides in India has shown a downward trend from 75,000 MT in 1991-1992 to 45,390 MT in 2012-2013 mainly due to ban on the Heptachlor, Chlordane and BHC, availability of newer pesticides, which are effective at very low dosages and introduction of GM crops. Although pesticide consumption in India has reduced over the years, the adoption of IPM practices remains low. Lack of commercial availability of bio-pesticides and inappropriate institutional technology transfer mechanisms are the critical impediments to increased application of IPM.

Farmers' perception about pests, pesticides, and pest control as well as their decision making process in pest management have been shown to be influenced by farm characteristics and the outside influences composed of social, economic, political, and institutional factors. The location specific technologies are needed to enhance the adoptability of integrated pest management practices among farmers as the agro ecological conditions may vary from one location to other. IPM is a complex process and farmers are deficient in understanding the biological processes of pests and their predators and methods of application of new technology components. There are a number of IPM practices that work best when applied by the entire community and in a synchronized mode. This is can only be achieved by demonstrating benefits of group approach, and external motivation and support to the farmers.

7. Conclusion

Ehler (2006) asserted, "Much of what is billed as IPM is better described as integrated pesticidemanagement, i.e., the 'other IPM.' Integrated pesticide management can be defined as the discriminateuse of pesticides, and is similar in some ways to supervised control of the late 1940s. This other IPM is not necessarily a bad thing, as judicious use of pesticides should be encouraged." Pesticides are the "magic bullet" for the risk-averse farmer because these are easy to apply, provide a quick fix solution, and require little or no ecological understanding of the target system. Also, alternative methods often require relatively more effort to implement as well as greater ecological understanding of the target system. In future, the 'discriminate' use of pesticides shall continue to be a dominant theme in agriculture because the real IPM demands an ecological understanding of pest problems and can be challenging to implement. However, the true IPM shall remain a worthy goal for the 21st century. This is achievable if government policies promote a proper understanding of IPM, address how IPM adoption will be measured in the field, and provide incentives to encourage adoption.

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Judicious Use of Herbicides

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1. Introduction

Herbicides are the chemicals used for killing or suppressing the growth of weed plants from field / horticultural / plantation crops as well as non-cropped areas/water bodies etc. The herbicide is said to be an ideal herbicide when it is very safe to the crop on which it is applied and on the other hand, it must control all associated weeds effectively. Also ideal herbicides should leave no residues on the succeeding crop(s). Herbicides are of two types i.e. (i) Selective and (ii) Non-Selective. A selective herbicide is that which is very safe to crop plants but unsafe to weed plants e.g. atrazine in maize, clodinafop in wheat etc. On the other hand, non-selective herbicides are those which kills all green plants including crop and weed plants which come in their contact e.g. paraquat and glyphosate. However, a non-selective herbicide can be used as selective herbicide by applying as directed application only on weeds with the use of spray hood. Avoid the contact of non-selective especially translocated herbicides (glyphosate) with the crop at the time of spray in order to avoid crop losses. Glyphosate is non-selective, very popularly used for controlling annual and perennial weeds from non-cropped lands as blanket application and from wider row crops as directed application only on weeds. Glyphosate is a translocated type of herbicide and its contact with the crop must be avoided. On the other hand paraquat (Gramoxone) is a non-translated herbicide and its limited contact especially with lower leaves leads to non significant loss of crop. However its contact with growing points of crop plants is harmful.

In crop production, it is not possible to eliminate the use of herbicides because chemical weed control is the only option available with the farmers for controlling weeds from the field crops as it is very economical method as compared to other methods. The scope of mechanical weeding is decreasing day by day due to high wages of farm labour and their non – availability when required. Chemical weeding has become more popular method of weed control in field crops as compared to other methods as it eliminates early crop weed competition, controls both inter-row and intra-row weeds very effectively, less influenced by environmental factors, very economical and quick method of weed control etc. Herbicides are very useful tool for improving crop produce provided these are used judiciously. Indiscriminate/wrong use of these agrochemicals (herbicides) may lead to many harmful effects such as environmental pollution, residues in crop produce as well as in soil, crop toxicity, human health problems, herbicide drift and run-off, un-uniform control of weeds etc.

However, herbicides are more safe as compared to other pesticides like insecticides, fungicides, rodenticides etc. and on the other hand losses due to weeds for agricultural crops are much more than insects and disease organisms. The use of herbicide is very popular especially in rice and wheat for the control of grassy and broad leaf weeds. In Punjab state about 90 to 95 per cent area each under rice and wheat is treated with one or the other herbicide, which may be due to the presence of morphologically similar weeds in these crops, which are very difficult to control with mechanical method of weed control. Hence farmers prefer chemical weeding, as it is more effective and economical method of weed control. Apart from these crops, herbicide use is also very common in maize, cotton, sugarcane, oilseeds, pulses, fodder crops etc. Few non-selective herbicides such as paraquat and glyphosate are very common in non-cropped areas as well as in horticultural and plantation crops. For annual weeds, use paraquat where as for joint control of annual and perennial weeds, use glyphosate. Paraquat is non-translated and glyphosate is translocated and non-selective herbicide. For perennial weed control, use low dose so that leaves are not killed quickly and herbicide may be translocated to the root stock in higher amount. The spray can be repeated if need be i.e. if weeds regenerate or on left over weeds. The objective for perennial weed control is to kill the root stock with herbicides (especially glyphosate) and foliage must be killed due to starvation. So, judicious use of herbicide may lead to good results, which are not possible with other methods of weed control.

Agriculture cannot be made successful/economical without the use of herbicides but these agrochemicals must be used judiciously so that their benefits can be harvested. Adoption of following points/tips will not only help in effective kill of weeds but will lead to more safety of crop plants without any soil or environmental pollution.

Herbicides are meant for killing the specific weed(s) and spectrum of weed kill is different for different herbicides. So, before planning regarding choice of herbicide, it is very important to know the weed flora present in the field so that a selective and effective herbicide can be purchased for spraying. Even the history of previous weed flora (of last year) must be known especially for pre-emergence applications. For instance farmers of Punjab State invariably use pre-emergence (to weeds) herbicides such as butachlor, anilofos, pretilachlor, pyrazosulfuran, etc. in the fields which do not have specific (target) weeds such as *Echinochloa crusgalli*(swank/maddal), *Ischaemum rugosum* (wrinkle grass), etc. for which these are effective. Hence, it is non-judicious use of herbicides, which must be avoided. In case sedges and grassy weeds are present in rice crop, use of bispyribac as post-emergence must be done.

Similarly, in wheat non-judicious use of herbicides is also on the increase, as farmers do not select specific herbicide at the time of spray. For instance, 2, 4-D is commonly used for the control of all types of broad leaf weeds from wheat whereas few hardy weeds (difficult to control) are not killed with 2, 4-D. Select metsulfuron when Kandyali Palak (*Rumex spinosus*) is present and for control of Button weed (*Malva neglecta*) effectively use carfentrazone. These herbicides also control other broad leaf weeds from wheat crop and these are substitute for 2, 4-D. So, select herbicide as per weed flora. Similarly if wild oats (*Avena ludoviciana*) and gullidanda (*Phalaris minor*) are present, use clodinafop, pinoxadin or fenoxaprop-p-ethyl. Prefer to select mesosulfuron + iodosulfuron 3.6 WDG or sulfosulfuron + metsulfuron 75 WG or fenoxaprop 8% + metribuzin 14% for fields of wheat crop having joint infestations of grassy and broad leaf weeds. So, knowledge regarding type of weeds infesting the crop is very important and herbicides should be selected according to type/dominance of weed flora. It is not advisable to use herbicides every year and its use can be omitted if weeds are not present or they are in low population. Other methods of weed control like mechanical weeding or cultural control measures can be adopted if weed pressure is low. Only need based use of herbicides should be done i.e. when it is not possible to control weeds infesting the crop with any other weed control method.

Lot of herbicides and brands of unapproved herbicides are available in the market. The use of un-recommended herbicides or un-recommended brands of recommended herbicides may lead to many serious problems such as poor or no control of weeds, toxicity on crop / complete crop failure or many times toxicity on succeeding crops is also observed. Many Punjab farmers used un-recommended brands of sulfosulfuron (recommended chemical) for the control of *Phalaris minor* from wheat, which resulted in 70 to 100% damage of wheat crop. Also, due to severe residual toxicity especially due to toxic metabolites of sulfosulsfuron in soil, these farmers were unable to grow catch crops such as summer moong/summer mash/cucurbits/fodders like maize, sorghum, bajra etc. Poor selectivity (tolerance) of wheat crop to unapproved brands of sulfosulfuron may be due to poor quality or incompatibility of used surface active agents (surfactants) with herbicide i.e. sulfosulfuron. Also few farmers use metribuzin (un-recommended herbicide) for the control of *Phalaris minor* in wheat and suffered a great loss due to its low selectivity margin as slight overdosing may kill wheat crop.

So, after identifying the weed flora of the field, suitable herbicide should be selected, which is duly recommended by State Agricultural Universities. The use of un-recommended herbicides as well as un-recommended brands of recommended herbicides may lead to severe problems such as poor control of weeds as well as crop toxicity. So, for safe (judicious) use of herbicide, use only recommended herbicides along with their approved brands. Never select wrong herbicide and always select herbicide as per the weed flora present in the crop. Do not adopt one policy (one herbicide) for your entire farm but selection of herbicide may vary from one field to another field depending upon weed flora.

Apart from above points, the nature of succeeding crops and type of the crop growing-in the adjoining fields should be kept in mind. For instance, do not use sulfosulfuron but go for other recommended herbicides like clodinafop, fenoxaprop-p-ethyl or pinoxadin for the control of *Phalaris minor* in wheat fields, which are to be succeeded, by maize, sorghum, bajra, etc. in order to avoid risk of herbicide residues on succeeding crops. Similarly, the use of 2,4-D in wheat should be avoided when adjoining field is of broad leaf crops like oil seed crops, gram, vegetables etc. During summers, do not use 2,4-D in sugarcane field adjoining to cotton field as cotton is very sensitive to 2,4-D as even traces of 2,4-D can damage cotton crop very badly. Apart from wind drift, vapour drift is also very important in 2,4-D, which may damage the distant crops (sensitive) especially during hot days so, judicious use of herbicides will lead to no harmful effects.

Pre-plant herbicides should be applied just before sowing the crop on the prepared field and there should be minimum gap between land preparation and herbicide application as well as between herbicide application and sowing of crop for better results. Also pre-emergence herbicides must be applied immediately after sowing the crop so that there is good soil moisture for better herbicide results. Another very important point is that during hot months, do not spray during noon hours but always spray pre-emergence herbicides either in the morning or in the evening hours. Many post-emergence herbicides (for example 2,4-D) have no direct effect with soil moisture but foliage of weeds should be fully open so that there is more retention, adsorption, penetration and translocation of herbicide. So, do not spray post-emergence herbicides on wilted foliage. On the other hand avoid to spray during excessive foggy hours of the day (morning) during winters, as retention of spray fluid on foliage will be less. Do not spray on windy days which may lead to not only un-uniform application of herbicide but drift of herbicide will also be high, which can damage the adjoining sensitive crops. Another very important point is that always spray on actively growing weeds so that there is maximum uptake and transport of herbicide in the target plants. For instance herbicides used in wheat for control of *Phalaris minor* are more effective on fertilized fields (especially nitrogen) than on non-fertilized fields, which may be due to more uptake due to fast metabolic activities under the former conditions.

The last but not the least important point regarding time of herbicide application is that these must be sprayed as per recommended growth stage of crop and weeds. Application of herbicide before the recommended time may lead to crop toxicity whereas its delayed application may lead to poor weed control. For instance, wheat can tolerate 2,4-D when applied at maximum tillering stage but it's wrong application (before or after the optimum stage) may lead to many deformities in wheat plant such as tubular leaves, branching of the ears, swelling of wheat ears, spikelet's without grains etc. In transplanted paddy, there should be minimum gap between puddling and transplanting as well as between transplanting and herbicide application for better weed control efficiency. For effective control of perennial weeds, time of application is very important. Always spray on actively growing weeds and do not spray on grown up weeds due to their poor metabolic activities. Cut the foliage of grown up weeds and for better results spray post-emergence herbicides when new growth appears.

Depending upon crop tolerance, nature of soil, climatic conditions and type of weeds present in the field, herbicides are recommended at different doses. The content of soil organic matter also decides dose of herbicide to be applied. Fields with high organic matter content needs higher dose of herbicide due to more adsorption capacity of such fields. Herbicides must be used at the recommended doses as per State Agricultural University. The dose of herbicide is recommended to fulfill the following two criterions i.e., i) weeds must receive lethal dose (minimum dose required for killing the target weeds), and ii) crop must tolerate to even double the recommended dose. The use of lower dose may lead to poor weed control as well as early development of resistance in weeds and on the other hand use of higher dose may lead to crop toxicity as well as residual problems in the present as well as in the succeeding crops. Under dose of herbicide may lead to poor weed control and hence more losses in grain yield apart from increasing soil weed seed bank status, which leads to more weed problems during coming years. So, for proper and sustainable weed control, use herbicides at the recommended rates. Also the phenomenon of resistance in weeds is delayed when herbicides are used at proper rates, whereas under/over dose of herbicide may lead to early development of resistance in weeds. Proper dose of herbicide will provide better weed control, no soil residual problems on succeeding crops, no residues in crop produces as well as any environmental pollution.

Conclusion

It may be concluded that herbicides use in agriculture is necessary for controlling weeds. However, their need based use is required and avoid their indiscriminate use which is done at present. If herbicides are used judiciously i.e. as per recommended schedule, they do not leave any residues in soil, no environmental pollution is created, no residues are detected from crop produce. Also there will be no pollution of underground water. The problems due to herbicides may be observed when their indiscriminate use is made i.e. overdosing, wrong time of application, use of un-recommended herbicides or their brands, use of herbicides in many splits etc. Due to these wrong practices not only the present crop but succeeding crops may be damaged and there will be more problems of crop residues. For exploiting the benefits of herbicides, always use recommended herbicides with recommended technology. On the other hand, sole dependence upon the herbicides for weed control is also not desirable. For sustainable weed management, integrate judicious use of herbicides with other methods of weed control such as preventive, mechanical, cultural, etc.

Sustainable Development of Farmers - A Success Story

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1. Introduction

Indian Agriculture today is facing a biggest challenge than ever before particularly after the globalization and commercialization of agriculture. Although India is proud of achieving self sufficiency and even surplus in food production including milk, poultry, fruits and vegetables but the question is how to sustain them. The GDP contribution from agriculture was 58 percent during 1950s and today it is going at less than 14 percent. Farmers are not only losing interest in farming but also confidence. The impact is so much that there is indiscriminate migration of Rural Youth in general and Farm Youth in particular to urban areas; in the process many families and villages are becoming old age homes. During 2011, the migration of farm Youth to urban areas in India was at 45 per cent while it was 90 per cent in China. The trend is increasing year after year, there are no labour available in some families even to supervise the harvest of perennial produces on the farm, leave alone other farm operations. It is said that migration is because of farming is becoming less profitable venture as well as growing unemployment problem in rural areas while increasing labour scarcity for farm operations is a paradoxy. In the days to come, if no corrective measures are taken for the holistic development of farmers, the number of farmers looking for non agriculture vocations are likely to increase and difficult to hold back the farmers in farming sector directly affecting food security.

The development in agriculture and allied sectors in the five decades clearly revealed that the productivity and production has increased significantly but the farmers economy did not improve concurrently. There are many factors which have contributed for the present status of indiscriminate increase in cost of production resulting in very narrow profit margin among majority of farm enterprises closely followed by non-availability of labour, over exploitation of natural resources, drying up of public extension system impacting on inadequate and dependable information system, non-availability of critical inputs at the easy reach of majority of farmers including non-availability of custom hire services of farm machinery, weak convergence among various institutions working for farmers, lack of assured price and inadequate marketing facility at the grass-root level, more specifically the farmers share of consumers payment is around one third across the farm produces, increase in nucleus families, decline in per capita land availability and fragmentation of land holdings. There is an increasing social problem than economic problems in rural India particularly not finding alliance for those engaged in farming besides increased factions. The climate impact in the recent years is further aggravating on all the production functions.

The challenge during pre-green revolution era was to ensure food security by increasing productivity and production but now the need of the hour is profitability, nutritional security and improving the standard of living of the farming families in particular and rural people at large. Therefore more distinct measures are required to address emerging challenges in rural India.

2. Rural Bio-resource Complex Project

The Department of Biotechnology launched five Rural bio-resource complex projects (RBCs) during 2004 across the country; one of the Centres was given to UAS Bangalore. UAS Bangalore took all the initiatives to implement the project during the later part of 2004. Keeping the present and future challenges, the RBC project developed holistic approach for bringing sustainable production, profitability, nutritional security and improved standard of living keeping all the aforesaid issues in focus. Two pronged strategy namely; integrated farming system approach and end to end issues were incorporated to achieve the desired objectives of the project.

3. Structure, Location and Duration

The project was headed by Project Coordinator and assisted by Associate Project Co-ordinator with 32 interdisciplinary senior scientists to identify appropriate proven technology and also to train young scientists to work at the grass-root level. Committees were also constituted at the University and DBT level to provide required guidance and support for the effective implementation of the project. The project was implemented involving 8340 families of Tubagere Hobli in Doddaballapur Taluk of Bangalore Rural District located 50 km away from state head quarters for a period of five years from April 2005 to March 2010 with a budget outlay of Rs. 436 lakhs. Bench mark information was collected from all the 8340 families, analyzed the relevant areas needed for addressing the mandates.

4. Strategy

Initially five point strategy was designed to achieve the mandated objectives namely:

Promotion of capsule of technologies: Identification and screening of suitable technological packages comprising of different agricultural and allied enterprises were formulated by involving inter-disciplinary team of scientists from the university. The technology components mainly comprised of Integrated Farming System

Modules (IFS), processing and value addition, seed production with an emphasis on good agricultural practices, climate resilient agricultural practices with special emphasis on efficient natural resource management. The specific technologies promoted are as follows;

Field crops

- Improved Finger Millet Cultivation
- Improved Maize cultivation
- Improved Pigeon Pea cultivation
- Improved Sunflower cultivation
- Improved Pop corn cultivation
- Introduction of Sweet corn cultivation and
- Introduction of Baby corn cultivation

Horticultural crops

- Improved cultivation practices in banana
- Improved Drumstick cultivation
- Improved French Beans production
- Introduction of Open field rose cultivation

Animal based enterprises

- Fish culture
- Improved Sheep rearing
- Backyard poultry

Natural resource conservation and management

- Soil and moisture conservation
- Water use efficiency
- Organic Farming
- Vermicomposting
- Integrated farming system
- Apiary
- Biofuels
- Farm forestry

Seed/ seedling /graft production activities in all the selected crops and enterprises

Sericulture and chawki rearing centre

Value added products in finger millet, maize, pigeon pea, jackfruit and biofuels

Ensuring effective information support system: Due to decline in the presence of public extension system, the rural sector in general and agricultural sector in particular are inadequate of both knowledge and skills required for synthesizing information and technological application required for the farm growth. The success of any technology promoted depends on availability of accurate and timely information. Efforts were made under this project to empower farmers and landless families with opportunities and new knowledge. Farmers were constantly supported by providing relevant information in support of technologies promoted and other related issues. The empowerment activities includes; training, demonstrations, field visits, teleconferences, agromet advisories, field days, participation in Krishi Melas, study tours and campaigns besides supplementing through relevant literatures, mobiles sharing experiences of awardees and recognized farmers.

Providing quality critical inputs and custom hire services of farm agricultural machineries: Availability and affordability of critical inputs are major factors having direct bearing on productivity, production and cost of production. Apart from cost of input, quality, easy and timely access, overhead charges also play an important role in minimizing cost of production and increasing profit margin of each farm produce. Effective input management system is essential in bridging the gap in agricultural production. The project aimed at empowering farmers to get access to quality inputs by developing possible and effective input management system as well as providing them timely at the easy reach.

The maximum cost of input in farming today is incurred towards labour. Timely availability, cost and quality of labour not only impacts on timely farm operations but also on cost of production and profitability of the farm enterprises. Therefore required farm machinery was made available at the project site for availing them on hire basis, the facility was very helpful to small and marginal farmers in particular and other farmers in general.

Effective functional linkage with related institutions: Promotion of technology per se cannot help farmers towards economic security unless other backward and forward linkages are adequately addressed. Thus critical gaps in input supply, subsidy, insurance, access to credit, marketing, end user linkage, value addition, access to various other services and resources are crucial to make farming a profitable venture. The project envisaged effective use of the services of other organizations including financial, development Departments, input agencies, marketing organizations, research institutions, local institutions and NGOs functioning in the area. Project worked towards the convergence of all the stakeholders for the development of farm families particularly continuous use during the project period.

Market empowerment: The farmers share from the consumers payment across the farm produces revolves around one third. Unfortunately, marketing network continues to be a weak link creating hardship to farming community. Farming enterprises suffer from lack of proper market linkages with consumers, poor storage and Agro-processing industries. Several thousands of tons of fruits, vegetables and food grains are lost every year due to lack of such linkages and infrastructure. Project took all the initiatives to empower the farming community on market related issues through continuous capacity building, knowledge and skill imparting activities. More emphasis was given to value addition, grading, processing, packing and branding of agricultural produces for maximum realization profit and of minimization of wastages. Project provided special attention towards establishing marketing linkages of farm produces to marketing organizations and industries.

All these components were effectively implemented in the first year of the project. It was observed at the end of first year that providing respectable price and marketing facilities to farmers could not be ensured satisfactorily particularly for the small and marginal farmers. A series of debates were held involving all the stake holders on how to find a lasting solution to the affore said issues. After weighing all the available options, it was decided to promote commodity based associations not only to address effective marketing of all the farm produces but also to ensure other backward and forward linkages.

Establishment of commodity based associations (CBAs): In order to achieve mandates, the project team took initiative to promote farmers associations during second year as means of strengthening backward and forward linkages with a special focus to ensure profitable sale of farm produce with least overhead charges. These associations are built around group of farmers/farm women, which is proven to be reliable vehicles for sustainable productivity, production, profitability besides social harmony.

The necessity of CBAs have become more important today than ever before in view of increasing nucleus families, fragmentation and division of land holdings, uneconomical size of land holdings, difficulty in availing various support systems, inadequate availability of inputs at the easy reach, difficulty in availing and using improved implements, poor marketing arrangement, inadequate transport facility, lack of local market for their produce, problems of factions and associated social issues. Profitable marketing of produce of farmers is given top most priority through organized arrangements. The continuation of the interventions introduced during the post project period greatly depends upon active involvement of stakeholders which was possible due to the start of various associations.

CBAs are platforms where farmers share knowledge and experience on the use of appropriate and affordable technologies aimed at increasing their agricultural produce. They help in establishment of strong forward and backward linkages between farmers and service delivery institutions. CBAs enjoy similar status as that cooperatives in terms of legal / administrative procedures, transparency in financial management, but autonomy as that of SHGs and they are free from rigidities associated with contract farming as decisions are made by members of CBA from time to time.

The following associations were formed in a span of two years from 2006 – 2008:

- Rural Biofuel Growers Association, Hadonahalli
- Jack Growers Association, Hadonahalli
- Organic Farming Farmers Association, Karnala
- Federation of Women SHGs, Tubagere
- Fish Farmers Association, Tubagere
- Flower Growers Association, Hadonahalli
- Corn Growers Association, Hadonahalli

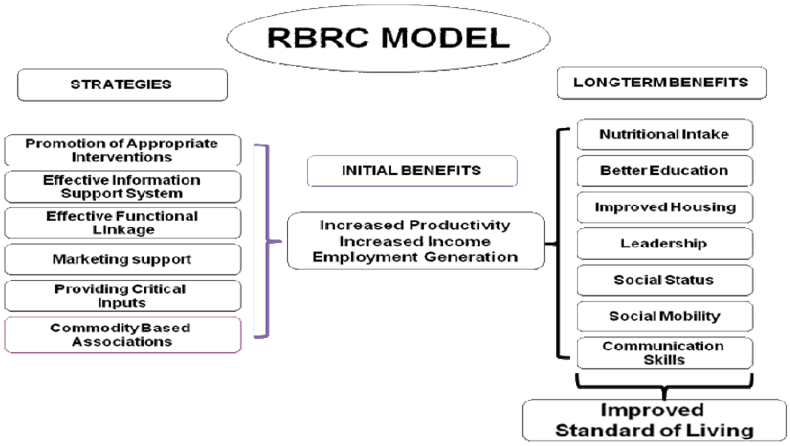
- Fruits & Vegetables Growers Association, Hadonahalli
- Agro Processing Centre, Melekote
- Chawki Rearing Centre, Gangasandra

These ten commodity based associations were established in strategic places of the project area. Creation of community/common infrastructural facility for the benefit of small and marginal farmers were specially encouraged. The most innovative aspect of the model is the use of the underutilized Milk Producers Co-operative Societies (MPCSs) in each village as the base for the procurement of the village produces, namely, bio-fuel seeds, fruits and vegetables, vermicompost manure and a range of other produces as well as storage of critical inputs for the timely distribution at the easy access of stakeholders.

5. Benefits of CBAs

- Registered bodies under the Registrar of Firms & Societies
- Autonomy, flexibility and transparency in the system
- Strengthens backward and forward linkages
- Promotes division of labour and specialization
- Resource sharing including machinery and infrastructure
- Provide equal opportunities for all sections of rural society
- Shared labour concept is reintroduced

I. RBC Model



6. New Institutions/Infrastructure Facilities Established/Created

During the project period, need based permanent infrastructure facilities were created in the project area with the involvement of different stakeholders for ensuring continuation of activities initiated and sustainable development of the area;

- Establishment of KVK by ICAR, New Delhi, 2007
- VRC and Expert Centre in collaboration with ISRO,2007
- Biofuel Extraction unit,2008
- Automatic Weather Station in the KVK,2008
- Chawki Rearing Centre,2008
- Fish Demonstration units,2008
- Marketing Complex for Sale of VAPs,2009
- Poultry Demonstration Units,2009
- Two Agro-Processing Units2009
- Marketing Complex for the sale of Agri.-Hort. Produce,2011

7. Evaluations and Research Studies Conducted

- The evaluation studies were conducted by two external agencies; one being the midterm appraisal during 2007-08 and the other one at the end of project during 2010 keeping the mandates in view. Both the reports have concurred that the project was implemented as per the mandates besides many emerging issues are addressed keeping the farmers in view.
- In between one M.Sc. in agricultural Economics and three Ph.D in Agricultural Extension were conducted. The papers from these studies are published in state, national and international journals which have attracted the attention of many academicians, planners and administrators.

- Biofuel network book published by APARI has gone for global circulation and gone for fifth time publication.
- National and international seminars were organised on jack fruit has attracted the attention of many national and International Scientists on Jackfruit. The article published in GLOBAL EARTH Journal has attracted the attention of Global attention on Jack fruit.

8. Significant Contributions from the Nodal Organisations

✓ **Corporation Bank**
  - Financial assistance of Rs.40,000/- for the construction of Marketing complex
  - Instituted two Corp Prasasthi Awards for best farmers in the university.
  - Provided a loan of Rs 6,00,000 for establishment of biofuel extraction unit.
  - Provided loan to various interventions running to few crores.

✓ **Karnataka State Department of Horticulture**
  - Provided subsidy of 5.00 lakhs for banana, mango, sapota and flower crops
  - Provided 50% subsidy for establishment of 22 vermicompost units at a cost of Rs.3,20,000/-
  - Sanctioned two projects on bhendi and beans seed production during 2008-09 and 2009-10 under NHM with budget outlay of Rs.2.5 lakhs and Rs. 7,98,60, respectively.
  - Provided financial assistance to organize National and International workshops on Jack with the financial assistance under NHM.
  - Actively involved in HRD activities

✓ **Karnataka State Department of Agriculture**
  - Provided a grant of Rs.4.00 lakhs for the promotion of organic farming
  - Provided a subsidy of Rs.56,500/- for the purchase of improved implements for custom hire services.
  - Provided subsidy of one lakh for establishment of biofuel plant.
  - Cold storage facility for sweet corn and baby corn
  - Market linkage for sale of corn and Banana

✓ **Karnataka State Department of Sericulture**
  - Provided a sum of Rs.1.00 lakh for the construction of two Chawki Rearing Centres.
  - A subsidy of Rs.8,00,000/- for undertaking drip irrigation in newly established mulberry crop during 2008-09.

✓ **Department of Forest**
  - Rejuvenated the degraded forest land of 2500 ha. around Ghati Sri Subbramanya temple
  - Provided seedlings to needy farmers to take up agro forestry

✓ **IIHR, Bangalore**
  - HRD for seed production activities
  - Seed and plant materials

✓ **Indian Space Research Organization (ISRO)**
  - Establishment of "Expert Centre" at the University main campus and One "Village Resource Centre" at Hadonahalli

✓ **Grama Panchayat, Hadonahalli**
  - Provided a building free of cost for RBC office for four years

9. Achievements/Outcomes

The farming community in the project area had realized higher net income from increased productivity from the existing crops, shift from subsistence agriculture to seed production and nursery multiplication, introduction of new crops like open rose, sweet corn, baby corn, increasing the area under mulberry, introduction of tissue culture banana and subsidiary rural enterprises like sheep, fish farming, apiary, vermi-compost and value addition to agricultural based products (VAPs). Further, introduction of integrated farming system demonstrations, improved water use efficiency measures, cultivation of biofuels and agro-forestry in non-arable land, promotion of custom hire services of tractors and improved agricultural implements, integrated farming and start of 10 different commodity based associations had cumulative impact on enhancing the income of stakeholders.

The stakeholders showed increased interest in the project due to increase in the farm income and sustenance of the productivity. The added net income generated during the end of project period it rose to Rs. 182.2 million added as against Rs.49.6 million during the bench mark year (2004). The project implementation resulted in direct employment generation of 2.52 lakh man days per annum during 2007-08 with sustained increase in subsequent years. An overall assessment indicated that project was able to realize 11 per cent growth rate in agriculture. It was an encouraging outcome, which provided confidence to all the stake holders particularly farmers. The project amply proved that with the promotion of aforesaid interventions coupled with other activities it is possible to sustain the growth of agriculture and rural economy.

The RBC model in a span of five years of its implementation provided direct benefits to the stakeholders through sustained agricultural growth and income. Besides direct benefits many indirect benefits accrued are; improved soil fertility, soil moisture conservation, decrease in cost of production, reduction in overhead charges, improved environmental conditions, decline in migration especially farm youth, enhanced food and nutritional security, improved leadership qualities and higher confidence among farmers particularly farm youth and women. All the RBC beneficiaries were satisfied about the benefits derived from the project. The coverage in mass media, opportunity to share their experiences in various media and public events had improved their confidence level. Further, the recognitions and awards for achievements by the farmers had helped them to derive greater satisfaction in their vocations. The project has impacted positively in terms of sustained adoption of technologies, effective functioning of local institutions, farmers to farmers' knowledge sharing even after completion of project. It stands testimony and demonstrates the resilience, sustainability of the project elements and robustness of the project concept as a pilot model.

10. Replications/Scaling Up

- ✓ NBDB has advocated the replication of this model in North Eastern States during 2008-09.
- ✓ Litchi Growers Associations have been established in Bihar on the lines of Commodity Based Associations.
- ✓ Karnataka Government has replicated IFSD approach of RBC project in all 29 KVKs in Karnataka covering 1.25 lakh farm families from 2011-12 to 2013-14 (Rs.75 crores).
- ✓ Governments of Andhra Pradesh and Odisha have approached the University to provide technical expertise to replicate this model in their states.
- ✓ Sri Lankan Government has shown keen interest in replicating this model. The Government of Sri Lanka has deputed around 400 Srilankan Bank officers in 14 batches over a period of three years to observe the project activities for replication in their country.
- ✓ Established 18 VRC's across the state by ISRO, Bangalore.

11. Recognition to Farmers/Institutions

- Institution of Two Corp Prasasthi Awards sponsored by Corporation Bank, Mangalore by depositing an amount of Rs.3 lakhs with the University. Awards are given every year from the interest amount accrued. Each award carries a cash amount of Rs.10,000/- to be presented in the annual Krishimela at GKVK Campus. These two awards were presented for the first time in the Krishimela 2007.
- Three awards were also given to best farmers/farm women in the project area during Maize Field Day in October 2007. The prize amount was sponsored by Corporation Bank, Tubagere. Best women achievers were recognized during important occasions.
- Best Progressive Farm Women District Award presented to Smt. Channamma, Antharahalli village of the project area during the Krishimela 2007 held at UAS, GKVK.
- Best Progressive Farmer District Award presented to Sri H.Sadananda, Thapasihalli village who happens to be an IFSD farmer of the project during the Krishimela 2008 held at UAS, GKVK.
- IARI best Farmer National Award for the year 2008 was presented to Sri H. Sadananda, Thapasihalli village who happens to be an IFSD farmer of our project during the Krishimela 2008 held at IARI, New Delhi.
- Jamsetji Tata National Virtual Academy (NVA) Fellow-2009 to Smt. Chennamma Antharahalli by Sri. MS Swaminathan Research Foundation Chennai, 2009 and another four farmers in the subsequent years.
- Swami Sahajananda Sarswathi Extension Scientists of the ICAR-2008 was conferred to Dr. K. Narayana Gowda, Project Co-ordinator, RBC on the foundation day of ICAR – 16.07.09. This award was given based on the report submitted about the project work.
- Sri H. Sadananda Tapasihalli received HARVEST OF HOPE- A Tribute to the Enduring sprit of Indian farmers conferred by Department of Agricultural Cooperation, New Delhi 2010.
- Sri H. Sadananda Tapasihalli received Krishi Pandith award – 2010 conferred by Govt. of Karnataka in 2010.

- IACR South Zone KVK Award 2013 and ICAR National Award 2014 to the KVK, Bangalore Rural District for outstanding performance SPECIALY mentioning continuation of project activities
- Majority of scientists involved in the project participated in national and International seminars based on the outcome of project work.

12. Important Visitors from India/Abroad

The project attracted many distinguished visitors from within and outside the state as well as across twenty two countries. The other visitors include Farmers, Students, Officers, Entrepreneurs, Planning Commission Senior Officers, Administrators, Elected Representatives and so on.

The most important visitors are:

Dr. S. Ayyappan, Secretary, DARE and DG, ICAR, New Delhi,

Dr. M. Mahadevappa, Former Chairman, ASRB, New Delhi.

Dr. R. Dwarkinath, Former Vice Chancellor, UAS, Bangalore &FAO Advisor to Indonesia.

Dr. G Trivedi, Former Vice chancellor, RAU, Bihar

Sri Umesh Katti, Hon'ble Minister of Agriculture, GOK

Sri M Veerappa Moily, Hon'ble Former Union Minister for Law and Parliamentary Affairs, GoI

Dr. Hansraj Bharadwaj, His Excellency, Governor of Karnataka

Sri. H D Deve Gowda, Hon'ble Former Prime Minister of India

Sri Gopala Gowda, Supreme Court Judge New Delhi.

Sri. Sri. Sri. Nirmalanandanatha Swamiji, Adhichuuchanagiri Mutt, Karnataka.

13. Path Breaking Activities

Interestingly the project outcome was brought in tremendous impact in many fronts. The most important ones are;

- The Karnataka Government sanctioned Biofuel Park at Hassan Agricultural College with a substantial funding support followed by Biofuel Task Force during 2008. Thereafter Government of Karnataka established Biofuel Development Board during 2010 with a budget outlay of Rupees 80 crores to take up large scale plantation of different biofuel species and to replicate the model of establishing processing plant across the state.
- DBT sanctioned a project "value chain in Jackfruit" with a budget outlay of 4.65 crores during 2012 to implement five states.
- The momentum was given to the start of FPAS at the state level in case of coconut, sericulture, sheep, jack fruit, mango and banana.
- Large scale processing plant in Jackfruit is encouraged during 2013 by inviting prospective entrepreneurs across jack growing states. The first jack processing plant is commissioned in Kerala during 2015; three are in the pipeline in Karnataka.

14. Conclusion

At a time when the country is struggling hard to achieve two per cent growth rate in agriculture, this model has demonstrated 11 per cent growth, besides threefold increase in added net income, increased employment among younger generation with a modest expenditure of Rs. 5500 per family for a period of five years. As a result of increased sustainable income, it was possible to hold majority of youth in rural areas. Therefore the model could be replicated across the country as well as other Asian countries with suitable refinement to suit different agro-climatic zones. The sustainable development goes with mobilizing local people to take the responsibility for continuation of technology realizing best price for the produce as well as undertaking value addition and processing which was effectively addressed through the start of need based commodity based associations.

Acknowledgements

Profusely thank DBT for not only providing funds for the project but also having provided operational freedom for implementation with constant guidance. Many thanks to the UAS(B) particularly to Dr. M.N. Sheelavanther, the then Vice Chancellor and team of scientists including junior scientists particularly Late. Dr. Doddahanumaiah and Dr. K.C. Narayanaswamy, Sri G.R. Venugopal, Accountant for their dedicated involvement in implementing the project. Thanks are due to all the other stakeholders particularly farmers, local leaders, officials and scientists who were actively involved in this endeavor.

Land Degradation Cycle in the Shivaliks of Jammu and Kashmir

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1. Introduction

The predominantly hilly state of Jammu and Kashmir is divided into three political divisions viz. Jammu, Kashmir and Ladakh; each having its own set of agro-climatic zones. These agro-climatic zones suffer enormously from land degradation processes of different magnitude. The lower Siwaliks or the foothill Himalayas fall under the Jammu division of the state, extending from district Kathua in the southeast to Rajouri in the northwest, constituting about 12% of the total area of Jammu region. It is a dry semi-hilly belt, locally known as kandi. Land degradation is common in the catchments of lower Siwaliks of Jammu. The productivity of the soils of this region of Jammu is not only low but highly unstable. Soil erosion due to high runoff, results in sizeable loss of soil and nutrient and, is primarily responsible for low productivity and poor economic status of the farmers in these rainfed areas. The loss of top soil results in loss of nutrients necessary for plant growth, which influences the production and productivity of the crops. Soil erosion in the Siwalik or Southern Himalayas is due to massive deforestation and severe denudation of the hills and causes severe floods in the plains besides removal of more than 80 tonnes of soil ha^{-1} $year^{-1}$ (Sharma, 2004). Loss of plant nutrients, however, varies according to landuse pattern. The top soils from forest and well managed cultivated land contained 0.83 and 0.58 per cent organic carbon, respectively, as compared to0.40 and 0.30 per cent from the barren and unmanaged cultivated land (Gupta, 1994). Due to fragility, marginality, low accessibility and resource heterogeneity, there is little scope for enhancing crop productivity with the existing infrastructural facilities and the level of adoption of technologies. There is urgent need to identify the processes promoting land degradation and site specific technologies need to be developed for resource conservation.

2. Physiography

The lower shivaliks of Jammu and Kashmir are classified under the physiographic unit Hills ranging from 320 to 720 meters above mean sea level (Rashid and Arora, 2007). The area is mostly dominated by Siwalik, Muree and Subathu group of sediments. The general lithology is sandstone, conglomerate, shale, silt stone and limestone. The lower Siwalik rainfed area of Jammu has unique land, soil and climatic features representing a semi-arid or sub-humid type of climate. However, the climate of the whole area is characterized by sub-tropical nature.The region is characterized by erratic rainfall (750-1200 mm annually), undulating terrain, frequent droughts, low soil organic matter and coarse textured soils. The soil surface is infested with sand stones and water retention capacity is extremely poor. The agriculture in the region is totally dependent on monsoonal rains. About 80 % of the rains occur in first two months of monsoon season (July-August), with high intensity rainstorms. The average temperature during summer, winter and rainy seasons varies between 18°C and 40°C, 4°C and 23°C and 14°C and 32°C, respectively. During the rainy season the soil erosion is heavy, resulting in loss of nutrients and removal of top fertile soil layer. Comparison of crop yields showed that average productivity of various crops is poor in kandi region compared to the state as a whole or country (Table 1). Economically, this is the most underdeveloped part of the state in which a substantial proportion of the population is living in poverty (Husain, 2000).

3. Land Degradation Process

The entire lower shivaliks are drained by a number of major and minor rivers which include Chenab, Tawi, Basantar and Ujh. Apart from these, there are ephemeral streams(*khads*) like Devak, Bain, Bhagar and Sahar dotting the landscape.The degradation of catchments in terms of land, soil and vegetation is enormous. It seems that there exists a continuous cycle of events, involving both natural and anthropogenic factors, promoting land degradation in the region (Fig. 1).

Natural factors: The physiographic characteristic of the area is in itself a major factor contributing to the continuous degradation of these catchments. The weak lithology of the lower Shivaliks consisting of rocks like sandstone, conglomerate, shale, silt stone and limestone are relatively easily weatherable and therefore prone to quick erosion. The topography of the region ranging from gently sloping to moderately-steep sloping retards the vertical development of soils. Due to great variation in steepness of the slope in this region, erosion is the major problem of land husbandry (Gupta and Gupta, 2004). Sloping relief pattern results in accelerated erosion causing removal of surface material. Surface runoff is higher on sloping lands resulting in lesser percolation of water which is essential for profile development. Further, lesser water is available for the growth of plants and trees which are responsible for checking soil erosion.

Major share of the total rainfall received in the area is contributed by monsoons between July and September. The rainfall in monsoon is usually accompanied with thunderstorms due to lower pressure created because of warmer temperatures resulting in high intensity rainfall albeit for a shorter period. This high intensity rainfall is capable of disturbing the top soil, and in turn loosening it, resulting in sheet and rill erosion. The rills if not attended to may lead to the formation of small gullies. The problem is further aggravated as the soil in the area is coarse textured and prone to erosion (Sharma *et al.,* 2004). It is generally considered that as the silt (0.002-0.05 mm) or silt and very fine sand (0.05-0.10 mm) fraction increases, soil erodibility increases (Wischmeieramd Mannering, 1969). This is because of binding affect of clay, transportability of fine and non-aggregate particles and the detachability of sand and silt (Le-Bissonnais, 1996). The extent of rill soil erosion can be discerned in number of broad longitudinal valleys known as *Duns* like Udhampur, Jhajjar Kotli and Dansal in lower Shivaliks of Jammu region.

The seasonal high intensity rains also results in sudden and flash floods in rivers, nallahs and khads fed by their respective catchments. The water loaded with sediments from the catchments exerts enormous pressure on the banks resulting in stream bank erosion resulting in loss of size chunks of productive land over time.

Anthropogenic factors: Increased human and cattle population pressure and decreased size of land holdings in the area have resulted in indiscriminate felling of trees, removal of bushes and grazing and browsing. The human population of the state increased at an annual compound growth rate of 2.64 % as against 1.08 % ACGR of foodgrains between 1961 and 2001 (Table 2; Sharma and Sharma, 2003). This indicated that while increase in the population was substantial, the foodgrain production did not cope with this increase. The situation is still worse in the kandi region where there has remained acute shortage of foodgrains.

Lack of knowledge regarding soil and water conservation measures is an important factor contributing towards land degradation in the area. It has been observed that only about 43 per cent of the farmers in the lower Siwaliks of Jammu are aware about the severity of the problems related to runoff and soil loss (Sharma *et al.*, 2004). Only 31 per cent of the farmers adopt any of the soil and moisture/water conservation measures in the area. More than 76 per cent of the farmers are cultivating land along the slope resulting in soil, nutrient and water loss as only 24 per cent of the respondents plough across the slope.

The community in these areas faces a lot of constraints in adoption of improved soil and water conservation measures. About 76.6 per cent of the farmers feel that they had lack of skill in handling the practices like contour bunding, staggered trenches etc. (Table 3; Sharma *et al.,* 2005).About 95 per cent of the inhabitants had problems due to undulating topography which causes problem in application of different practices. They had to rely more on human labour rather than machinery because they had sloping and fragmented fields. Small and fragmented land holdings of the farmers in the area is also one of the major constraint for adoption of improved practices. Further, poor economic condition of the farmers restricts them from employing any labour or using any machinery.

The land holdings in the kandi region are small and fragmented. A sample survey in the area showed that 92% of the families have cultivable holdings of less than 2 ha and 80 % have less than 1.5 ha (Arora *et al.*, 2006). The tenancy law of transferring the land to all children of the family has made the matter still complicated. At present, the land exists in different small to large categories of < 1.0 ha, 1 to 5 ha and > 5 ha holdings in the region (Table 4). Though the family size is bigger in the region, most of the members of the family go for job or labour work to earn their bread instead of performing agriculture practices on their small lands.

In order to meet the demand of food, fiber, fuel and fodder due to exponential increase in population pressure, there has been large scale deforestation. It has led to unabated soil loss and land degradation.Forest cover plays significant role not only in checking the soil erosion and run-off losses but also maintains the balance in physical landscape through the regeneration of degraded and eroded lands. It has also been found that natural fallows under grasses and shrubs or grasses alone have negligible run-off and soil loss than cultivated fallows, which give maximum rate of run-off and soil loss (Gupta, 2005). Vegetative cover increases the water stable aggregates in soil, protects it against rain drop, reduce water velocity, increases infiltration capacity and fertility of the soil.

4. Opportunities and Challenges

All the above factors lead to continuous land degradation, thereby reducing the productivity of these lands, which in turn affects the economic condition of the farmers luring them to other sources of employment and the cycle continues so on. Increased human population resulting in smaller land holdings coupled with poverty is putting pressure on land maintenance. Younger generations among the farming community have started looking for other avenues for making their ends meet. This has led to lesser interest in farming and therefore the maintenance of land takes a back seat.The challenges and opportunities thus can be grouped in five major areas: overcoming constraints to technology adoption; managing conflict; balancing local economic and environmental services; and strengthening organizational and learning processes. Leach *et al.* (2002) indicated that public policy making and implementation in the United States are increasingly handled through local consensus seeking partnerships involving most affected stakeholders. The stake holders perceive that their partnerships have been most effective in addressing local problems. In short the stakeholder should be the central figure in any planning process for the rehabilitation of these degraded lands. Keeping in view the poor socio-economic status of the farmers and the inherent causes of soil erosion and land degradation prevalent in the area, the challenge lies in protecting the limited land resource from further degradation, improving productivity of land and eroding poverty in kandi region of the state.To rehabilitate the area, it is required to conserve soil against erosion, manage rainwater efficiently to produce more crops, to provide food, fodder and fuel. In fact poverty in itself is the number one constraint towards the rehabilitation of such areas. Land holdings being small possibility of subsidiary occupations like poultry, fisheries, animal husbandry, paper industry, etc. needs to be explored. Traditionally practiced agro-forestry needs to be developed on scientific lines to produce more biomass without degradation of resources. Horticulture has a good scope in the area. The possibility of combining horticulture and forestry with agricultural crops, grasses and fodders needs to be explored on scientific basis. This requires and integrated multidisciplinary approach for development in the area. Thus there is need to develop these areas for improving not only the productivity but also to check soil loss and conserve water.

5. Conclusion

Wide scale land degradation of catchments in terms of land, soil and vegetation has been observed in the foothill Himalayas of Jammu region. An attempt was made to identify and relate the factors involved in land degradation. It was found that there exists a continuous cycle of events, involving both natural and anthropogenic factors, promoting land degradation. The weak lithology of the lower Shivaliks consisting of rocks like sandstone, conglomerate, shale, silt stone and limestone are relatively easily weatherable and therefore prone to quick erosion. Sloping relief pattern results in accelerated erosion causing removal of surface material. Surface runoff is higher on sloping lands resulting in lesser percolation of water which is essential for profile development. The high intensity rainfall during monsoon disturbs the top soil, and in turn loosens it, resulting in sheet and rill erosion. Increased population coupled with poverty is putting pressure on land maintenance. Younger generations among the farming community has lesser interest in farming and, therefore, the maintenance of land takes a back seat. Lack of knowledge regarding soil and water conservation measures is another important factor contributing towards land degradation in the area. Only 43 per cent of the farmers in the lower Shivaliks of Jammu are aware about the severity of the problems related to runoff and soil loss. Increased population pressure and smaller land holdings have promoted deforestation leading to unabated soil loss and land degradation. All the above factors lead to continuous land degradation, thereby reducing the productivity of theses lands, which in turn affects the economic condition of the farmers luring them to other sources of employment and the cycle continues. The challenge lies in protecting the limited land resource from further degradation, improving productivity of land and eroding poverty in Jammu region of the state.

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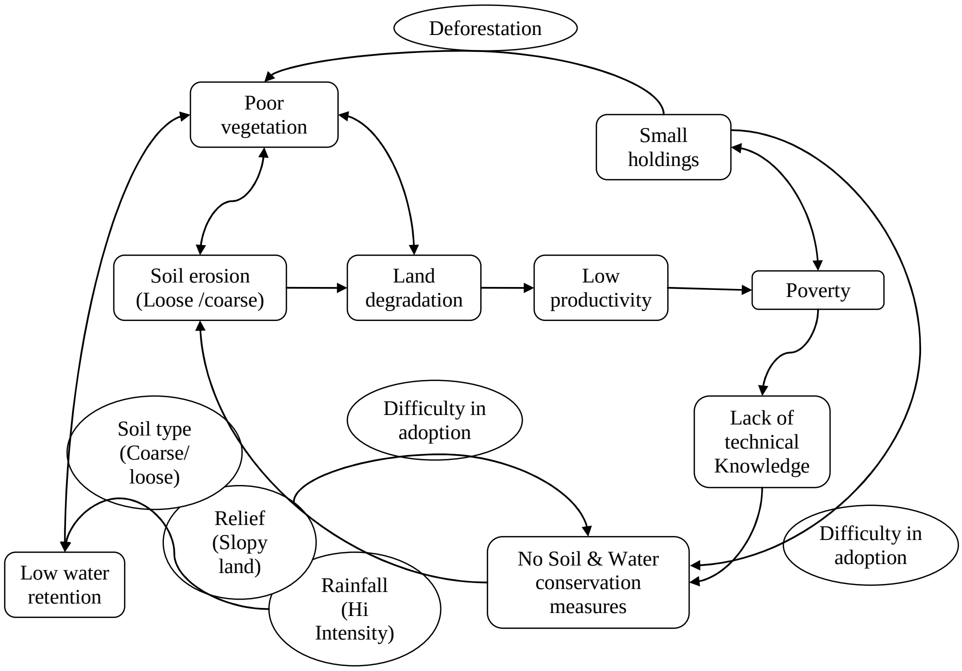

Fig. 1: Land degradation cycle in lower Siwaliks of Jammu.

Table 1. Comparison of major crop yields of kandi region of Jammu

Crop	Yield (kg ha^{-1})		
	Lower Shivaliks (Kandi region)	**J&K state**	**All India**
Wheat	890	1530	2583
Maize	1205	1710	1755
Coarse cereals	1165	1617	1065
Pulses	450	564	622

Table 2. Population and food grain production in J&K state

Year	Population	Food grain production (million tones)
1961	3.56	0.96
1971	4.61	1.00
1981	5.95	1.17
1991	7.72	1.32
2001	10.12	1.48

Table 3. Constraints in adoption of soil and rainwater management practices (n=120)

S.No.	Constraints for adoption of soil and rain water conservation practices	No. of Farmers	Per cent
1	Non-availability of design and implements used for rainwater harvesting	107	89.20
2	Lack of technical knowledge	92	76.60
3	Topographical problems	114	95.00
4	Ignorance of rainwater management practices	69	57.50
5	Small & fragmented land holdings	102	85.00
6	Poor socio-economic condition	105	87.50

Sharma *et al.* (2005)

Table 4. Land holding and family size in kandi region of Jammu

Category	Land holdings	Family size category	Families
< 1.0 ha	61.9 %	< 4	16 %
1.0 to 5.0 ha	36.9 %	8	41 %
> 5.0 ha	1.2 %	> 8	43 %

Arora *et al.* (2006)

Notes: ....

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