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Climate Resilient Agricultural Technologies for Future

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Contents

Microbial Technologies for Land Rejuvenation and Climate Resilient Crop Productivity

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Summary

Most of the cultivable lands around the world are severely affected by environmental factors leading to decline in the crop productivity by 10%. Besides these factors, indiscriminate use of chemical fertilizers along with pesticides and unavailability of organic manures also led to considerable reduction of crop productivity thereby deteriorating the sustainability of soil health and agricultural ecosystems including rice. Therefore, a wider range of adaptations and mitigation strategies would be required to meet the challenges of enhancing productivity of rice. Beneficial microorganisms are one of the best options to overcome these situations. Inadequate rice-specific biofertilizers and microbial pesticides prompted us to develop microbial technologies especially to manage nutrient and pest problems of rice. So far, ICAR-National Rice Research Institute, Cuttack has developed numerous microbial technologies such as *Azotobacter chrococcum* and *A.vinelandii* bioinoculants, soil-based *Azolla*sporocarp*,* phosphate solubilizing bacteria, arbuscularmycorrhiza, entomopathogens (*Bacillus thuringiensis*, *Beauveria* and *Metarrhizium*), exopolysachharide producing bioinoculants and straw decomposition microbial consortia, to resolve many problems allied to nutrient (nitrogen and phosphorous), climatic, pest and straw decomposition.

Key words: Rice, Biofertilizers, Microbial pesticides, Straw decomposition, *Azolla*

1. Introduction

Agriculture is highly dependent on the climate. Increases in temperature, carbon dioxide (CO_2), moisture, water availability and other factors directly or indirectly affect crop's growth and productivity. Increasing level of atmospheric CO_2 is not only causing global warming but also altering the agricultural ecosystem (Panneerselvam et al., 2019). Moreover, overuse of chemical fertilizers and pesticides also deteriorated the soil health and sustainability of the agriculture systems (Kumar et al., 2018a). Hence, concrete strategies would be required for enhancing crop productivity. Beneficial microorganisms are one of the best options to overcome this situation, by exploring their potentiality mostly unique properties of tolerance to extremities, ubiquity, genetic diversity, and their interaction with crop plants for sustainable rice production. In the present chapter, NRRI-developed rice-specific microbial technologies have been highlighted and these technologies may serve as a potential measures in suppression of some of the major global problems related to sustainability of rice crop.

2. Microbial technologies

2.1 Biofertilizer

Biofertilizers contain carrier based (solid or liquid) living microorganisms which are agriculturally useful in terms of nitrogen fixation, phosphorus solubilization or nutrient mobilization, to increase the productivity of the soil and/or crop plants. Presently, biofertilizers have emerged as a highly potent alternative to chemical fertilizers because of their eco-friendly, easy to apply, non-toxic and cost-effective nature. In addition, biofertilizers are one of the promising technologies for rice productions, however, it is not popular among farming community, due to lack of knowledge and awareness of its effective use. Moreover, Government has also taken many steps to showcase its effective use in agriculture. Some of the most useful biofertilizers for rice and their recommended doses are mentioned in Table 1.

Table1. Recommendation of bio-fertilizers for rice crop

Inoculants	Recommendations	Nutrients supply to plants	Gain in grain yield
Cyanobacteria/ Blue green algae	50-60 kg fresh wt/ha (or) 6-7 kg dry weight	20-25 kg /ha/season	10-20%
Azolla	10-15 t fresh wt/ha	20-40 kg N/ ha/ 20-75 days	10-30%
Azospirillum	5-6 kg solid/ 500 ml liquid/ ha	5-10 kg N/ha	5-15%
Azotobacter	5-6 kg solid/ 500 ml liquid/ ha	5-10 kg N/ha	5-15%

AM fungi	1 ton soil based inoculums/ha (Upland rice)	Supplemented 30% Phosphorus	15-25% (upland rice)
Phosphate solubilizing bacteria (PSB)	5-6 kg solid/ 500 ml liquid/ ha	Supplemented 10-20% Phosphorus	5-15% (upland rice)

2.1.1. Bio-prospects of *Azolla*

Azolla technology is widely accepted throughout the world as efficient nitrogen contributor in rice ecology through symbiotically associated cyanobacteria (Kumar et al., 2019a). As regards to the biomass production, and quantity of nitrogen fixation and nutrient recycling, *Azolla* is highly efficient, cost-effective and ecologically sound biofertilizer. To produce *Azolla* inoculum in paddy fields, its vegetative fronds in large scale are required but there are several physical constraints in *Azolla* production and utilization. The thick wall of megasporocarp can withstand high temperature, drought condition, and pest attack. Most of the researchers have documented the sporocarp production of *Azolla* only from a limited number of species but it has to be studied thoroughly with 102 strains available at NRRI germplasm collections (Kumar and Nayak 2019; Kumar et al., 2018c). Soil-based *Azolla*sporocarp, *Azolla*pellets for livestock feed and *Azolla*-based microbial medium had been developed at NRRI.

2.2. Microbial formulations to manage rice pests

Adequate pest management is essential for sustainable agricultural production. In the worldwide agriculture system, the commonly used pesticides come under synthetic origin. Excessive use of these synthetic compounds led to environmental pollution. Hence, biopesticides are considered as an alternative to synthetic pesticides that are highly effective, target specific and reduce environmental risks. At NRRI, we are actively working since long to identify efficient entomopathogens to manage rice leaf folder and finally able to identify the following bacterial and fungal strains *viz., Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and formulations of these strains were also filed for Indian patents. In addition, recently we have identified one efficient entomopathogenic bacterium (*Skermanella* sp.) against rice leaf folder and pink stem borer (Panneerselvam et al., 2018).

2.3 Microbe-mediated paddy straw decomposition

In India, we are generating nearly 158 million tonnes of paddy straw every year and recycling of these wastes properly retrieve the considerable amount of nutrients to the soil in addition to improving soil health and reducing greenhouse gas emission to the environment. It has been frequently reported that the application of rice straw to paddy fields increases methane emissions. Therefore, promotion of the oxidative decomposition of rice straw in and out of the field is important for not only reducing methane emissions but also enhancing the carbon stock in the soil. At NRRI, *Bacillus*, *Aspergillus*, *Trichoderma*, and *Streptomyces* spp., consortia were identified to decompose paddy straw within 45 days.

2.4. Role of arbuscular mycorrhizal fungi (AMF) in rice

AMF colonization in rice plant has been documented by many researchers and this fungal association in rice found to enhancing P acquisition. At NRRI Cuttack**,** AMF association was studied in 72 different rice cultivars including two low P tolerant checks *viz*., Kasalath and Dular, which were raised in P deficient soil (< 6.0 – 8.0 ppm). The AM fungal root colonization was recorded in the range of 20-90 %, whereas, it was 80-90 % in Kasalath and Dular cultivars. These two varieties have the dominant unique type of vesicle-forming AMF colonization, which was not observed in many low P tolerant varieties. This observation clearly indicates that some genera of AM fungi may prefer the specific rice genotype of rice.

2.5. Microbial products/ formulations developed at NRRI, Cuttack

Presently, the following microbial products/formulations are available at NRRI, Cuttack (Fig. 1; Fig. 2):

- Liquid bioinoculant of endophytic nitrogen fixing *Azotobacter chrococcum* AVi2 and rhizospheric *A. vinelandii* SRIAz3 for nitrogen management in rice which could replace ~25% of chemical nitrogen without compromising yield.
- Soil-based sporocarp formulation of *Azolla* has been developed to considerably reduce the initial inoculums load of *Azolla* in paddy field.
- *Azolla*-based microbial medium and *Azolla* pellets for livestock feed had been developed

- ❖ Six Indian patents on entomopathogens formulations for management of rice leaf folder were filed by NRRI with the following numbers 264/KOL/2015, 263/KOL/2015, 261/KOL/2015, 262/KOL/2015, 260/KOL/2015, 265/KOL/2015.
- ❖ Arka Microbial consortium and Actino plus microbial packages have been standardized for nutrient management in low-land and aerobic rice production systems.
- ❖ Phosphate solubilizing and exopolysachharide producing liquid bacterial bioinoculants had been developed in rice, respectively.

Fig. 1.(a) *Azolla* feed pellets; (b) NRRI *Azolla* medium for microbial growth; (c) bacterial liquid formulation for alleviating drought stress.

Fig. 2. Rice-specific microbial bioinoculants developed at NRRI, Cuttack (ENF: Endophytic nitrogen fixer; RNF: Rhizospheric nitrogen fixer; AS: *Azolla*sporocarop; AMF: Arbuscular mycorrhizal fungi; PSB: Phospahte solubilizing bacteria; ESP: Exopolysaccharide producing bacteria)

3. Conclusion and way forward

The present chapter describes the management of nutrient, pest, residue and drought stress alleviation by harnessing microbial resources especially for rice crop. In future, following microbe-mediated strategies are essentially required for sustainable development of rice crop particularly in eastern India.

- Microbial consortia must be developed for managing major and minor nutrients, pest, paddy straw and abiotic stress alleviation exclusively for rice crop.
- Molecular markers of *Azolla* must be identified for better understanding of *Azolla*-cyanobiont interactions for sustainable production of rice.
- Latest molecular tools must be explored to understand the soil biological nutrient cycling in paddy soil.

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Indicator Based Approach for Vulnerability Assessment

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Summary

Conceptual framework of vulnerability assessment is discussed along with the various definitions of vulnerability and its components. . Further we elaborate various approaches to estimate vulnerability to climate change. The integrated approach to estimate vulnerability is discussed in detail with a special emphasis on the Indicator based approaches and composite vulnerability index calculation. There is discussion on how to compute vulnerability index and applications of vulnerability assessment in agriculture with special emphasis on social scientists are presented.

1. Introduction

There has been a considerable increase in global surface temperatures, changes in precipitation patterns and an increase in incidence of extreme weather events across the globe since the turn of the new millennia. Climate change is possibly the most intricate and challenging adversity faced by mankind and is increasingly being identified as a major threat to agriculture in general and to food security in particular. Climate change is defined as 'a change in the state of the climate that can be identified (e.g. using statistical tests), by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer' (Parry *et al*, 2007). The occurrence and consequence of climate change are pertinent on a global scale, but developing countries like India tend to be affected more adversely by it. Climate change projections made for India indicate an overall rise in temperature by 1–4 ^{0}C and precipitation by 9–16% by 2050 (Kumar *et al*, 2011). However, different regions are predicted to encounter disparities in change in rainfall and temperature in the immediate future. The incidence of extreme weather events like floods, droughts and cyclones are expected to increase in the future. These predicted changes are expected to affect climate sensitive sectors like agriculture, human health and forestry adversely.

IPCC has identified that adaptation is as important as mitigation in tackling climate change as even drastic mitigation measures will fail to stop the projected increase in temperature at least till 2100. Hence off late greater emphasis has been laid on adaptive measures in research as well as policy formulation. For the development and targeting of appropriate adaptation measures the identification of regions that are affected more severely by climate change is quintessential. Vulnerability assessment aids us in identifying regions that are likely to be affected severely and prioritizing investment and designing and disseminating adaptive measures accordingly.

The current chapter presents a various techniques employed in vulnerability assessment. Further, the steps involved in computation of vulnerability indices to climate change are elaborated in detail.

2. Vulnerability: Conceptual Framework

Vulnerability in present research context is a multi-disciplinary theme characterized by rapid changes in climate and social and economic systems. The concept of vulnerability is viewed differently in different disciplines. In the context of climate change and agriculture vulnerability may be viewed as the proclivity of an individual or community to face climate shocks and suffer losses in production or income. IPCC has defined vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.

$$\boldsymbol{Vits} = \boldsymbol{f}(\boldsymbol{Eits}, \boldsymbol{Aits})$$

Here vulnerability of a system 'i' to a climate stimulus's' at time 't' is defined as a function of the exposure of system 'i' to climate stimulus's' and the adaptive capacity of the system at time 't'.

The definition of vulnerability has been further simplified by IPCC where in vulnerability (V) of a system is a function of exposure (E), sensitivity (S) and adaptive capacity (A).

$$\boldsymbol{Vulnerability} = \boldsymbol{f}(\boldsymbol{Exposure}, \boldsymbol{Sensitivity}, \boldsymbol{Adaptivecapacity})$$

$$\boldsymbol{Vulnerability} = \boldsymbol{f}(\boldsymbol{PotentialImpact} - \boldsymbol{Adaptivecapacity})$$

A higher adaptive capacity is linked with lower vulnerability while a higher impact is characterized by higher vulnerability of the system. Given the above equation, vulnerability is defined as a function of a range of biophysical and socio-economic factors, aggregated into three components: exposure, sensitivity and adaptive capacity to climate variability and change. The conceptual framework for vulnerability assessment as proposed by IPCC has been depicted in figure 1.

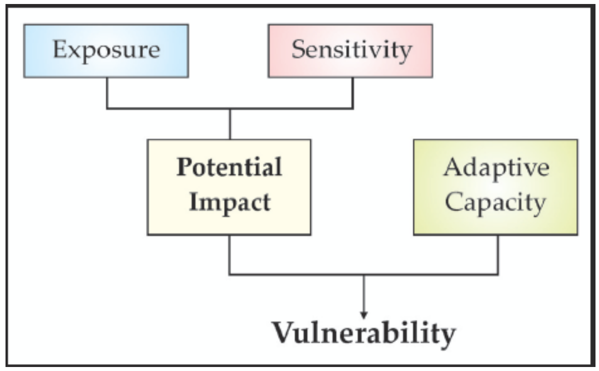

Fig.1: Conceptual framework of vulnerability of agriculture to climate change (Parry *et al,* 2007)

3. Components of Vulnerability

3.1 Exposure

Exposure is defined as 'the nature and degree to which a system is exposed to significant climatic variations'. Thus, exposure pertains to climate stress upon a particular unit of analysis (Gbetibouo and Ringler, 2009). 'A more comprehensive measure of exposure to future climate change would entail consideration of projected changes in climate for each unit of analysis.

3.2 Sensitivity

Sensitivity is defined as 'the degree to which a system is affected, either adversely or beneficially, by climate related stimuli'. It is influenced to a great extent by the demographic and environmental status of the particular region.

3.3 Adaptive capacity

Adaptive capacity is 'the ability of a system to adjust to climate change, including climate variability and extremes to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. It is considered to be 'a function of technology, education, wealth, and infrastructure, access to resources, information, skills and management abilities (Eriyagama *et al.*2012).

4. Approaches to Vulnerability Assessment

4.1 Socio-economic Approach

This approach focuses primarily on the socio-economic status of individuals or communities. The individuals or communities in a region tend to differ in various social and economic characteristics like wealth, education, health status, access to information, access to credit, ownership or access to resources, social capital etc. The socio-economic approaches emphasize that differences in socio-economic characteristics are responsible to differential vulnerability of individuals or social groups (Adger and Kelly 2012). Hence in this approach vulnerability is defined as a 'staring point or state' before a hazard event is encountered.

4.2 Bio-physical Approach

In this approach the level of damage caused by an environmental stress on an entity (social or biological) is estimated. This approach is popularly identified with impact assessment or hazard loss relationship. In contrast to the socio-economic approach here the focus is on the 'end point or state'. In agriculture the potential impact of climate change on crop yields are simulated (Srivastava *et al* 2011, Boomiraj *et al* 2010).

4.3 Integrated Approach

The integrated approach combines both bio-physical and socio-economic approaches to determine the vulnerability of a system to climate change. The integrated approach is consistent with IPCC's definition of vulnerability. Herein the sensitivity component is consistent with bio-physical approach while adaptive capacity is drawn from the socio-economic approach. Sensitivity and adaptive capacity comprise the internal dimension while exposure component is viewed as the external dimension (Rao *et al.* 2016).

5. Vulnerability Index

Composite vulnerability indices is an integrated has been extensively by social scientist to determine the vulnerability to climate change. It is an integrated assessment tool that combines both socio-economic and bio-physical factors. It is based on the indicator approach wherein indicators are combined to form sub-indices which in turn are aggregated into a composite index. The advantages and disadvantages of the indicator approach are tabulated in Table 1.

Table 1: Pros and cons of composite vulnerability indices

Advantages	Disadvantages
• Quantifies vulnerability of different regions and helps in identification of susceptible regions. • Easily understandable • Are flexible tools and can be used to	• Subjective selection of variables. • As it is an average, loss of specificity and masking of information is eminent. • Amplification of measurement errors • Fails to explain process that shapes

track changes over time. • Promotes multi-stakeholder dialogue. • Overcomes problems of reliability, accuracy and validity	vulnerability. • Fails to depict intra-regional vulnerability status

Vulnerability indices serve as an effective starting point in determining climate susceptible regions and framing policies and prioritizing investment to tackle the detrimental effects of climate change on agriculture.

6. Steps involved in developing vulnerability index

There are four steps involved in the construction of a composite vulnerability index. These steps have been elaborated in this section.

Step1- Selection of relevant indicators for components:There is no standard procedure for selection of indicators. The common procedure followed is review of literature to identify our base category of relevant variables. These variables are then subjected to expert review before finalizing the list of indicator variables. The number of variables selected under exposure, sensitivity and adaptive capacity are left of the discretion of the researcher. Some of the commonly used indicators in exposure are average *Kharif* rainfall, average *Rabi* rainfall, variability in *Kharif* rainfall, variability in *Rabi* rainfall, projected changes in maximum and minimum temperature, number of extreme rainfall events, number of dry spells (Rao *et al*. 2016, Suresh *et al*. 2016, Tripathi 2016, o'Brien *et al* 2004). The commonly employed indicators for sensitivity are proportion of small and marginal farmers, percentage of rainfed area, proportion of population engaged in agriculture, population density per acre of farms, rural population density, percentage of agricultural GDP (Rao *et al*. 2016, Suresh *et al*. 2016, Tripathi 2016, o'Brien *et al* 2004). Some of the indicators extensively used to capture adaptive capacity are level of education, per capita income, poverty incidence, percentage of rural electrification, percentage of paved roads, livestock population density, proportion of SC/ST population and access to markets (Rao et al. 2016, Suresh et al. 2016, Tripathi 2016, o'Brien *et al* 2004).

Step 2- Scaling and Normalization: Since the indicators are measured in different units they are normalized to bring values on a comparable scale namely 0 and 1. Normalization is carried out on the basis of functional relationship between the indicator variables and their respective indices. If the relationship is positive then the following formula is used

$$Yit = \frac{Xit - MaxXit}{MaxXit - MinXit}$$

Where in Y_{ij} is the index for the i^{th} indicator for the j^{th} district and X_{it} is the actual observed value of the i^{th} indicator for the j^{th} district, Max X_{it} is the maximum observed value for the i^{th}indicator among all districts and Min X_{it} is the minimum observed value for the i^{th}indicator among all districts.

If the relationship is negative then the following formula is used

$$Yit = \frac{MinXit - Xit}{MaxXit - MinXit}$$

Where in Y_{ij} is the index for the i^{th} indicator for the j^{th} district and X_{it} is the actual observed value of the i^{th} indicator for the j^{th} district, Max X_{it} is the maximum observed value for the i^{th}indicator among all districts and Min X_{it} is the minimum observed value for the i^{th}indicator among all districts. Alternatively in some studies (100-$Index_{sd}$) in case of indicators with negative relationship so as to ensure that high index values indicate high vulnerability (Tripathi 2016).

Step 3- Assigning weights to indicators and aggregation: Several techniques have been used to assign weights to different indicators. One of the most commonly used techniques is to assign equal weights. However this method might turn out to be too arbitrary and could result in underweighting of a few key indicators. Weights are assigned by subject matter specialists for each indicator but this method is often prone to subjectivity bias or lack of consensus among the experts. Principal component analysis is another technique used to assign weights. In this technique the first principal component contains maximum information regarding the underlying data, hence the factor loadings of the first principal component is used to assign weights to each indicator. After assigning weights the indicators are aggregated using either the additive approach or the functional approach. The former is preferred to the latter owing to its simplicity. Further the districts are divided into different groups based on quartile analysis (Suresh et al. 2016).

Step 4- Validation: The final step is validation which is undertaken so as to arrive at a consensus between various stakeholders. Validation is done using item analysis or external validation. In case of the former the correlation between index scores and components are assessed and certain indicators that are weakly correlated are subsequently dropped. However dropping variables that may not be significant statistically but relevant theoretically may lead to underestimation of the index. In external validation, we first selected some items or variables that are not included as indicating variables of the composite index and then, we assessed the relationship between components and index scores and selected an item or variable among them as a validator**.**

7. Conclusion and way forward

In this chapter we have discussed the conceptual framework of vulnerability and various approaches to assessing vulnerability. Further we have discussed in detail various steps involved in computing composite climate vulnerability index. Vulnerability index is not an absolute measure but a relative one. Thus the primary application of vulnerability assessment index would be in identifying climate susceptible regions. Vulnerability index can facilitate decision making and can be useful for setting targets and priorities as it provides a single-value, easy to comprehend estimate, and facilitates easy and meaningful monitoring and evaluation of progress.Therefore, indicators are being increasingly recognized as useful tools for policy making and public communication in conveying information on performance in diverse fields such as environment, economy, society or technological development. Vulnerability assessment with the help of indicators is vital as it facilitates the identification of climate susceptible regions and, can act as an entry point for understanding and addressing the processes that cause and exacerbate vulnerability.

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Integrated Pest Management (IPM) in Rice under Changing Climate

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Summary: Global warming and climate change will trigger major changes in geographical distribution and population dynamics of insect pests, insect-host plant interactions, activity and abundance of natural enemies, and efficacy of crop protection technologies. Changes in geographical distribution and incidence will affect both crop production and food security. Insect pests presently confined to tropical and subtropical regions will move to temperate regions along with a shift in the areas of production of their host plants; while distribution and relative abundance of some insect species vulnerable to high temperatures in the temperate regions may decrease as a result of global warming. The relative efficacy of pest control measures such as host-plant resistance, natural enemies, bio-pesticides, and synthetic chemicals is likely to change as a result of global warming and climate change. The rice crop is prone biotic to stress throughout the crop growth period. In the era of climate change, it can have effect on all organisms, including plants, insects and their interactions among weather, plants and herbivores. Moreover, the insect physiology, behaviour, development and species distribution may also be affected in a changing climate. There is an urgent need to assess the efficacy of various Integrated Pest Management technologies under diverse environmental conditions, and develop appropriate strategies to mitigate the adverse effects of climate change.

Key words: IPM, Rice, Climate

1. Introduction

Insect pests cause an estimated annual loss of 13.6% globally, and the extent of losses in India has been estimated to be 17.5% (Dhaliwal et al., 2010). Rice is a staple food for a large part of the world's human population, grows in a wide range of environment. India has the largest area under rice among the rice growing countries of the world and ranks second in total production. In India, the area under rice is 427.44 lakh ha, with an annual production of 108.86.Despite centuries of technological development, insect pests continue to exact a very high toll on agricultural production and human health. On the other hand, the population abundance of an insect species is manipulated by the host plant, natural enemies or extreme weather conditions

(Huang et al. 2010) which finally lead to severe infestation of insect pests in the field. In order to combat this, a well-established, successful and most merited approach to this problem is the use of concept called Integrated Pest Management (IPM). Adoption of integrated pest management (IPM) strategies is the best solution to tackle the pest problems. An IPM practice in rice production initiatives includes regular pest monitoring, research on the optimal use of pesticides, and alternative cultural and biological controls. In this regard, several efforts have been made to develop, verify, demonstrate and document location specific IPM technologies suited to different ecosystems. Since IPM is a dynamic process, therefore, it needs continuous up gradation of the technology as per the changing pest scenario. IPM in rice seeks to optimize production and to maximize profits through its various practices. Following are the major insect pests of rice

Major effects of climate change on insect pests (Sharma 2013)

- Effects on arthropod diversity and extinction of species
- Change in geographic distribution and population dynamics of insect pests
- Effects on expression of resistance to insect pests
- Reduced activity and abundance of natural enemies
- Reduced efficacy of biopesticides and synthetic insecticides

2. Major Insect's pests of Rice

National Significance	Regional Significance
1. Yellow stem borer (*Scirpophagaincertulas*	1. Termite (*Odontotermesobesus*Rambur)
2. Brown plant hopper (*Nilaparvatalugens*)	2. Swarming caterpillar (*Spodopteramauritia*)
3. Leaf folder (*Cnaphalocrocismedinalis*)	3. Rice Hispa (*Dicladispaarmigera* Oliver)
4. White backed plant hopper (*Sogatellafurcifera*)	4.Climbing cutworm/Rice Ear Cutting Caterpillar/ Armyworm (*Mythimnaseparata*)
5. Gall midge (*Orseoliaoryzae*)	5. Caseworm (*Nymphuladepunctalis*)
6. Gundhi bug (*Leptocorisaacuta*)	6. Panicle mite (*Steneotarsonemusspinki*)

3. IPM practices in Rice

3. 1. Pest Monitoring: It is one of the first and foremost steps in IPM. It can undertake through surveys (roving survey or through field scouting). It could also be done by Pest monitoring pheromones/light traps etc. Following are the ETL defined for insect pests. Management practices are to be initiated once pest reaches the following threshold limit (Prakash et al., 2014).

Pests	Economic threshold level
Yellow Stem borer	10% Dead heart or 2% white ear
BPH	10 hoppers/hill
Leaf folder	10% leaf damage (at vegetative stage) 5% leaf damage (at Boot leaf stage)
Gall midge	10% Silver shoot
GLH	5 hoppers /hill at vegetative stage, 10 hoppers/hill flowering stage
Gundhi Bug	1 or 2 bugs/hill

3. 2. Agro Eco System Analysis (AESA): In today's IPM, much of the emphasis is given to Agro Eco System Analysis (AESA) where farmers take decisions based on field observations. It is an approach, which can be employed by extension functionaries and farmers to analyse field situations with regard to pests. Basic components of AESA includes

- Plant health at different crop stages
- Built-in-compensation abilities of the plants
- Pest and defender population dynamics
- Climatic factors
- Farmers past experience

3. 3. Cultural Practices

- **Proper preparatory cultivation**: Several insects which live or hide in the soil get exposed to sun as well as predators like birds etc. during preparatory cultivation. Summer ploughing of fields also expose larvae and pupae of rice swarming or ear cutting caterpillar (climbing cutworm) hidden in the soil to birds and weather factors.
- **Clean cultivation**: Weeds can act as alternate hosts to insect pests. Paddy gall midge *Orseolia oryzae* breeds on grasses such as *Panicum* sp., *Cynodon dactylon* etc.

- **Adjusting planting or sowing or harvesting times to avoid certain pests**: Manipulation of planting time helps to minimize pest damage by producing asynchrony between host plants and the pest or synchronizing insect pests with their natural enemies. Eg. Early planting of paddy in *kharif* and late planting in*rabi* minimize the infestation of rice stem borer.
- **Balance use of fertilizers:**Excessive application N fertilizers favour the development of many insect pest specially the brown planthopper. Similarly Nitrogen fertilizer use at optimal dosages and split applications reduce the rice caseworm's abundance.
- **Flooding the field**: Flooding of fields is recommended for reducing the attack of cutworms, army worms, termites, root grubs etc. Eg: paddy swarming caterpillar (*Spodopteramauritinana* and *S. exiqua*).
- **Draining the fields**: In case of paddy case worm *N. depunctalis* which travel from plant to plant *via* water and can be eliminated by draining or drying the field. Alternate drying and wetting at 10 days interval starting from 35 DAT reduces the BPH and WBPH infestation and is an important practice to reduce these pests.
- **Alley ways**: While planting forming of alley ways of 30 cm for every 2 m in rice field which alters the microclimate congenial for BPH and reduces same.
- **Harvesting of the crop:** Harvest close to ground level to destroy insect pest present in the internodes/stubbles. This will also expose the insects to birds thus help in natural biocontrol of insect pests

3.4.Mechanical Practices

- ✓ Clipping off tip of rice seedlings at the time of transplanting minimize carryover of rice hispa, case worm and stem borer infestation from seed bed to the transplanted fields.
- ✓ Use of coir rope in rice crop for dislodging case worm, cut worm and swarming caterpillar and leaf folder larvae etc. on to kerosenized water (1 L of kerosene mixed on 25 kg soil and broadcast in 1ha).
- ✓ Removal and destruction (burn) of diseased/pest infested plant parts.
- ✓ Mass trapping of yellow stem borer male moths by installing pheromone traps @ 20 traps/ha with lures at 20 days after transplanting.

3.5. Biological Practices

- ❖ Inundative release egg parasitoids (Available as Trichocards) viz., *Trichogrammajaponicum* and *T. chilonis* @ 50000 eggs/ha, six such releases are made at every ten days interval or till egg masses/moth activity is not seen whichever is earlier. This can be taken up once appearance of egg masses / moth activity of yellow stem borer and leaf folder is noticed in the field.
- ❖ Natural biocontrol agents such as spiders, water bugs, mirid bugs, damsel flies, dragonflies, meadow grasshoppers, staphylinid beetles, carabids, coccinellids, *Apanteles*, *Bracon, Platygaster* etc. should be conserved. Avoid pesticides during peak period of natural enemy's activity.

3.6. Chemical Practices: Application of pesticides should be last resort in IPM. If all other methods fail to suppress the pest, judicious application of pesticides is recommended. Need based application of pesticides is to be followed. Following are some of the precautions while applying pesticides as much of the tragedy arrives due to pesticides.

- Use only pesticides recommended by Central Insecticide Board and Registration committee (CIBRC)
- While purchasing pesticides, read the pesticide label carefully
- Choose the form of pesticide best suited to your target site and the pest you want to control
- Do not purchase pesticides whose containers are leaking/loose/ unsealed
- Toxicity labels such as red, yellow, blue and green represents toxicity to human beings not to the target pests
- Avoid frequent and repeated application of similar pesticide
- Avoid situations where the pesticide may drift from the application area and contaminate non-targets
- Use the proper safety equipment and protective clothing (hand gloves, face masks, cap, apron, full trouser etc.)

List of CIBRC recommended insecticides for managing rice pests in India

Stem borer	Specific to Brown plant hopper (BPH)	Leaf folder
Acephate 95 % SG @ 563 g a.i./ha	Acephate 95 % SG @ 563 g a.i./ha	Acephate 95 % SG @ 563 g a.i./ha
Acephate 75 % SP @ 500-750 g a.i./ha	Azadirachtin 5 % w/w @ 200 ml/ha	Acephate 75 % SP @ 500-750 g a.i./ha
Azadirachtin 0.15 % w/w @ 1500-2500 ml/ha	Benfuracarb 3 % GR @ 1000 g a.i./ha	Azadirachtin 0.15 % w/w @ 1500-2500 ml/ha
Azadirachtin 5 % w/w @ 200 ml/ha	Carbaryl5 % DP @ 1250 g a.i./ha	Azadirachtin 5 % w/w @ 200 ml/ha
Benfuracarb 3 % GR @ 1000 g a.i./ha	Dichlorovos 76 % EC @ 375 g a.i./ha	Benfuracarb 3 % GR @ 1000 g a.i./ha

Bifenthrin 10 % EC @ 50 g a.i./ha Carbaryl 50 % WP @ 1000 g a.i./ha Carbofuran 3 % CG @ 750 g a.i./ha Carbosulfan 25 % EC @ 200-250 g a.i./ha Carbosulfan 6 % G @ 1000 g a.i./ha Cartap hydrochloride 4 % G @ 750-1000 g a.i./ha Chlorantraniliprole 0.4 % G @ 40 g a.i./ha Chlorantraniliprole 18.5 % SC @ 30 g a.i./ha Chlorpyriphos 20 % EC @ 250 g a.i./ha Deltamethrin 1.8 % EC @ 10-12.5 g a.i./ha Ethofenprox 10 % EC @ 50-75 g a.i./ha Fenpropatrhin 30 % EC @ 100 g a.i./ha Flubendiamide 20 % WG @ 25 g a.i./ha Lambda cyhalothrin 5 % EC @ 12.5 g a.i./ha Methyl parathion 50 % EC @ 500 g a.i./ha Phorate 10 % G @ 1000 g a.i./ha Phosphamidon 40 % SL @ 500 g a.i./ha Quinalphos 25 % EC @ 325 g a.i./ha Thiamethoxam 25 % WG @ 25 g a.i./ha	Dinotefuran 20 % SG @ 30-40 g a.i./ha Flonicamide 50 % WG @ 75 g a.i./ha Pymetrozine 50 % WG @ 150 g a.i./ha Azadirachtin 0.15 % w/w @ 1500-2500 ml/ha Lambda cyhalothrin 5 % EC @ 12.5 g a.i./ha Acetamiprid 20 % SP @ 10-20 g a.i./ha Clothionidin 50 % WDG @ 10-12 g a.i./ha Triflumezopyrim 10.6SC @ 237 ml /ha **Specific to Green leaf hopper (GLH)** Bifenthrin 10 % EC @ 50 g a.i./ha Lambda cyhalothrin 5 % EC @ 12.5 g a.i./ha Methyl parathion 50 % EC @ 750 g a.i./ha Carbosulfan 6 % G @ 1000 g a.i./ha	Bifenthrin 10 % EC @ 50 g a.i./ha Carbaryl10 % DP @ 2500 g a.i./ha Carbaryl5 % DP @ 1250 g a.i./ha Carbosulfan 6 % G @ 1000 g a.i./ha Cartap hydrochloride 4 % G @ 750-1000 g a.i./ha Chlorantraniliprole 18.5 % SC @ 30 g a.i./ha Chlorpyriphos 20 % EC @ 375 g a.i./ha Deltamethrin 1.8 % EC @ 10-12.5 g a.i./ha Ethofenprox 10 % EC @ 50-75 g a.i./ha Fenpropatrhin 30 % EC @ 100 g a.i./ha Fipronil 5 % SC @ 50-75 g a.i./ha Flubendiamide 20 % WG @ 25 g a.i./ha Lambda cyhalothrin 5 % EC @ 12.5 g a.i./ha Methyl parathion 50 % EC @ 300 g a.i./ha Phosphamidon 40 % SL @ 500 g a.i./ha Quinalphos 25 % EC @ 250 g a.i./ha Thiamethoxam 25 % WG @ 25 g a.i./ha
Gall midge	**All hoppers (BPH, WBPH, GLH)**	**Hispa**
Carbofuran 3 % CG @ 750 g a.i./ha Carbosulfan 25 % EC @ 200-250 g a.i./ha Carbosulfan 6 % G @ 1000 g a.i./ha Chlorpyriphos 20 % EC @ 375 g a.i./ha Ethofenprox 10 % EC @ 50-75 g a.i./ha Fipronil 5 % SC @ 50-75 g a.i./ha Lambda cyhalothrin 5 % EC @ 12.5 g a.i./ha Methyl parathion 50 % EC @ 750 g a.i./ha Phorate 10 % G @ 1000 g a.i./ha Thiamethoxam 25 % WG @ 25 g a.i./ha	Acephate 75 % SP @ 500-750 g a.i./ha Bufrofezin 25 % SC @ 200 g a.i./ha Carbaryl 50 % WP @ 1000 g a.i./ha Carbofuran 3 % CG @ 750 g a.i./ha Carbosulfan 25 % EC @ 200-250 g a.i./ha Ethofenprox 10 % EC @ 50-75 g a.i./ha Fenobucarb (BPMC) 50 % EC @ 250-750 g a.i./ha Fipronil 5 % SC @ 50-75 g a.i./ha Imidachloprid 17.8 % SL @ 20-25 g a.i./ha Oxydemeton methyl 25 % EC @ 250 g a.i./ha Phorate 10 % G @ 1000 g a.i./ha Phosphamidon 40 % SL @ 350 g a.i./ha Quinalphos 25 % EC @ 375 g a.i./ha Thiamethoxam 25 % WG @ 25 g a.i./ha	Carbofuran 3 % CG @ 750 g a.i./ha Chlorpyriphos 20 % EC @ 250 g a.i./ha Lambda cyhalothrin 5 % EC @ 12.5 g a.i./ha Malathion 5 % DP @ 1250 g a.i./ha Malathion 50 % EC @ 575 g a.i./ha Methyl parathion 50 % EC @ 300 g a.i./ha Phorate 10 % G @ 1000 g a.i./ha Quinalphos 25 % EC @ 500 g a.i./ha
Whorl maggot	**Thrips**	**Caseworm**
Cartap hydrochloride 4 % G @ 750-1000 g a.i./ha Chlorpyriphos 20 % EC @ 250 g a.i./ha Ethofenprox 10 % EC @ 50-75 g a.i./ha Fipronil 5 % SC @ 50-75 g a.i./ha Methyl parathion 50 % EC @ 500 g a.i./ha	Azadirachtin 0.15 % w/w @ 1500-2500 ml/ha Imidachloprid 17.8 % SL @ 20-25 g a.i./ha Lambda cyhalothrin 5 % EC @ 12.5 g a.i./ha Thiamethoxam 25 % WG @ 25 g a.i./ha	Carbaryl10 % DP @ 2500 g a.i./ha Phenthoate 50 % EC @ 500 g a.i./ha

4. Conclusion and way forward

Part from insecticides, cultural practices, natural enemies, host plant resistance, biopesticides, and synthetic pesticides are now being widely used for pest management. Many of the methods of IPM discussed above are highly sensitive to the environment. Therefore, there is a need to develop appropriate strategies for pest management that will be effective under situations of global warming in future. Hence, we need to use an integrated pest management system that takes into consideration the change in pest spectrum, cropping patterns and effectiveness of different components of pest management for sustainable crop production.

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Resource Conservation Technologies and Conservation Agriculture Based Climate Resilient Agriculture

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Summary

In recent years, the major emphasis has been on alternative resource conservation technologies (RCTs) to reduce the cost of cultivation and energy consumption, to sustain productivity, to increase the profit margin of farmers and to make the agricultural production system more climate resilient. Benefits of conservation tillage especially zero tillage (ZT) systems that leave crop residues on the soil surface for the stabilization of soil moisture and temperature, an improvement of aggregate stability and an increase in soil organic matter, higher water infiltration rates, reduction in soil erosion and control of weed population. Under the changing climate scenario resource conservation technologies are viable options to shift production oriented to profit oriented sustainable farming. Improved agricultural machines have been found to be very effective on fields by reducing GHG emission. Increasing SOC in passive pool is one of the moto of climate smart agriculture. Therefore, resource conservation technologies may be considered as a realistic solution of the above-mentioned concerns.

Key words: Climate change; global warming; crop residue; soil quality

1. Introduction

Rice is the staple food for over half of the world's population and is economically, socially, and culturally important to a large number of people in many countries. In India, rice plays a major role in diet, economy, employment, culture and history. With 43.8 million hectares (2017-18), India has the biggest area under rice worldwide, producing 112.8 million tons of milled rice at productivity of 2.6 tons per hectare. Over the last six decades the average production per year has increased by about five times and this growth in agricultural production has come mainly from yield increase and to a lesser extent from area expansion. Now the agricultural land available per capita is expected to decline. Furthermore, in high intensity agricultural production areas, yield increase seems to have reached a ceiling despite higher input use. Therefore, future expansion in production has to come from productivity increase only through technological advancement.

The agricultural production system across the globe has been under threat due to the negative impacts of the climate change. In India, where a huge population depends on agriculture, this becomes a serious issue for the poor farming communities. Here, it has been widely held that the occurrence of extreme climatic events, such as droughts and floods have been adversely affecting agricultural production and productivity in most parts of the country, affecting the farming population the most. The temperature levels over the past 100 years have been showing an increase of 0.60°C whose impact is projected to become serious or worse for many crops, especially, food crops, thus impacting security in food grains. Since agriculture accounts for 15 percent of India's GDP, adverse impact on production may lead to an increase in the cost of farming activities.Hence, it is critical for making agriculture sector more resilient to climate change effects, thus enhancing agricultural productivity for ensuring nutritional and food security for all.

The current agricultural production practices under intensive agricultural production systems are neither sustainable nor environmentally sound that has led to the environmental degradation. (Ladha et al., 2009). Current practices require large amounts of resources (labor, water, energy, and biocide) with low input-use efficiencies. At the same time, these resources are becoming scarce and expensive, making conventional practices less profitable and sustainable. Improved production technologies would help to face the challenges to produce more food at less cost and improve water productivity, increase nutrient use efficiency and adapt the effects of climate change. So, there is dire need of an energy, water and labor efficient alternate system that helps to sustain soil and environmental quality, and produce more at less cost (Jat et al., 2011) for sustainable and ecologically safe rice farming.

Recently, for achieving food security the emphasis has been shifting from exploitative agriculture to conservation agriculture through the use of resource conservation technologies in order to preserve the natural resources as well as to efficiently use the external inputs like water, chemical fertilizers and pesticides. Resource conservation technologies (RCTs) can assist in the adaptation to climate change by improving the resilience of agricultural cropping systems and hence making them less vulnerable to abnormal climatic situations.

2. Resource conservation technologies and conservation agriculture

Resource conservation technologies (RCTs) and conservation agriculture (CA) are the two approaches which often used synonymously. However, there is distinct variation among the two. The resource conservation technologies refer to any of those practices that enhance resource- or input- use efficiency. It has a wide dimension and may include any agricultural practices that aim to conserve the natural resources and improve their use efficiencies. Direct seeding of rice which saves water, energy and labour may be considered RCTs. New varieties that use nitrogen more efficiently and Zero or reduced tillage practices that save fuel and improve plot-level water productivity may also be considered RCTs, as may land leveling practices that help save water. There are many, many more. In contrast the term "conservation agriculture" (CA) according to the FAO, is an approach tomanaging agro-ecosystems for improved andsustained productivity, increased profits andfood security while preserving and enhancingthe resource base and the environment' (Friedrich et al., 2012). CA has been designed on the principles of integrated management of soil, water and other agricultural resources in order to reach the objective of economically, ecologically and socially sustainable agricultural production. CA is characterized by three major principles (FAO, 2012)i) minimal mechanical soil disturbance by direct planting through the soil coverwithout seedbed preparation; ii) maintenance of a permanent soil coverby mulch or growing cover crops to protectthe soilsurface; and iii) diversifying and fitting crop rotationsand associations in the case of annualcrops and plantassociations in the caseof perennial crops.

Usually under CA, retention of 30% surface cover by residues is essential that cover the soil surface either by crop residues, cover crops or biomass sourced ex-situ through agroforestry measures. This surface cover provides physical protection for the soil against agents of soil degradation and food for the soil biota. The burning or incorporation of crop residues is strictly avoided in CA. Another important component of CA is zero tillage (ZT) technique, which implies to put the seed in the soil without any prior soil disturbance through any kind of tillage activity or only with minimum soil mechanical disturbance. In zero tilled fields, the functions of traditional soil tillage such as loosening the soil and mixing the organic matter are taken over by the soil biota with time. Due to the minimum soil disturbance in CA, soil biota and biological processes are not disturbed, which is crucial for a fertile soil supporting healthy plant growth and development. At the same time varied crop rotations involving legumes in CA help to manage pest and disease problems and improve soil quality through biological nitrogen fixation and addition of organic matter (Baudron et al., 2012).

3. Coverage of conservation agricultural practices

Globally, conservation agriculture using various RCTs is being practiced on about 125 M ha and the countries who adopted these technologies largely are USA (26.5 M ha), Brazil (25.5 M ha), Argentina (25.5 M ha), Canada (13.5 M ha) and Australia (17.0 M ha) (Bhan and Behera, 2014). In India, adoption of these technologies is still in the initial phases. Over the past few years, adoption of zero tillage and other technologies has expanded to cover about 1.5 million ha (Jat et al., 2012). The major conservation agriculture based technologies being adopted is zero-till wheat in the rice-wheat system of the Indo-Gangetic plains. In other crops and cropping systems, the conventional agriculture-based crop management systems are gradually undergoing a paradigm shift from intensive tillage to reduced/zero-tillage operations. In many countries of Latin America, RCT systems are finding rapid acceptance by farmers.In year 2016 in South Asia the adoption level of RCT technology i.e. DSR 22.54 %, Zero tillage drill 11.21%, Laser land leveling 6.51%, Double no till 0.21%, and Turbo seeder 0.10 % (D'souza and Mishra 2018). Most RCTs have been aiming at the two most crucial natural resources, water and soil. However, some of them would also affect the efficiency of other production resources and inputs such as labor and farm power or fertilizer. Some of the more popular RCTs, particularly in irrigated or rice-based cropping systems, are the following:

National Rice Research Institute has been in the forefront of developing and refining resource conservation technologies for lowland rice in eastern India. Many of the earlier works of the NRRI was focused on improving the use efficiency of the natural resources, increasing productivity of rice and reducing GHG emission along with building up of carbon by developing the technologies related to direct seeding, system of rice intensification, cropping system research involving legume crops, rice residue management, minimum tillage and zero tillage both under transplanted and direct seeded conditions (Shahid et al., 2017). The institute also worked upon the designing and development of farm equipment for small and medium farmer's related to rice sowing and weeding. Some of the major findings are discussed below.

4. Benefits of resource conservation technologies and conservation agriculture

As it is now well documented that resource conservation technologiesare generally a "win-win" situation for both farmers and the environment and is a viable alternative to conventional agricultural practices that are having obvious negative impact on the environment. Few of the benefits are listed below:

- Increased water infiltration
- Reduced moisture evaporation
- Less water run-off and soil erosion
- Reduction in labour and energy use
- Less turnaround time between crops
- Reduction in production costs
- Increases in soil organic matter
- Increases in nutrient availability
- Greater biological pest control
- Reduction in GHG emission

Conservation agriculture improves soil structure and protects the soil against erosion and nutrient losses by maintaining a permanent soil cover and minimizing soil disturbance. It also enhances the soil organic carbon levels and nutrient availability by utilizing the previous crop residues or growing green manure/ cover crops and keeping these residues as surface mulch rather than burning. The crop residues left on the soil surface also improves the soil water holding capacity increased infiltration that results in the less use of water. Mulches also protect the soil surface from extreme temperatures and greatly reduce surface evaporation. Soil nutrient supplies and cycling are enhanced by the biochemical decomposition of organic crop residues at the soil surface that are also vital for feeding the soil microbes. While much of the nitrogen needs of primary food crops can be achieved by planting nitrogen-fixing legume species, other plant essential nutrients often must be supplemented by additional chemical and/or organic fertilizer inputs. In general, soil fertility is built up over time under conservation agriculture, and fewer fertilizer amendments are required to achieve optimal yields over time.

Insect pests and other disease causing organisms are held in check by an abundant and diverse community of beneficial soil organisms, including predatory wasps, spiders, nematodes, springtails, mites and beneficial bacteria and fungi, among other species. Furthermore, the burrowing activity of earthworms and other fauna create tiny channels or pores in the soil that facilitate the exchange of water and gases and loosen the soil for enhanced root penetration.Conservation agriculture represents an environmentally-friendly set of technologies. Because it uses resources more efficiently than conventional agriculture, these resources become available for other uses, including conserving them for future generations. The significant reduction in fossil fuel use under no-till agriculture results in fewer greenhouse gases being emitted into the atmosphere and cleaner air in general. Reduced applications of agrochemicals under CA also significantly lessen pollution levels in air, soil and water.

5. Conclusion

Integrating concerns of productivity, resource conservation and quality and environment is now fundamental to sustained productivity growth. Resource conservation technologies offer a new paradigm for agricultural research and development different from earlier one, which mainly aimed at achieving specific food grains production targets. The resource conservation technologies involving no- or minimum tillage with direct seeding and bed planting, residue management (mainly residue retention) and crop diversification have potential for improving productivity and soil quality, mainly by soil organic matter (SOM) build-up. The RCTs bring many possible benefits including reduced water and energy use (fossil fuels and electricity), reduced greenhouse gas (GHG) emissions, soil erosion and degradation of the natural resource base, increased yields and farm incomes, and reduced labor shortages.

Overall, CA as an alternative paradigm for sustainable production offers many benefits to producers, the economy, consumers and the environment that cannot be obtained from tillage agriculture. With CA, production becomes a matter of output rather than inputs, so, it is not only climate-smart, but smart in many other ways.

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Cropping System Approach to Cope Up With Climate Change

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1. Introduction

Earth's climate is changing as a consequence of human activity on the planet. The most important aspect of this change is that the average temperature of the Earth is rising, slowly but steadily, as a consequence of the increased emission of greenhouse gases (GHGs) in the atmosphere.Of the greenhouse gases that contribute to global warming, carbon dioxide (CO_2) is by far the most significant, although there are other gases that also play this role, notably methane. This warming on the earth's surface over the last 50 years is mostly due to anthropogenic activities. Further, it is predicted that the rise in global mean surface temperature will likely be in the range of 0.3-0.7°C during the next two decades. This rise in temperature may cause various changes such as a rise in mean sea-level, melting of snow sheets and change in rainfall patterns. Hence, global warming can be considered as the major affecting parameter in changing the earth's climate. In India, it is predicted that the average temperature may increase by 2-4^{o}C change in both distribution and rainfall patterns, less number of rainy days with higher intensity and occurrence of frequent and intensive cyclonic storms.

2. Present scenario of Indian agriculture in context to climate change

Agriculture is a major source of GHGs which contribute to the greenhouse effect and climate change. However, the changing climate is having far-reaching impacts on agricultural production. In India, more than 60% area is under rainfed agriculture which is highly vulnerable to climate change. Similarly, more than 80 percent of farmers in India are small and marginal (having less than 1 ha of land) thus having less capacity to cope with climate change impacts on agriculture. India's 200 backward districts as ranked by the Planning Commission are distinguished for the large-scale practice of rain-fed agriculture. With the changing food habits and market conditions, farmers prefer wheat or rice in most parts of the country. Some studies have already projected a greater loss in rabi crop yields (e.g. in wheat yield) as compared to kharif crops.Climate change will affect different parts of India in different ways. These differences are illustrated by the fact that, while large areas in Rajasthan, Andhra Pradesh, Gujarat, Odisha and Uttar Pradesh are frequently affected by drought, approximately 40 million hectares of land in the north and north-eastern belt is flood-prone.

Developing nations like India are adversely affected in comparison to the developed nations. These climatic disasters, therefore, make the livelihood of the people more susceptible, especially in India as they are already vulnerable to conventional problems like poverty and food insecurity. It is argued that India is particularly vulnerable to predicted climate changes because of its high population density, low adaptive capacity, several unique and valuable ecosystems (coral reef, large deltaic region with rich biodiversity) and vast low-altitude agricultural activities. India has to maintain the sustainability of its ecosystems to meet the food and non-food needs of a growing population.Climate change is likely to contribute substantially to food insecurity in the future, by increasing food prices and reducing food production. Food may become more expensive as climate change mitigation efforts increase energy prices.

3. Impacts of Climate Change on Agriculture in India

Recent research on the impact of climate change also indicates that an increase in carbon dioxide is likely to be beneficial to several crops but the associated increase in temperature and increased variability in rainfall would considerably affect food production. Further, the warmer and drier summers may lead to increased fallowing throughout this century in rainfed areas that are currently cropped on an annual basis. This could reduce yields, accelerate erosion, and lowers carbon sequestration, increasing sustainability challenges. Similarly, a World Bank report studied two drought-prone regions in Andhra Pradesh and Maharashtra and one in Odisha on the effect of climate change. It indicated that climate change could have the following serious negative impacts:

(i) Dryland farmers in Andhra Pradesh may experience a 20% reduction in their incomes;
(ii) Sugarcane yields in Maharashtra may fall dramatically by 25-30 per cent and
(iii) Flooding will rise dramatically leading to a drop in rice yields by as much as 12%in some districts of Odisha.

It is also projected that increasing glacier melt in the Himalayas will affect the availability of irrigation water especially in the Indo-Gangetic plains, which, in turn, will have large consequences on our food production. Studies at the Indian Agricultural Research Institute

(IARI) and others indicate greater loss is expected in the rabi crops as compared to kharif crops. Every 1°C rise in temperature can reduce wheat production by 4-5 million tonnes.

The productivity of two major staple food crops i.e., rice and wheat yields could decline considerably with climatic changes. However, the vulnerability of agricultural production to climate change depends not only on the physiological response of the affected plant, but also on the ability of the affected socio-economic systems of production to cope with changes in yield, as well as with changes in the frequency of droughts or floods. As pathogens and insect populations are strongly dependent upon temperature and humidity, an increase in these parameters will change their population density resulting in loss in yield.The adaptability of farmers in India is severely restricted by the heavy reliance on natural factors and the lack of complementary inputs and institutional support systems. The loss in net revenue at the farm level is estimated to range between 9% and 25% for a temperature rise of 2 °C to 3.5 °C. Scientists in our country also estimated that a 2°C rise in mean temperature and a 7% increase in mean precipitation would reduce net revenues by 12.3% for the country as a whole.

4. Diversification of cropping system in changing climate

Crop diversification in space (substituting one crop for another) and time (changing crop rotation or cropping system) can be a rational and cost-effective way to build the resilience of the agricultural system under climate change. This also helps the cropping system adapted to increased water stress. For example, the rice-wheat system in North Indian states is a water resource-intensive system requiring 1.9 m^3 of water/ kg of output and consequently more vulnerable to rising temperature as irrigation water requirement increases with temperature. Replacing this cropping system with less water-intensive cropping systems (e.g., maize–wheat system) can enhance the adaptation of the production system to moisture stress (Pimentel *et al*. 1997; Akanda 2011). Farmers in India use leguminous crops, mostly red grams, mung bean, and peanutsto supplement nitrogen to the soil which is lost due to soil erosion or excess flooding. In the regions with cool and humid climate, legumes are planted/mixed with the main crop, to protect the fallow land. Cropping systems in which pigeon peais grown as a perennial crop with soybean and maize have a smothering effect on weeds and provide two harvests per season: pigeon pea and soybean; and maize and pigeon pea. Instead of growing maize as a sole crop, or maize in rotation with soybean, pigeon pea is grown with soybean. Once these legumes are harvested, the pigeon pea is allowed to regrow; then maize is planted into the pigeon pea(Batello *etal*., 2013). Thus, diversifying the existing cropping systems with less resource or input requiring crops will help the small and marginal farmers to cope with climate change.

5. Managing cropping systems for climate change adaptation

An effective management of agricultural ecosystems contributes to both climate change adaptation andmitigation. It is critical for the sustainable intensification of crop production.Therefore, the negative impacts of climate change can be reduced through adaptation of drought/temperature tolerant varieties, advancing the planting dates of rabi crops in areas with terminal heat stress, water saving paddy cultivation methods (SRI, aerobic, direct seeding), community nurseries for delayed monsoon, custom hiring centers for farm machineries for timely planting**,** location specific intercropping systems with high sustainable yield index etc.

Increase in temperature can affect agriculture through its impact on cropping seasons, increase in evapotranspiration, irrigation water requirements, and heat stress. Farmers can cultivate millets based on their suitability to a particular agro-climatic region, as the millets are hardy crops that can tolerate higher temperatures and heat stress.

Introduction of short duration crop varieties and planting early/late maturing varieties maycurtail the adverse impacts of climate risk also adopting heat-/moisture-tolerant seed varieties can address the problem of excess heat or moisture. For instance, the introduction of short duration and improved varieties in pigeon pea, soybean, wheat, and sorghum in India to improve yield by 75%, 15%, 27%, and 91%, respectively (Sonune and Mane 2018).A large proportion of rice growing areas in India such as Uttar Pradesh (8%), Bihar and West Bengal (40%), and Odisha (27%) suffer from submergence due to flood. Almost 80% of the rice-growing areas in Eastern India are rain-fed and thus suffer either from excess water or from drought depending upon rainfall pattern. Flood-tolerant rice variety i.e., *Swarna sub-1* can withstand 17 days of complete water submergence and yield up to 3 t/ ha under flash flood conditions, thereby adapting to these excess water stresses ((Reyes 2009). Similarly, planting drought-tolerant rice varieties such as *SahbhagiDhan, DRR 44,* and *Sushk Samrat* can help farmers in Eastern India to cope up with moisture stress. These varieties have approximately 1 t/ ha yield advantage in drought years over other varieties under similar conditions. Effect of drought and flood is equally severe also in maize and wheat crop. Drought is responsible for 15–20% yield loss in maize in South Asian countries. Drought-tolerant maize varieties developed by CIMMYT yield 2–3 t/ha under drought conditions in which other varieties yield less than 1 tons/ha (Zaidi *et al.* 2004). Heat tolerant wheat varieties like DBW 16, Raj 3765, Lok 1 and GW 322 have been popularized through national programs. Similarly, several hybrids of maize have been released in order to address the issue of heat, cold, or frost. Varieties like HQPM-1 and HHM-1 are tolerant to both cold and frost, while HM-1 is tolerant to frost only. Chickpea varieties like JG 1 1, that are tolerant to heat are being promoted in rainfed areas of Eastern India.

Besides, changing the cropping pattern, introducing new crops or replacing existing crops, or changing crop sequence,change in planting time can be a way to climate change adaptation.A recent study in Ludhiana of India shows that shifting the planting date of wheat and transplanting date of rice to 15 days earlier than the usual date could minimize yield loss by more than 4% (Jalota*et al.* 2013). Likewise, delaying the sowing dates would be favorable for reducing the yield loss of soybean at all locations in India.In drought-prone areas of India, farmers use drought-adapted crops such as sorghum and also adjust their production practices as a mechanism to spread risk such as staggered planting(Satapathy*et al*. 2011).

Indian soils are deficient in many major and micro-nutrients which are result of desertification due to deforestation, soil erosion, run-off losses and indiscriminate use of fertilizers. In rice-rice, rice-wheat, and many rice-based cropping systems, the carryover nutrients are not taken into account and inefficient utilization of resources takes place which leads to socio-economic imbalance upon climate change which otherwise could have been utilized at the time of need. Application of sulphur and micronutrient like zinc that are deficient in the soil can increase the yield of crops significantly and help the farmer to compensate for the yield loss that may occur due to climate change.

Irrigation is one of the most important strategies to contain harmful effects of climate change on cropping systems.A number of water saving technologies has already been developed for irrigated paddy/lowland rice production. These options include no-tillage in combination with mulching to provide soil cover; raised beds; laser land leveling; alternate wetting and drying irrigation; and aerobic rice (Thakur *et al*., 2011). Irrigation can be applied through flash flooding, furrow irrigation (with the rice growing on raised beds) or sprinklers.Non-continuous water regimes, i.e., alternate wetting and drying, can reduce water demands and allow water to be allocated for other uses. This is particularly beneficial in major irrigated rice areas where the water supply is forecast to be insufficient to meet the demands. This technique also reduces fuel for pumping water, which reduces farmers' expenses. Similarly, the aerobic rice production system also needs less water at the field level than conventional lowland rice and may be targeted at relatively water-short irrigated or rainfed lowland environments.Like nutrient and water, the weed menace in crops and cropping systems can be addressed through diversification of crops in the system. For example; the population of *Phalaris minor* in wheat under rice-wheat cropping systems can be reduced by sowing berseem instead of wheat once in three years during rabican minimize the build-up of *Phalaris minor* for next two years. Therefore, adopting the optimal management practices can be the best way of addressing the negative impacts of climate change. Besides, crop diversification and efficient management practices financial support to the farming community through adoption of national policies like viz; National mission for sustainable agriculture, National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission aims canmake Indian agriculture better adapted to climate change.

6. Conclusion and way forward:

Climate change is a reality and has already been experienced in different parts of our country as well as abroad. Indian agriculture is more vulnerable to climate change at its current stage due to the existence of large areas of rainfed agriculture. Besides Indian farmers are mostly small and marginal and resource poor which aggravates the situation. The productivity of major food crops in India is predicted to be lowered due to climate change. The decline in productivity can be restored substantially through diversification of the existing production systems with low input requiring crops. Further, changing the management practices of the individual crops following system approach, not only provides a better adaptation option but also mitigates the cause of climate change. Thus, better agronomy of crops is the best way of addressing climate change.

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Climate Smart Water Management Technologies for Enhancing Rice Production

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1. Introduction

Irrigation plays an important role in global food security, helping to produce 40 percent of crops worldwide on just 20 percent of the world's cultivated area. Indian population is expected to reach 1.6 billion by 2050, which along with a large number of livestock need to be supported from the available resources. To achieve food security of this large population, productivity increase is the only option as the land devoted for agriculture sector is limited. This agrarian sector is the principal source of livelihood for over 60 percent of rural households. As per United Nations Food and Agriculture Organization (UNFAO, 2011), irrigation and livestock segments use 91% of water withdrawal in India. Due to high demand from the agriculture and domestic sector ground water level is depleting very fast. Now-a-days, about 54% of India suffers from deficit water stress. The ground water which is withdrawn from a greater depth is difficult to be recharged from rainfall, hence there is an urgent need for judicious use of ground water resources.

2. What is climate-smart agriculture?

Climate-smart agriculture (CSA) is often defined as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces or removes greenhouse gases where possible and enhances achievement of national food security and development goals" (FAO, 2013a). Our agricultural practices should be focused in such a way so that our soils and plants act as carbon sinks and absorb carbon dioxide (CO_2) from the atmosphere. Climate smart agriculture differs from existing approaches because it focuses on principles of increased productivity and sustainability along with explicitly addressing adaptation and mitigation challenges while working towards food security for all.

3. Climate-smart irrigation

Climate-smart irrigation (CSI) is a good irrigation practice specific to agro-climatic and societal context that takes into consideration the challenges and opportunities that may result directly or indirectly from different facets of climate change. It is based on three CSA pillars like :- (1)

Productivity: CSI aims at increasing the productivity and net farm income without degrading the environment. It tries to safeguard the interests of farm family and improves the sustainability of irrigated cropping systems. (2) Adaptation: CSI aims to strengthening the existing irrigation system to cope up the short-term risks. Focus is given to maintain productivity and profitability while improving the ability of farmers to adapt to climate change. (3) Mitigation: CSI aims at adopting the irrigation practices which reduce greenhouse gas emissions up to and beyond the farm gate. It focuses on the use of green energy for operating the irrigation systems to maintain the ecological harmony.

4. Approaches for Enhancing Water-use Efficiency

Supplemental irrigation combined with on-farm water-harvesting practices, such as mulching or increasing bund height, reduces susceptibility to drought and helps farmers to get the most out of the scarce resources. Mitigating the effects of short-term drought is therefore a key step in achieving higher yields and water productivity in rainfed areas. Discussed hereunder are various means of enhancing use-efficiency and productivity of water in agricultural production system.

(i) ***No Over-irrigation*****:** Applying too much water to crops wastes soil and fertilizer as well as water. Frequent, light irrigations help keep water and mobile nutrients in the root zone where plants can use them. This practice is helpful in avoiding wastage of irrigation water as well as soil erosion.

(ii) ***Select Crops and Cropping Systems Based on Available Water Supplies:*** The crop selection for a particular agro ecosystem should be done on the basis of availability of water. As monsoon varies and water scarcity issue persists, aerobic rice varieties are being developed to require less water.

(iii) ***Mixed Cropping System:*** The water use efficiency in the mixed cropping fields of corn grasses were much higher than those in the fields where only corn or grass was grown. It is true for many mixed cropping systems.

(iv) ***Irrigation Scheduling Based on Evapotranspiration (ET), Soil Water Content or Soil Water Tension*****:**Seasonal demand pattern for water varies from crop to crop. The optimal time to irrigate a particular field depends on the soil water-holding capacity, water extraction by the crops and rate of ET. Knowledge of water-holding capacity of the field soils helps in fixing the time for re irrigation. A sandy loam soil will not hold as much water as a silt loam; thus, it must be irrigated more frequently with less water per irrigation. Extra water is lost to runoff and goes deep into the ground. Moisture meter and tensiometer help in determining the moisture content in the soil.These instruments, when used with ET charts, provide a fairly accurate estimate of irrigation needs.

(v) ***Use Full Irrigation at Critical Growth Stages and Deficit Irrigation at Rest of the Stages*****:**Deficit irrigation is irrigation that applies less water than the crop needs. Under deficit irrigation at non critical stages the water productivity of the crops increases significantly with minor yield loss due to decrease in irrigation water input.Deficit irrigation particularly works well with deep-rooted crops such as wheat and corn, which minor test weight and yield loss. Know each crop's tolerance of drought stress, and irrigate accordingly.

vi) ***Practice Conservation Tillage:*** Modern agricultural practices like conservation tillage, minimum tillage, no till, and strip till are essentially required for conserving soil moisture. Under these practices tillage operation is reduced and crop residue from the previous crop is at least partially retained on the soil surface. The retention of crop residues helps in reducing water loss from the soil to the air and cools the soil. Tillage exposes the soil to drying; conversely, reductions in tillage help conserve soil water. For strip tillage, cultivate only within the row zone and leave the inter-row zone undisturbed. This usually leaves at least 30 percent of the previous crop residue on the surface after planting. Soil infiltration capacity of the inter-row zone is increased, allowing water to go where it's needed.

(vii) ***Carefully Manage Surface Irrigation*****:**The irrigation efficiencies of surface irrigation systems are very low. They also bring a heavy flow of water in direct contact with soil, dislodging soil particles. Under surface irrigation the top of the field often results in over-irrigation and the bottom is under-irrigated. Over-watering the top of the field stresses plants and causes nitrogen deficiency as nitrogen leaches below the root zone. Slightly drought stressing the bottom of the field often causes production losses similar to those caused by over-watering the top of the field. Mulch the bottom of the field with straw so the water that gets there soaks in.

Use of polyacrylamide or straw mulch helps in improving water infiltration and water holding capacity of tight soils. Alternate-row irrigation can be a viable option for crops that are less sensitive to moisture stress. In wheel traffic rows water infiltrates comparatively at slower rate hence one of the strategy should be to irrigate only compacted rows. Compact the soft, non-traffic rows in furrow-irrigated fields, so their infiltration rate is similar to that of the wheel-traffic rows.

Switching over to micro irrigation methods like sprinkler irrigation or drip irrigation helps to manage water more efficiently and even often increase yields. Micro irrigation can save about 30-50% of water (Table 1) than the amount used for furrow irrigation. The irrigation methods having greater irrigation efficiency are different methods of micro-irrigation like drip and sprinkler irrigation. Drip irrigation and Sprinkler irrigation are the usual micro-irrigation systems followed.

Table 1: Water Use Efficiency (%) Under Different Irrigation Systems

	Surface irrigation	**Sprinkler irrigation**	**Drip irrigation**
Conveyance efficiency (%)	50-70	Not applicable	Not applicable
Application efficiency (%)	40-70	60-80	90
Surface water moisture evaporation (%)	30-40	30-40	20-25
Overall efficiency (%)	30-35	50-70	80-90

Drip irrigation system irrigates the root zone of the crop, not the whole surface. It provides a continuous supply of water throughout the day by releasing frequent, but small quantities of water continuously unlike surface irrigation where feast and famine cycles affect growth and yield parameters. In sprinkler irrigation, water is distributed through a system of pipes, is sprayed on the crops and falls as smaller water drops.

5. Micro-irrigation: Way to More Crop per Drop

Micro-irrigation is helpful in increasing the water productivity by reducing the water input in fields. This system helps to increase the input use efficiency by cutting down the overall irrigation costs by saving water, electricity and labour. In this system, the different losses of water like evaporation, runoff and deep percolation loss are minimized. As the water is applied at right place like the root zone or selected places which actually need water, hence significant amount of water saving takes place. As a result of reduction in input cost farmers have more choice to introduce new crops on their farms which is evident from the data that about 30% of micro-irrigation adopting farmers have adopted new crops.

Micro-irrigation techniques are helpful in improving power use efficiency by 30-50% due to lowering of electricity consumption because of the lower power and fewer hours are involved in irrigating the fields. In this system, practice of fertigation helps in judicious use of fertilizer and application of fertilizer to the root zone improves fertilizer consumption efficiency by 20-30%. This system is helpful in saving significant amount of electricity and fertilizers which ultimately bring down the subsidy amount provided to the farmers for this purpose amounting to thousands of crores.

As water is applied in a controlled manner at the targeted places the soil moisture remains at optimal levels and in turn increases the crop productivity of fruit (42.3%) as well as vegetable crops (52.8%). This helps in increasing the income of the farmers. The economic viability analysis of micro-irrigation tilts in favour of farmers. Though the farmer has to pay the installation cost at first, the benefits to the farmer is really promising and sustainable.

6. Indian Government Initiatives on Micro-irrigation

Some of the Government supports via various micro-irrigation focus schemes/projects are as follows:-

i) National Mission on Micro-irrigation: NMMI (2010-2014)

The NMMI is regarded as a strong and well visioned programme. Under this programme, the area under micro-irrigation almost doubled, growing from 3.09 million ha in 2005 to 6.14 million ha in 2012. Overall, many states achieved more than 90 percent of set physical and financial targets.

ii) National Mission for Sustainable Agriculture: NMSA (2014-15)

In this mission, the 'On Farm Water Management' component addresses micro-irrigation issue. Efficient on-farm water management technologies enhance water use efficiency. It also focuses on effective harvesting and management of rain water.

iii) Pradhan Mantri Krishi Sinchayee Yojna: PMKSY (2015-2019)

It was launched in July 2015 for the period 2015-16 to 2019-20 with a financial outlay of INR 50,000 crores for 2015-19. The objective of the scheme is "to achieve convergence of investment in irrigation at the field level, expand cultivable area under assured irrigation." In short a need to converge all ongoing efforts and to bridge gaps through location specific interventions.

Government is hoping to encash the many gaps through this scheme. It is realized that only about 20% of rainfall is actually utilized by agriculture, only marginal increase in irrigation can bring an additional thousands of hectares under assured irrigation. It also emphasizes utilizing the potential groundwater reserve of 202 billion cubic meters. Micro-irrigation fits into the '*Per Drop More Crop'* component, which advocates improving water use efficiency by use of precision water application devices like drips, sprinklers, pivots, rain-guns etc. on the farms. It also aims to construct micro-irrigation structures like tube wells and dug wells, along with water lifting devices like diesel/electric/solar powered pump sets including water carriage pipes, underground piping system. Thus, this aims to create infrastructures on micro-irrigation within certain months, not years as in Watershed Development Scheme. This vision is welcomed from every sector involved in micro-irrigation, but the success rate is needed to be seen, as financial hurdles, administrative lags and awareness among farmers is still lacking. The vision is optimistic and can have far reaching consequences. A whole hearted approach from political, beaurocrats, extension workers and farmers is needed to achieve its objective.

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Is integrated farming system a promising approach for risk minimizing in the changing climatic scenario?

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Summary
Agriculture is threatened due to degradation of natural resources and climate change. It impacts crops, livestock, forestry, fisheries and aquaculture, and can cause grave social and economic consequences in the form of reduced incomes, eroded livelihoods, trade disruption and adverse health impacts. However, it is important to note that the net impact of climate change depends not only on the extent of the climatic shock but also on the underlying vulnerabilities. Therefore, farming method must change according to present situation for meeting the need of food security and also withstanding under changing climatic situation. So there is a need to modify agricultural practices in a more sustainable way to overcome these problems. Developing climate-resilient agriculture is thus crucial for achieving future food security and climate change goals. It helps the agricultural system to resist damage and recover quickly by adaptation and mitigation strategies. Mitigation strategies reduce the contribution of agriculture system to greenhouse gas emission, and adaptation strategies provide agriculture production under changing scenarios.

Key words: Integrated Farming System, climate change**,** rainfed, diversification

1. Introduction

Rice being the staple food is grown in the country in around 43.5 million (m) ha under various ecologies of which about 50 % area is rainfed. More than 80% of the rice farmers belong to small and marginal groups and the average per capita land holding in India is only about 0.17 ha. (Poonam et al., 2017) In view of the population growth, competition of land with industrialization and urbanization, declining farm holding size and the dietary nutrition requirement of the farm families, it is necessary to look for the optimum use of resources through shift from conventional rice farming to integrated farming systems. Rice based farming system involving rice, other field and horticultural crops, agro-forestry, fish birds livestock and further income generating enterprises will be the right approach in this respect. However, this will be more relevant in the risk prone *rainfed* ecologies which are mostly located in the eastern part of the country. Rice based integrated farming systems can provide household food, nutrition, income and employment without degrading the environment.

Farming family in tropical India is mainly dependent on *rainfed* farming with high risk of weather uncertainty. In a constant struggle to survive, the small and marginal farmers over the years have evolved techniques which have benefited them immensely. But without knowing the scientific basis of such integration they have been practicing the system for a long time. In India, traditionally, farming has been family based and majority of them are smallholders. The success of farming family lies not in 'specialization' but in practicing farming to meet diverse household needs rather than market opportunities alone. Hence, income from seasonal field crops alone in small and marginal farms is hardly sufficient to sustain the farming family. As such agriculture in India is facing the challenge to achieve sustainable food security with shrinking land resources by producing an additional 50 million tonnes of food to meet the requirement of prognosticated population of 1000 million in the country. Because of declining per capita availability of land in India, there is hardly any scope for horizontal expansion of land for food production. Hence, intelligent management of available resources including optimum allocation of resources is important to alleviate the risk related land sustainability.

Monocropping in flood and drought prone area is risky practices for farmers. Dependence on single enterprises not only increases the risk of crop failure but also leads to food, income and environmental insecurity especially in rain-fed area. Integrated farming system (IFS) modules minimize risk from a single enterprise in the face of natural calamities, and diversified enterprises bring in the much needed year round income to farmers in monocropped paddy-growing areas and improve their livelihoods and resilience to extreme weather events. Integrated farming system is defined as the integration of different interrelated, interacting and interdependent farm enterprises which are suited to agro-climatic condition socioeconomic situation of the farmers. Integrated fish-duck farming and Rice-fish poultry farming have been developed for small and marginal farmers (Prasad et al., 2014).

2. Impact of climate change on agriculture

Worldwide, more than a billion of farmers and their families face a great challenge of climate change because agriculture sector is the most vulnerable sector for climate change. Change in climate at the global, regional and local level is very likely to affect food security. Excess rain, flood and drought like situation can disrupt food availability, reduce access to food and affect food quality (Brown et al., 2015).Thus, directly affecting the lives and livelihoods of farmers by climate change, that urge the need to implement many of the solutions to overcome this problem. Despite the attention paid to agricultural development and food security over the past decades, there are still about 800 million undernourished and 1 billion malnourished people in the world. At the same time, global food consumption trends are drastically changing. If the current trends in consumption patterns and food waste continue, it is estimated that we will require 60% more food production by 2050 (Alexandratos and Bruninsma, 2012).

Many advance technologies, such as improved crop varieties, pest control methods, genetically modified organisms and irrigation systems, are widely adopted for crop improvement. It is also expected that India will experience more seasonal variation in temperature with more variability in summer monsoon precipitation. Due to rainfall variability, changes in the frequency and severity of droughts and floods could pose challenges for farmers and ranchers and will ultimately threaten global food security (Ziska et al 2016). Meanwhile, the rise in sea level and warming of sea water are likely to cause the habitat ranges of many fish species to shift, which could disrupt ecosystems. Overall, climate change would adversely affect over crops, animals and marine life. Along with effects of climate change on agriculture, other evolving factors that affect agricultural production, such as changes in farming practices and technology, need to be addressed.

3. Possible solutions in addressing these challenges

Farming system or the cultivation of crops per unit of land per unit of time is a promising adaptation strategy for small and marginal farmers to reduce risk of complete crop failure. Integrated Farming Systems (IFS) employ a unique resource management strategy to help achieving economic benefit and sustain agricultural production without undermining the resource base and environmental quality. Investing in such farming ensures that the growth in agriculture is inclusive, pro-poor, and environmentally sustainable (Altieri, 2002) and this can also be the most effective route to bring about economic growth and poverty reduction, with enhanced resilience of small farmers to disasters (Altieri et al., 2012). This is particularly important since sustainable intensification of small farms is now considered to be of critical need for feeding the future generation (Tilman et al., 2011). It is time to reckon these integrated systems as units of planning for effective natural resource management. Despite mixed fields are more labour intensive for farmers, they do have several other advantages. They are less prone to pest attacks, allow for a diversified diet, spread the risk of having no yields at all from failure of one crop and thus generate additional income in the long run.

Major shift in terms of diversification of agriculture into crops, commodities, enterprises and cropping/farming systems is called upon to revert the process of degradation of natural resources, rejuvenations of waste lands and also to make agriculture a profitable business. Diversified agricultural systems may be a productive way to build resilience into agricultural systems. Crop diversification helps farmer against aberrant weather conditions like early season drought, late season drought and dry spell during crop growth season. Intercropping of soybean + pigeonpea (4:2), pearlmillet + pigeonpea (3:3), pigeonpea + green gram (1:2) and cotton + green gram (1:1) are more economic than mono-cropping (Prasad et al., 2014)

4. Objectives of chapter

In areas prone to floods and extreme weather events and water scarcity, monocropping is generally practiced. In these vulnerable areas, dependence on single farm enterprises by farmers is risky as they have limited resilience to cope with climatic constraints. Integrating the available assets of a farm, and then contemplate the micro-intervention that are deliberately designed in a conscious livelihood based on their socioeconomic, bio-physical, political, and cultural situations. The goal of this article is to achieve multiple desirable livelihood outcomes at small farm level by minimizing the risk of climate vulnerability.

5. Case study

Sustainable integrated farms began to evolve as an alternative way of farming in many parts of the developing world as a method of crop cultivation because of its multi-functionality such as complementary weed and pest control, reduced application of agrochemicals, minimised environmental degradation, enhanced dietary standards, generation of gainful employment for family members, and improved resilience against climatic variations (Kathiresan, 2007). However, extensive study is reported in different agricultural systems or land use systems. Carbon storage in Agro-forestry systems vis-a-vis home garden systems is well recorded (Henry et al., 2009). Smallholders across the developing world maintain tree species in their farms and these often play a critical binding agent in farm-level sustainability (Preston, 1992), which is expected to store carbon within small farms for longer period. IFS encourage the maintenance of biodiversity in the agro-ecosystem by growing more number of crops/varieties (often by employing mixed and intercropping),by raising more number and breed of ruminants and non-ruminants in the farm, by maintaining several tree species, shrubs and herbs in the homestead and farm (to meet several household and farm-related needs), by encouraging the integrated management of pest and by enhancing soil microbial biodiversity by incorporating more organic matter into it. IFS results in improved household food consumption (Prein and Ahmed, 2000), especially for the vulnerable family members (children and women) through provisioning of animal proteins and vegetable/fruits.

6. Conclusion and way forward

Looking into the vulnerability of Indian agriculture to climate-induced natural disasters and their long-term impacts on agricultural output, livelihoods and nutrition, research efforts should be directed towards assessing and quantifying the impact of climate change on food security and sustainability with adequate policy interventions. Integrated farming system can be a best choice as climate smart strategies with the choice of suitable crop and cultivars, nutrient management through recycling of by products and residue management, intercropping with legume, conservation agriculture-based resource conservation technology, agro-forestry and crop diversification can help minimize negative impacts to some extent and strengthen farmers by sustainably increasing productivity and income. Location-specific designing and land shaping expertise is needed for inclusion of most compatible components with good agricultural practices especially in the extreme climatic event like high rainfall, drought, frost, hailstorms and heat waves. In general, integrated farming with the climate smart agriculture options need to integrate traditional and innovative practices, technologies and services that are relevant for particular location to meet food security of small and marginal farmers.

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Different strategies for nutrient management for climate smart rice production

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1. Introduction

Climate change and agriculture are interrelated and Climate change is posing a great threat to global agriculture (IPCC, 2014). Some of the agricultural practices also contribute to greenhouse gases such as carbon dioxide (CO2), methane and nitrous oxide. Deforestaion, rice cultivation, livestock and nutrient management are major contributor in agriculture, forestry and other land use' (AFOLU) category defined by IPCC which contributes to 21% of total global emission. Agriculture, Forestry and land use accounts for 49 and 30% of total emission of carbon dioxide and methane, respectively. The share of nitrous oxide in total AFOLU emissions is small, but accounts for as much as 75% of global anthropogenic emissions of the gas (FAO, 2016). It has been estimated that future climate change may affect negatively to crop production in countries at lower latitude while positive or negative both effects may occur in northern latitudes (Porter et al., 2014).

Agriculture sector being the most vulnerable sector for climate change, affect more than a billion farming families affecting their livelihoods. Before 2050,The global population is expected to reach 9.7 billion by 2050 (United Nations, 2015) and global food consumption trends are continuously changing to meet rich diets. There will be requirements of 60% more food production by 2050, if the current trends continue(Alexandratos and Bruninsma, 2012). The most affected from the climate change will be the poor and food insecurity would increase in these poor communities (Hoffmann, 2013).

Agriculture is one of the largest contributors to GHG emissions, derived from livestock farming and emissions from agricultural soils (i.e. application of excessive N fertilizers anddecomposition of organic material). On average, agriculture accounts for about14 percent of the total global GHG emissions (IPCC, 2007). Being part of the problem, agriculture is also part of the solution to climatechange impacts. If agricultural soils are properly managed and effective policiesare in place, they have the potential to sequester large amounts of carbon fromtheatmosphere and store it in the soils, thereby mitigating CH4 and CO2emissions (Smith et al., 2007).

Development of appropriate management strategy for enhancing nutrient use efficiency, and ensuring environmental sustainability of rice production system is a priority area of research. Considerable progress has been made so far from broad based blanket nutrient recommendation to supply and demand based site specific nutrient recommendation. The nutrient management researches in rice till dates mostly focus on "4 R" stewardship i.e. right dose, right time, right source and right place of nutrient application. Numerous technologies, tools and products such as soil test crop response (STCR) based N, P, K recommendation, optical sensor based real time N management, enhanced efficiency fertilizer materials have been developed and evaluated in rice and rice based systems to ensure 4 "R" principles of nutrient application and enhance yield and nutrient use efficiency.

Rice (Oryza sativa L.), a staple food for more than half of the world population, is commonly grown by transplanting seedlings into puddled soil in Asia. Puddling reduces water percolation losses, control weeds, facilitate easy seedling establishment, and also create anaerobic conditionsand thus contributes to methane emissions.

2. Climate smart strategies

Emhasis is being given now a day on farming practices and technologies which can conserve the natural resources by reducing the greenhouse gas emissions and also enhance the crop yield (Sapkota et al., 2015). Similarly, the new technologies and efficient farming technologies along with the use of information technologies and timely providing the weather and agro advisory services can reduce the impact of climate change (Mittal 2012). In general, the CSA options integrate innovative and traditional technologies, practices and services that are relevant for particular location and reduce the effect of climate change and provide the opportunities to stand such changing scenario. Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change. Studies on research and development needs to efficiently integrate in nutrient management programme enhance nutrient use efficiency and reduce the climate change effect to the environment climatic conditions such as described as follows:

2. 1.Real time Nitrogen application in two splits by using five panel Customized Leaf Colour Chart (CLCC): Adequate supply of essential plant nutrient is necessary for getting good yield of rice. Time and dose of nitrogen is important to minimize the losses of nitrogen and better availability of nutrients. General recommendations for NPK fertilizers in DSR in most part of the Eastern India are similar to those in transplanted rice (80:40:40 kg NPK ha-1), except that a slightly higher dose of nitrogen (N) is suggested in DSR. This is to compensate for the higher losses and lower availability of N from soil mineralization at the early stage as well as the longer duration of the crop in main field in dry-DSR. Dhaincha co-culture and efficient N management with CLCC can minimize this dose. Full dose of P and K should be applied with the help of ferti-seed drill at the time of seeding. Twenty five per cent (25%) need of N is satisfied with green manuring of dhaincha, and remaining is to be supplied with external use of fertilizers. 1/3rd of which is to be applied as basal after 10 days of sowing, rest of the N applied in two equal splits based on real time N management with customized leaf color chart (CLCC) to avoid excessive N application, reduction of nitrous oxide emission and maximum utilization by plants.

2.2. Conservation agriculture (CA): Conserves the resources while sustaining the crop production and conserving the environment. CA has three components i.e. I. Minimum mechanical soil disturbance: II. Permanent organic soil cover: III. Diversification of crop It provides opportunity to crop for efficient utilization of natural resources and also maintain soil fertility.

2.3. Integrated nutrient management (INM): System or aims at achieving higher yield by judicious use of chemical fertilizers in conjunction with organic manures (Mahajan and Sharma 2005). Substitution of 50% of the recommended N with organic source increases crop yields and soil carbon in semi-arid rain-fed systems of India (Prasad et al., 2016).

2.4. Site-specific nutrient management (SSNM): Applying the right nutrient source, at the right rate, at the right time, in the right place is essential to nutrient management. SSNM, a plant-based approach provides principles and tools for supplying nutrients as and when needed for plant to achieve high yields LCC-based urea application can reduce GWP of a rice-wheat system by 10.5% in LCC ≤ 4 treatment as compared to blanket application (Bhatia et al., 2012).

2.5. Changing the cropping sequence or cropping system or Relocation of crops: There is a need to identify the regions and crops that are more sensitive to climate changes/ variability and relocate them in more suitable areas.

2.6. Microbial resources for enhancing nutrient use efficiency: Microbes play a significant role in cycling of nutrient in soil-plant-atmosphere continuum. Strains of beneficial microbes that directly influence availability of nutrient such as potassium solubilizing bacteria (KSB), Zn-solubilization microbes, siderophores producing microbe have been identified. Most of the studies on these microbes are confined to laboratories; research is needed to explore the possibility of using these bacteria to enhance the use efficiency of both applied and inherent nutrients in field scale. In addition, application of improved molecular tools (metagenomics, q-PCR etc.) is needed to explore the untapped potential of rhizospheric and phyllospheric microbial resources for their utilization to enhance nutrient use efficiency of rice.

2.7. Better weather forecasting and crop insurance schemes: Weather forecasting at different spatial and temporal scales would be significant tool for adaption in agriculture under future climate change scenario. Information and Communication Technologies can also play a great role to disseminate the information (Rathore et al., 2016).

3. Nutrient management research in a changing climate scenario

Climate change variables including precipitation (amount and distribution), temperature and atmospheric CO2 concentrations change rice productivity. Agricultural productivity is potentially changed by associated changes in crop nutrient use. Understanding of crop-specific needs for achieving expected yields and soil-specific nutrient supply characteristics is the primary basis for nutrient management recommendations. In present scenario it is important to study the expected changes in ambient CO2 concentration, temperature and precipitation which are expected to influence the agriculture. Increases in air temperature and changes in precipitation will significantly impact prevailing root zone temperature and moisture regimes.

Nutrient availability, root growth and development are primarily affected by soil moisture and temperature. Limited work have been done to understand N and P dynamics in soil and their subsequent acquisition by crop under elevated CO2 and temperature condition, however, the nature and extent of the change in these two parameters is highly site- and soil specific. At the same time little information is available regarding impacts of elevated CO2 on nutrient concentrations in solution phase, whose availability will also be indirectly mediated by temperature and moisture changes. Research is needed to investigate the impact of elevated CO2 and temperature on dynamics of different nutrient element in soil, availability and mechanism of their acquisition by plant.

4.Conclusion

In the wake of climate change the climate smart agricultural technologies such as ecology wise crop cultivars, adopting Integated farming systems, site-specific nutrient management, residue management, intercropping with legume, conservation agriculture-based resource conservation technology, agro-forestry and crop diversification can help minimize negative impacts to some extent and strengthen farmers by sustainably increasing productivity and income. Water saving technologies and water-harvesting structures to enhance the availability of water at critical stages of crop growth will be important practice in chronically water-deficient areas. In general, the CSA options integrate traditional and innovative practices, technologies and services that are relevant for particular location. Thus, to meet food security we need such smart agricultural practices which are sustainable, economic and environmentally sound.

5. Forthcoming Drive

Precise and accurate weather forecasting for different location will help to make contingent plan for different crop and cropping systems. Researches on precise water, nutrient and application technologies suitable for small and marginal farmers are needed. Most of the straight and complex fertilizers currently being used in rice cultivation are in use for last 50-60 years. Research is needed to identify and develop cheap chemical and organic source of plant nutrients particularly customized fertilizer products specific to crop and region. The 4 'R' stewardship approach of nutrient management need to be relooked in the context of development of sensor based precision real time monitoring system and advent of next generation super, high protein, biofortified and climate resilient rice. In the context of climate change, nutrient management strategy for enhancing tolerance to biotic (disease and pests) and abiotic (drought, submergence, high and low temperature) stresses need to be devised. In addition to this, it is essential to develop nutrient management strategies for low input rice farming particularly in difficult ecology. Government policy support in form of fertilizer subsidy could address this problem. Coating seeds with nutrients formulation is a promising technique to enhance nutrient use efficiency and showed positive effect on P and N nutrition however this technique is in nascentstage and require further investigation for it practical use. Some emerging technologies like nano-technology, seed coating, liquid organic fertilization etc. have potential to bring about substantial improvement in nutrient use efficiency of arable crops. Both strategic and basic research is required to explore the possibility of using nano-fertilizers for N and P nutrition of rice and at the same time assess its undesirable side effects on soil flora and fauna.

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How food processing helps in averting the ill effect of climate change?

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Introduction

The world's poorest countries' quench for hunger and improved food nutrition can be mitigated by keeping an eye on the issues of food losses and food waste and arriving at a solution to meet them. Food losses have a prodigious impact on food security, food quality and safety, economic development as well ason the environment. There doesn't exist any clear cut reason for food losses/waste rather it depends on the specific conditions and local situation of a country.Surprisingly food losses/waste occur at each level from farm to fork of every nation but the quantity may vary.According to Food and Agriculture organization (FAO) of the UN, approximately one third of the food produced for the human consumption, which amounts to 1.3 billion tonnes, gets lost or wasted.

Food losses portray a giant wastage of resources utilized in the agricultural production inclusive of all inputs.Besides this, the grown but uneaten food adds unnecessary CO_2 emissions of 3.3 giga tons to the environment along with bagging loss of economic value of the food produced. FAO has also stated that if food waste is to be considered as a country, it would stand as the third largest carbon emitter following US and China.

India bears second largest population in the world and will exceed China's population in near future however, there exists hue and cry over the food demand. According to FAO estimates in 'The State of Food Security and Nutrition in the world, 2017' report, 190.7 million people are undernourished in India which shares 14.5% of the total population making India, the cradle of largest undernourished population in the world.Therefore, sustainable use of food produced can meet the future demand with less augmentation of the agricultural production.

Classification of the food waste/food loss

Various types of food loss/waste was estimated for the food supply chain (FSC) was identified considering the five distinguished system boundaries in the food supply chain(Parfitt et al., 2010).The following aspects were considered:

Vegetable based items:

The food loss associated with the Production segment includes losses during threshing pf grains, picking of fruits & vegetables.Post-harvest segment includes losses due to improper handling and inefficient storage facilities mostly cold storage chambers. The third segment i.e. processing incurs maximum losses where the fruits and vegetables are processed to get value added products like juice, chips, dehydrated products, canned, bakery products leaving behind peels, seeds, rotten parts etc. The Distribution segment comprises losses at the retail store and the entire market system.Lastly, the Consumption part which mostly involves individual perspective in wasting the food in the domestic sector.

Animal based items:

For the animal based food, production losses is mostly associated with the death of animals, discard of the sea foods. Besides, milk production losses is related to sickness of the dairy cows. In terms of post-harvest losses, it involves slaughtering, deterioration during icing, packaging, improper storage containers during transport. However, processing losses such as canning, smoking, sausage preparation, butter and yoghurt making etc. can be considered as minimum waste as it makes the animal based food fit for human consumption but imparts very high carbon and water footprint. The Distribution segment comprises losses at the retail store and the entire market system. Lastly, the Consumption part which mostly involves individual choice of wasting the food (Fig.1).

Fig. 1. Selling of fish in unhygienic conditions in open markets(a & b), local milk storage cans for selling milk in hot climate (c)

Extent of Food loss/waste

Globally, around 1/3rd of the food produced gets wasted or lost which contributes to nearly 1300 million ton per year (FAO,2011). As mentioned above, food waste occurs from farm to fork irrespective of the economic class of the countries. In medium- and high-income countries, significant food waste/loss eventuates at early segment of the food supply chain where the food is still fit for human consumption. In low-income countries, food is mainly lost during the early and middle stages of the food supply chain however much less food is wasted at the consumer level.

The South and Southeast Asia (which includes India) depicts the low income region where rice is the staple food and maximum food losses occurs at agricultural production and post-harvest handling and storage with minimum at distribution and consumption levels (Fig. 2). Maximum loss to the tuber crops commence at postharvest handling and storage segment due to inefficient and shortage of cold storage facilities across the continent. Highly perishable commodities such as fruits and vegetables suffers maximum loss at processing and packaging segment. These all commodities indicate that focus needs to be given to secondary processing of the commodities to alleviate the food loss/waste at the food supply chain.

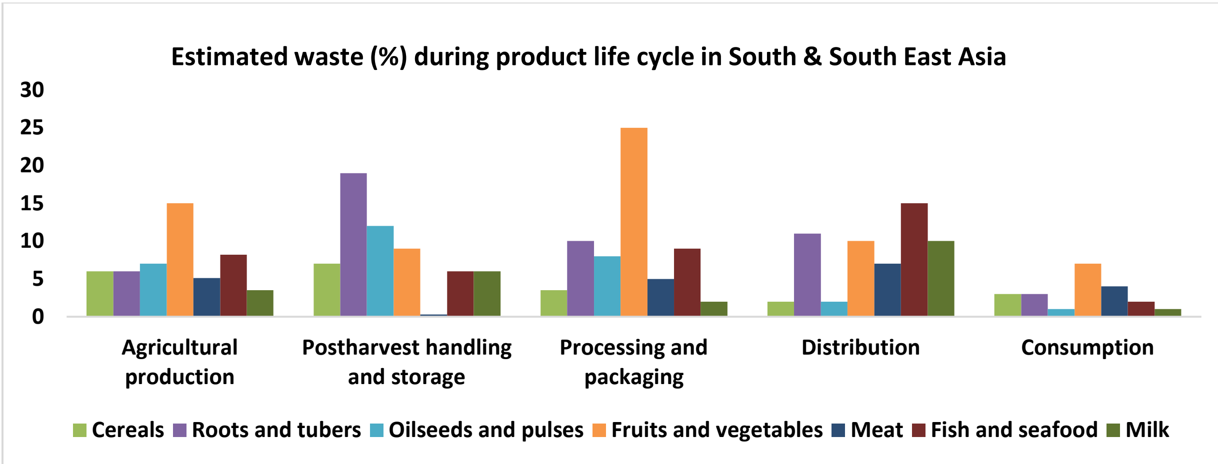

Fig. 2. Graph showing food waste(%) in the entire product life cycle in South & South East Asia

Narrowing down to India, the correlation between population explosion and demand of food supply is highly positive and always demands for excavation of more resources which leads to imbalance the environment. Huge acres of land are deforested to grow food. Nearly,45% of India's land is getting worse day by day because of deforestation, poor agricultural practices, and overexploitation of groundwater. Nevertheless, the agricultural production is now enough to feed the 1.35 billion people but food wastage stands ironically behind the billions of people (nearly 0.2 billion =194.4 millions) who are malnourished and India is the home to largest undernourished population in the world (FAO,2018) with a Global Hunger Index of 103 out of 119 countries in 2018 respectively.

A study carried out at CIPHET, Ludhiana estimated that the losses incurred in harvest and post-harvest of major agricultural produce bagged a value of Rs.92,651 crore (calculated using production data of 2012-13 at 2014 wholesale prices). Although the production of the agricultural commodities has increased manifolds, the food wastage has not decreased. In fig. 3, it is estimated that the cumulative wastage of food has risen from 2010 to 2015 with a maximum increase in fisheries (2.9 % to 10.52%) and poultry (from 3.7 % to 6.4%)

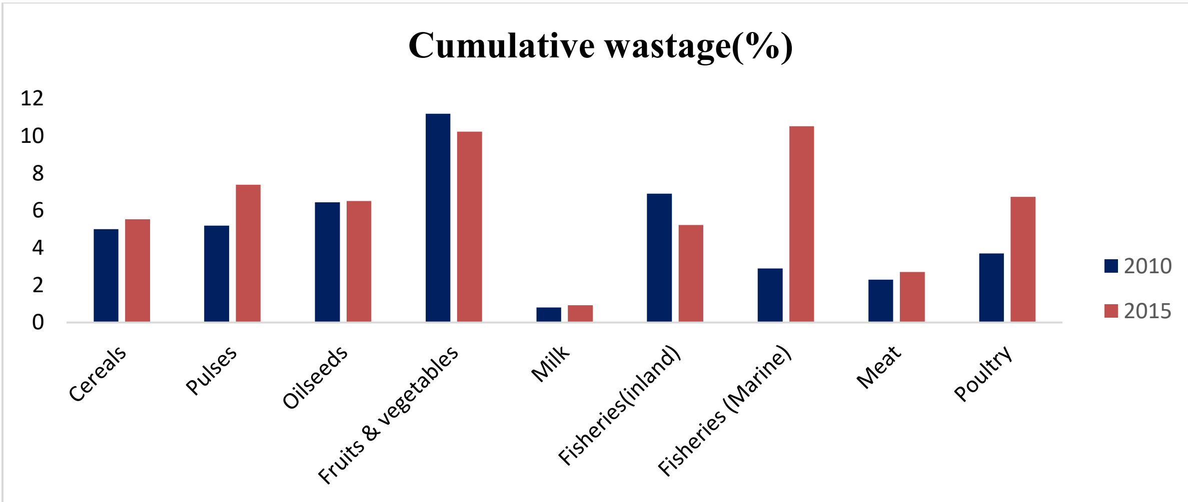

Fig 3: Comparison of cumulative food wastage (%) of different food items in year 2010 & 2015 in India

Relationship between food wastage and carbon footprint

Carbon footprint of a product can be defined as the summation of greenhouse gases (GHGs) it emits throughout the entire life cycle, mostly expressed in kilograms of CO_2 equivalents. It involves the emissions of the gases(mostly CO_2, CH_4, N_2O) from production phase till consumption at the domestic level. The calculation of CO_2 equivalent (in kg) from CH_4 and N_2O can be done by multiplying a weighing factor of 25 (for CH_4) and 298 (for N_2O) to the amount of respective gas emitted (IPCC 2007).

Fig.4 indicates the contribution of each commodity towards food wastage and carbon footprint. The ratio of food wastage and carbon footprint indicates the carbon intensity of the commodity showing the amount of GHG emissions per kg of the product.

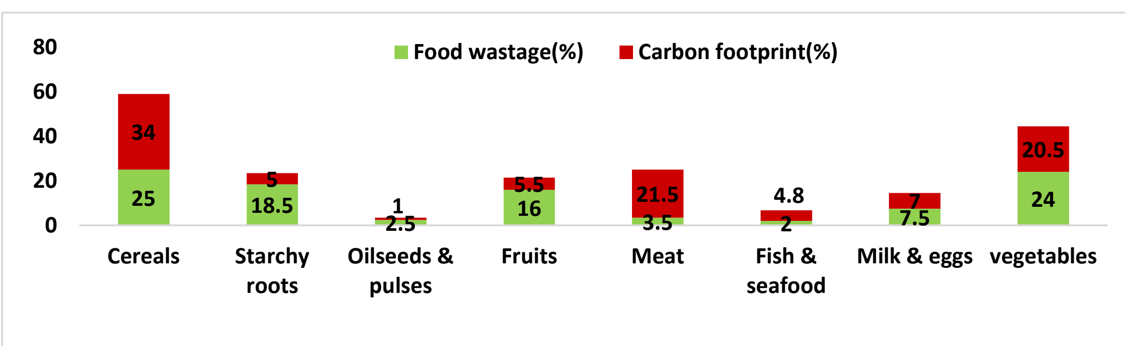

Fig. 4. Share of commodities to food wastage and carbon footprint

Measures to alleviate food wastage to combat climate change

In order to reduce the negative effect of climate change with respect to food wastage, we need to identify and priopritize practical solutions to the big challenge of feeding the country but without undermining our future. Below mentioned are various measures to reduce the food wastage and indirectly the emission of GHGs to the environment.

1. *Communication and cooperation between farmer*s: Travel of surplus production of crops to areas of deficit production (Stuart, 2009). Besides, the crop loss may be reduced by avoiding pre mature harvesting which includes loss of nutrition as well as economic returns.

2.*Diversification and upscaling of the farming system*: Organizing small farmers and diversifying and upscaling their production and marketing: Formation of FPOs (Farmer Producer Organisations) and SHGs (Self Help Groups) at village level with the financial support from banks, cooperatives etc. for integrated farming system such as rice, pulses, backyard poultry, duckery, fishery etc. rather than mono-cropping to get high economic benefits. Besides, the overproduction of a single crop is diverted to multiple cropping system.

3. *Consumer surveys by supermarkets***:** Supermarkets assume that consumers will only buy only commodities meeting the quality standards. But practically, customers bought things as long as its original flavour and aroma is not affected (Stuart, 2009). The consumer surveys can provide the supermarkets to bring a variety of products thereby reducing the food wastage.

4. *Investment in infrastructure and transportation:* Sale of the fresh commodities like fruits, vegetables, fish, meat at the consumer site can fetch good amount of money. But transporting of the commodities to a long distance spoils the commodities and lose consumer preference are highly perishable. Initiatives must be taken to improve roads, markets and sufficient cold storage facilities to make the commodities year round available at uniform price (Choudhury, 2006).

5. *Maintenance of quality standards*: Failure to meet with minimum food safety standards can give rise to food losses and, in extreme cases, impact on the food security status of a country. Numerous factors are responsible for making a food unsafe such as naturally occurring toxins, contaminated water, use of pesticides, and veterinary drug residues. Mostly poor and unhygienic handling and storage conditions, and lack of temperature and relative humidity control makes

food unsafe. Schemes needs to be developed and implemented to maintain the quality of the product. Trainings on food safety must be conducted right from the harvest of the crop till it reaches the retail store.

Fig5. (a).Excessive loading of vegetables, (b)Improper storage facilities for the grains, (c) Shelling of corn in unhygienic way

6. *Develop markets for 'sub-standard' products*: besides focusing on quality products, attention must also be given to sub-standard products like rice bran oil, value addition from peels, melons rinds, discarded samples etc. which are still fit for human consumption. This can reduce food wastage and at least provide value added products in off season to the consumer. Further, processing the sub -standard products reduce the carbon footprint also.

7. *Consumers attitude towards food*: 'Disposing off is always is cheaper than using or re-using' attitude in developing countries is one of the major reasons contributing to food wastage. Consumers attitude leads to high food waste in high class societies of the country. They can simply afford to waste food and never go for re-using of the leftover food. A number of restaurants offer buffets at fixed prices like Barbeque which revitalizes the customer to fill his plate than actually he can intake. This attitude needs to be changed to bring sustainability to the food consumption pattern.

8. *Public awareness*: Creating public awareness through audio visual aids and educating the people regarding both food wastage and its effect on climate is required. People's attitude must be changed if we really want to bring nutritional security through sustainable way to the country.

Conclusion

Escalating the food grain production is the foremost option to satisfy the ever rising population. However, burden of growing more food can somewhat be substituted by bridging the gap between production and access to food thereby reducing the food wastage. This can further help in reducing the potent GHGs emitting from the landfills. Reduction of food loss when carried with other solutions to combat climate change, several sustainable production and post-harvest measures can be taken like improved harvesting techniques, integrated nutrient management, silvi-pasture, efficient cold storage facilities etc. Besides, educating the farmers as well as creating public awareness to change their attitude towards food waste and climate effect must be considered. Globalization of the food supply chain has created production and consumption of various food items. Impact assessment needs to be done of this growing demand of the diversified food preference. Nevertheless, sufficient quantity of food can be produced and fed to the country from now to 2050 without harming the environment if the management practices are carried out in a sustainable way.

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Agricultural Mechanization for Small Holders Necessary for Climate Resilient Agriculture

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Summary

Primary reason for the low level of agricultural mechanization in India is the difficulty of mechanizing the small and marginal farms (< 2 ha) which is uneconomical for individual ownership of agriculture machinery. An energy/power requirement in agriculture sector depends on the size of cultivated land, level of mechanization, cropping pattern, and climatic conditions. For smallholder farmer, climate change poses challenge for maintaining and improving agriculture and labour productivity due to lack of access to labour saving technologies and improved farm tools. The use of improved farm implements has the potential to increase productivity, reduce cost of production, increase cropping intensity and promote timeliness in farming operations and help in drudgery reduction. There is a strong linear relationship between power available and agricultural productivity. Over the years there was rapid shift in farm power uses from animal power to mechanical power. Mechanization helps in timely farm operations with low labour and cost, but reduction in animal uses on farms increases the problem of crop biomass burning, especially wheat and paddy straw in northern India. Climate change and environmental sustainability are the key issues, must be dealt with while producing more food grains under use of various energy resources combined with conservation of the natural resources. As per the size of land holding and method of crop cultivation, selection of energy efficient technology is due important for sustainable agricultural mechanization.

Key words: Residue management, Agricultural mechanization, Conservation agriculture

1. Introduction

Agricultural mechanization is the use of tools, implements and machinery to improve the productivity of farm labour and of land. It consists of human, animal or motorized power, or a combination of these. The estimated levels of mechanization of various farm operations in India are: 40% for tillage, 30% for seeding/planting, 37% for irrigation and 48% for threshing of wheat, 5% for threshing of rest of the crops and 35% for plant protection (www.nabard.org). The use of improved farm implements has the potential to increase productivity by about 15% and reduction in cost of production by 20%, apart from increase in cropping intensity by 20%, timeliness in farm operations and drudgery reduction.

Agricultural machinery and equipment provides a package of technology which (i) augments the land productivity by improving timeliness of operations, reduction in crop losses and improved quality of agro-produce; (ii) enhances the efficiency of inputs used through their efficient measurement and placement (like seed and fertilizer application); (iii) enhance the labour productivity by using labour saving and drudgery reducing devices, and (iv) reduce cost of cultivation. Improved agricultural tools and equipment are estimated to contribute to the food and agricultural production in India by savings in seeds (15-20%), fertilizers (15-20%), time (20-30%), and labour (20-30%); and also by increase in cropping intensity (5-20%), and productivity (10-15%) (Mehta et al., 2014).

An energy/power requirement in agriculture sector depends on the size of cultivated land, level of mechanization, cropping pattern, and climatic conditions. Climate change and environmental sustainability are the key issues that must be dealt with while producing more food grains by using various energy resources. These issues can be addressed through efficient utilization and conservation of energy at the most. Maximum benefits in agricultural production can be drawn through optimal and proper utilization of energy inputs involved in various farm operations available with farmers. Presently, India is the largest manufacturer of tractors in the world accounting for about one third of the global production. India also has a big network of agricultural machinery manufacturers. However, there is wide variation among the states at the level of agricultural mechanization. The highest concentration of tractors is in northern India for land preparation. After liberalization, development of research prototypes of machines manufacturing got a big boost particularly in Haryana, Punjab, Rajasthan, Madhya Pradesh and Uttar Pradesh states.

Haryana state of India has the highest tractor density per thousand hectare of net seeded area of 84 tractors followed by 76 tractors in Punjab against all India average of 33 tractors. In Odisha state the availability of farm power is 0.60 kW/ha which is quite less than the average farm power availability of India (1.5 kW/ha) as the draught power and human muscle power still remain major power sources for agriculture and there are about 4.46 tractors per 1000 hectare area which is far less than the national average (http://farmech.dac.gov.in). The average farm power available per hectare in developed western countries is about 13 kW, while in India it is only 1.5 kW. For achieving the double food production to feed the country's increasing population, India has to increase its farm power availability to 3.5 kW/ha (Soni and Ou, 2010). Combine manufacturing is concentrated mainly in Punjab. About 700-800 combines are sold annually. Combine harvesting of wheat, paddy and soybean is well accepted by farmers.

Agricultural wages have traditionally been low, due to low productivity and large disguised unemployment in agriculture sector. However, in recent years there is sharp increase in agricultural wages due to economic growth and adoption of employment generation policy like the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and the Minimum Wages Act. According to the World Bank estimates, half of the Indian population would be urban by the year 2050. It is estimated that percentage of agricultural workers in total work force would drop from 58.2% in 2001 to 25.7% by 2050. Thus, there is a need to enhance the level of farm mechanization in the country. There is a strong linear relationship between power available and agricultural productivity.

About 85 % of the total land holdings are small and marginal in size, and hence require appropriately designed machinery, tools and implements. Mechanization technologies enable smallholders to enhance yields through the adoption of intensification, conservation agriculture, and other climate-resilient, labour- and energy-efficient, and gender-friendly machine/equipment. The small farms can be mechanized by use of improved manual tools and self-propelled farm equipment on individual ownership basis or high capacity farm machinery on custom hiring basis. Custom hiring centres provides access to small and marginal farmers to costly farm machinery which leads to timeliness in farm operations and efficient use of inputs. It promotes adoption of climate resilient practices and technologies by farmers because of availability of appropriate machines at reasonable hiring charges, which results of reduction in cost of cultivation and drudgery, crop residue recycling and prevents burning of residues. It provides work opportunities to skilled labour and small artisans.

2. Laser land leveler

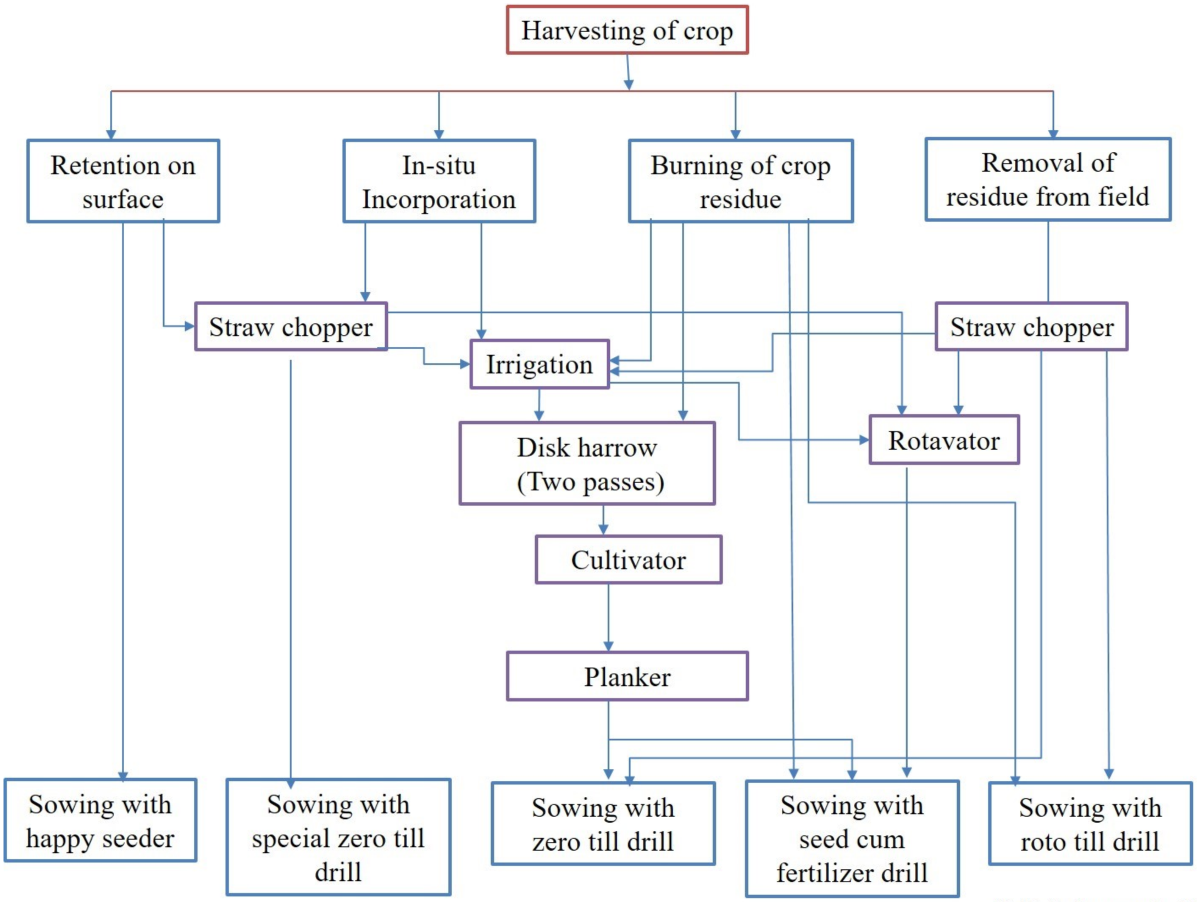
With the adverse climatic condition; rampant and injudicious usage of ground water resource, the water for agriculture witnessed a decrease in present days and in future too. There is about 67% loss of N fertilizers due to its unequal distribution. Uneven soil surface is one of the important factors for less input use efficiency. As uneven soil surface leads to the less germination, poor crop stand, and low yield of crops due to unequal water distribution and soil moisture. Although land levelling practices were traditionally predominant in farmers' fields using either animal drawn or tractor-drawn levellers, however the uneven distribution of irrigation water in the field remain as usual which resulted in water logging in low-lying areas and soil water deficit at elevated ground level.

Laser land leveller can be a precise alternative for levelling the field within certain degree of desired slope using a guided laser beam throughout the field. It consists of components which involve *drag bucket* which can be either 3-point linkage mounted on or pulled by a tractor. *Laser transmitter* which is mounted on a tripod, which allows the laser beam to sweep above the field. It emits an infrared beam of light that can travel up to 700m in a perfectly straight line. *Laser receiver* senses the infrared beam of light and converts it to an electrical signal. The electrical signal is directed by a control box to activate an electric hydraulic valve. *Control box* accepts and processes signals from the machine mounted receiver. It displays these signals to indicate the drag buckets position relative to the finished grade and Hydraulic system of the tractor which is used to supply oil to raise and lower the levelling bucket.

The benefits of laser land leveller are; it saves irrigation water, less weed infestation, increased cultivable area, top soil management, it saves labour costs, it saves fuel and it increased productivity.

3. Residue management

India produces 371 million tons (mt) of gross crop residue per year of which wheat and paddy residues constitutes 27–36% and 51– 57% respectively. *In-situ* burning of residue turn out to be huge problem in north-west Indian states, resulting residue management is of utmost important. The residue biomass not only contains plant nutrients but also it improves the soil-plant-atmospheric continuum. It pollutes environment and results in loss of appreciable amount of plant essential nutrients. *Ex-situ* method of crop residue management is using the crop residue as a fuel for the boilers by transforming it into briquettes. However, the ex-situ management of biomass residue is challenging and uneconomical due to collection and transportation of voluminous mass of residue. In this context, conservation agriculture (CA) farm machinery are the potential alternatives to manage crop residue and improving soil health, productivity, reducing pollution and achieving sustainable agriculture. Figure 1 indicates various in-situ management options for crop residue which further indicates that the farm machineries are the potential tool to combat the problems of climate change by inhibiting the factors which favours extreme climatic events.



(S.K. Lohan et al., 2018)

4. Conclusion and way forward

Agricultural/Farm mechanization is one of the most important elements of modernizing agriculture. It can reduce the risk of low yield, increases cropping intensity and increases work output per unit time, resulting in quality of life of farmer, better environment safety and food security.

5. Way forward

Weight and size of the machinery cannot be further physically optimized because of environmental and biological factors (e.g. soil compaction). Thus, only improvement is possible to increase equipment effectiveness. Equipment/machinery design suitable to small and medium farms, simple design and technology, versatility for use in several farm operation, cost effective, gender friendly and most important services like repair and maintenance are basic need for increase in agricultural mechanization. Sustainable agricultural mechanization (SAM) for climate-smart and environmentally benign technologies like no or minimum-tillage, direct seeding, bed planting and crop diversification with innovations in residue management.To make farming system more energy efficient on field straw management machinery (Happy seeder, Straw chopper, Straw management system for combine harvester etc.) need to be promoted among farmers.

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High Yielding Rice Varieties and Hybrids Developed at NRRI

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Rice is grown under varying eco-systems on a variety of soils under varying climatic and hydrological conditions ranging from waterlogged and poorly drained to well drained situations. Rice is also grown in different ecologies from irrigated to upland, rain-fed lowland, deep water and very deep or tidal wetland ecologies. Climate change brings erratic rainfall pattern and shortage of water in dams and reservoirs. It forces farmers to depend on more water from deep bore well and shifting of rice crop to other less water consuming crops. By following aerobic rice cultivation 30-40% water can be saved. In aerobic rice crop is cultivated like wheat, maize and pulse crop in direct seeded condition with suitable varieties and supplemental irrigation and other inputs. In upland condition rice is grown in around 6.0 million ha of well-drained soil where the moisture stress and blast are the major constraints and productivity is low. Mostly early maturing varieties of 80 to 110 days duration are grown, depending upon the rainfall pattern and soil topography.

Rainfed lowland rice is grown in around 13.0 million ha, mostly in eastern India, where soil moisture is available for longer period and rice varieties of 140-145 days duration to photosensitive types harvested from mid-November to mid-December are grown. The water depth varies in rain-fed lowlands and it can be shallow up to 25cm, and medium deep waterlogged up to 50cm. Shallow rain-fed lowlands can be either favorable or drought prone depending on land topography and soil types. In a normal year around 4 million ha is under drought prone rain-fed lowland,while 3 million ha, is favorable in coastal areas. Another 3 million ha is medium- deep waterlogged where water depth varies up to 50cm for a week or so. In submergence or flood prone areas, another 3 million is under cultivation,where plants remain submerged under water for a week or so and it survives, famers grow photo-sensitive late duration varieties which can be planted with aged seeding after flood recedes in standing water of 10-15cm.

Deep water rice is grown in areas where water depth is more than 50cm up to 2 meter and around 4 million has area is under cultivation in Eastern India with an average productivity of 0.8 t/ha. Most of the deep water rice areasare now under boro ice due to low productivity of deep water rice. Rice is also grown in Coastal wetlands in Eastern and Western Ghats where tidal water fluctuates as per Moon cycle and period of day. Soil salinity is a problem in areas near the creeks in wet season and in dry season rice. Around 1 million has is under coastal salinity in states of West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala and Maharashtra.

In India more than 1200 rice varieties were released for cultivation suitable different ecosystems out of them133 varieties (23 Upland, 9 Aerobic, 46 Irrigated, 2 Boro, 25 Shallow lowland, 16 Semi deep water,6 Deep water and 6 Coastal saline) have been contributed from NRRI, Cuttack. The varieties released by Central Varietal Release Committee (CVRC) have wider adaptability as they are recommended for more than one state. A list of promising and recently released varieties are furnished below with their duration, grain type, yield potential, reaction to major disease and insects, grain quality and tolerance to different adverse situations.

During the last decade, efforts were made to break the yield ceiling in rice. A limited success was achieved with development of cultivar with 10 t/ha yields from irrigated ecology and shallow lowlands. The cultivars namely Maudamani (CR Dhan 307) and CR Dhan 508 and few super rice cultures are able to find place with the farmers harvesting high yield. Recent years' endeavor on development of durable bacterial blight resistant variety like CR Dhan 800, Improved Lalat, Improved Tapaswini and climate smart variety CR Dhan 801, CR Dhan 802 in the background of popular variety Swarna through molecular breeding approach are notable achievements. The development of high protein rice variety CR Dhan 310 and subsequently development of high protein and high Zn containing rice variety CR Dhan 311 encouraged the rice breeders for further research on nutrient rich rice with high grain yield. A concerted research is going on to tackle the climate change related constraints by stacking and pyramiding of various biotic and abiotic tolerance genes.

Promising Rice varieties developed by ICAR-NRRI, Cuttack

Sl. No.	Variety	Ecology	Year of release	Duration	Grain type	Released for State	Reaction to diseases and pests and Average Grain Yield t/ha
1.	Ratna	Irrigated	1970	125	LS	CVRC	MR-BL, SB, 5.75 t/ha
2.	Samalei	Shallow lowlands	1980	150	LS	Orissa	R-GM & blast; 4.0-5.0t/ha.
3.	Savitri/ Ponmani	Shallow lowlands	1982	150-155	SB	Orissa and Tamil Nadu	MR-BL, ShBl, 3.8 t/ha
4.	Khitish	Irrigated	1982	120	LS	West Bengal	Suitable for dry season, 5.5 t/ha
5.	Annada	Upland	1987	110	SB	Orissa, MP	MR-BL, SB, 4.75 t/ha
6.	CR 1014	Medium Deep	1988	155	MS	Orissa	MR to ShBl, 3.5-4.0 t/ha
7.	Dharitri	Shallow lowlands	1988	145-160	SB	Orissa, WB, Assam and MP	SB; Semi dwarf (105-110 cm);MR-BL,BLB,SB,GM, Yield: 3.75-4.5 t/ha.
8.	Gayatri	Medium Deep	1988	155	SB	Orissa	SB; Semi dwarf (100 cm), MR- BLB, MR-Blast & GM; Yield: 4.0-6.0 t/ha.
9.	Heera	Upland	1988 / 1991	68	LB;	Orissa	LB; R- GM. Dwarf (70-75 cm), Yield: 2.5-3.5 t/ha.
10.	Padmini	Shallow lowlands	1988	145	MS	Orissa	R-BLB, good grain quality, 3.5-4 t/ha
11.	Lunishree	Coastal Saline	1992	145	LS	Orissa	Field tol. to major pests and diseases, Tol. to salinity 4.75 t/ha
12.	Vandana	Upland	1992/ 2000	95	LB;	Bihar, Orissa	MR-Bl, BS, 3.1t/ha
13.	Pooja	Shallow lowlands	1999	150	MS	Orissa, MP, Assam,	MS; R-Bl, Field tol. to major pests and diseases,4.5 t/ha

						Tripura, WB	
14.	Sarala	Medium Deep	2000	150	MS	Orissa	Photosensitive, 4.75 t/ha
15.	Shatabdi	Irrigated	2000	110	LS	West Bengal	MR-BB, SH.B, Sh.Rot, 3.7 t/ha
16.	Anjali	Upland	2002	95	SB	UP, Bihar, Jharkhand, Assam,	MR-BL, BS, SB, WBPH, GM, LF, 3 t/ha
17.	Chandrama	IrrigatedBoro	2006	130(Kh)170 (Boro)	SB	Assam	SB; R-Blast,MR-BLB,RTV,ShBl,SB,BPH,WBPH,GM, 15 d dormancy,
18.	Virender	Upland	2006	95	SB	Orissa, Gujarat	R-BS, GM, MR- BL , 2.75 t/ha
19.	Geetanjali (Aromatic)	Irrigated	2006	130	LS	Orissa	R-NB, MR-GM,4.5 t/ha
20.	Ketekijoha (Aromatic)	Shallow lowlands	2006	145	MS	Orissa	MR- BLB,ShBl,SB,GM, 3.5 t/ha
21.	Naveen	Irrigated	2006	120	MB	Orissa, Tripura	105 cm;R-BL,; 5.0-5.5t/ha
22.	Rajalaxmi (Hybrid)	Irrigated	2006	135	LS	Orissa, Assam	MR- SB, 5.85 t/ha
23.	Ajay (Hybrid)	Irrigated	2006	130	LS	Orissa	MR-BL, BLB,SB, BPH, WPH,GM, 6.07 t/ha
24.	Varshadhan	Semi-deep	2006	160	LB;	Orissa	150 cm, stiff straw MR-NBL, BLB, ShR, 3.5-4.0t/ha
25.	Nua kalajeera (Aromatic)	Shallow lowlands	2008	150	SB	Orissa	R-YSB, MR-BL, ShR , 2.8 t/ha
26.	Nua Dhusara (Aromatic)	Shallow lowlands	2008	150	SM	Orissa	R-NB, ShR, RTV; MR-GM Photosensitive, 3.0 t/ha
27.	Chandan (CR Borodhan 2)	Boro	2008	125	MS	Orissa, Assam	MR-SB, BPH, BL, BLB, ShBl, 6.1t/ha

28.	CR Dhan 40	Bunded Upland	2008	110	SB	Jharkhand Maharastra	MR-BL,BS,WBPH,SB,LF, R-GM,3.0 -3.5 t/ha
29.	Swarna Sub1	Shallow lowlands	2009	145	MS	Orissa	Tol. to submergence 15-17 days, 5.2 t/ha
30.	Sahbhagidhan	Rainfed upland	2009	105	LB	Orissa and Jharkhand	MR-BS,blast,SB,ShR,LF Tolerant to drought. 3.5-4 t/ha
31.	Reeta (CR Dhan 401)	Shallow low land	2010	150	MS	Orissa	R- LBt; MR- NB, BSt, Sh B, Sh R R- SB, LBl and LF,5.5 t/ha
32.	Luna Suvarna (CR Dhan 403	Coastal Saline	2010	150	MS	Orissa	R- BL, Tolerant- SB, BPH and LF, 3.5-4.0 t/ha
33.	Luna Sampad (CR Dhan 402	Coastal Saline	2010	140	SB	Orissa	R- Blast, Tolerant-SB, BPH, LF; 3.6-4.2 t/ha
34.	NuaChinikamini(Aromatic)	Shallow low land	2010	145-150	SB	Orissa	R- ShR, RTV,NBL,GM,MR-SB 3.5 t/ha
35.	CR Dhan 501	Semi-deep	2010	152	LB	UP, Assam	R- Neck blast, 3.4.t/ha
36.	CR Dhan 701 (Hybrid)	Shallow low land	2010, 2014	142	MS	Bihar, Guj., Odisha	MR-RTD, ShB, BS, 6.0 t/ha
37.	CR Dhan 601	Boro	2010	160 Boro; 135(Kh	MS	Orissa, WB and Assam	R- BL, RTV; MR-BS, ShR, SB, GLH, LF, Tolerant to Cold; 5.6 t/ha
38.	CR Dhan 500	Deep Water	2011	160	MS	Odisha, UP	MR- BL , NBL, BS, GM 1&5, SB, R- LF,3.5 t/ha
39.	Satyabhama (CR Dhan 100)	Upland	2012	110	MS	Odisha	R- LB, RTV, GD, SB, LF, WM; MR-WBPH,GM1, GM5, GY-2.3 - 4.7 t/ha
40.	Improved Lalat	Irrigated	2012	130	LS	Odisha	R- BLB, gall midge and MR-stem borer, 4.5 to 5.0 t/ha.
41.	Sumit (CR Dhan 404)	Shallow lowlands	2012	145	LB	Odisha	108-115 cm, , R-LB, SB, LF, 5.2 t/ha
42.	Poorna Bhog (CR Dhan 902	Shallow lowlands	2012	140	LS	Odisha	100 cm, R-NBL, GM and MR- ShR and SB.4.5-5 t/ha,
43.	Jalamani (CR	Deep	2012	160	MS	Odisha	MS; tall, . MR- LF, GLH,

	Dhan 503)	Water					BL, NBL, BS, GM, SB,4.6 t/ha
44.	Luna Barial; CR Dhan 406	Coastal Saline	2012	150	SB	Odisha	120 cm, MR-BL, LF and ShB, 4.1 t/ha
45.	Luna Sankhi; CR Dhan 405	Coastal Saline	2012	110	MS	Odisha	MR-BL and ShB,, 4.6 t/ha
46.	CR Dhan 907 (Aromatic)	Irrigated Late (Aromatic)	2013	150	MS	Chhattisgarh , Odisha, Gujarat	R-NBL, GMand MR- ShR and SB, 4.0-4.5 t/ha
47.	CR Dhan 300	Irrigated	2013	140	LS	Maharashtra Odisha, Bhar	R- LF, MR-LB, NBL, ShR and SB, 5.0-5.5t/ha
48.	CR Dhan 303	Irrigated	2014	125	SB	MP, UP, Odisha	MR- BL, NBL, ShR and RTV, 5.0 t/ha
49.	CR Dhan 305	Irrigated	2014	125	SB	Jharkhand, Maharashtra and AP	LS; MR- leaf blast, BPH and WBPH, 4.8 t/ha
50.	CR Dhan 304	Irrigated	2014	130	SB	Odisha and West Bengal	R- GM , 5.0 t/ha
51.	CR Dhan 202	Aerobic	2014	115	LB	Jharkhand and Odisha	MR- LB, BS,ShR, SB, LF, WM 3.7-4.5 t/ha
52.	CR Dhan 505	Deep water	2014	162	MS	Odisha and Assam	MR-LB,NB, BLB, ShR,SB, LF, WBPH Sub.tol. 4.5 t/ha
53.	CR Dhan 101 (Ankit)	Upland	2014	110	MS	Odisha	MR-LB,NB,BS ShR,SB, LF, GLH 3.98 t/ha
54.	CR Dhan 203 (Sachala)	Aerobic	2014	110	LS	Odisha	MR-LB,BS ShR,SB, LF 4.05 t/ha
55.	CR Dhan 206 (Gopinath)	Aerobic	2014	115	SB	Odisha	MR-LB,BS ShR,SB, LF 3.95 t/ha
56.	CR Dhan 307 (Maudamani)	Irrigated	2014	135	SB	Odisha	MR-LB,BS ShR,SB, LF 110cm, 4.8 t/ha
57.	CR Dhan 408 (Chaka Akhi)	Shallow lowland	2014	165 PS	LB	Odisha	MR-LB,NB, BLB, ShR,SB, LF, WBPH ,4.8t/ha

58.	CR Dhan 310 (High protein)	Irrigated	2015	125	MS	Odisha, MP and Uttar Pradesh.	High protein grain(10.5%), 5.0 t/ha
59.	CR Dhan 209 (Priya)	Aerobic	2016	112-115	LS	Odisha	MR- Bl, NBl,BS, RTV,SB, LF,GLH, WBPH 4.07 t/ha
60.	CR Dhan 409 (Pradhan Dhan)	Semi-deep	2016	160-165	LS	Odisha	MR- Bl, NBl,ShBl, ShR,SB,LF 4.7 t/ha
61.	CR Dhan 507 (Prasant)	Deep Water	2016	160	MS	Odisha	140-155cm, MR-NBl, BS, ShB, ShR,SB,LF,WM 4.75 t/ha
62.	CR Dhan 800	Shallow lowland	2016	140	MS	Odisha	90cm,MR-BLB, ShB, 5.75t/ha
63.	CR Sugandh Dhan 910 (Aromatic)	Irrigated Late	2016	142-145	MS	Odisha	101cm, MR-BL,NBl, ShR,RTV, SB, LF,WBPH, 4.38 t/ha
64.	CR Dhan 311 (Mukul) High protein	Irrigated	2016	120-126	LB	Odisha	Tol- BL, GD, BS, RTD, BLB, MR-GM, SB, Protein 10.1%, Zn-20ppm,5.54t/ha
65.	CR Dhan 508	Deep Water	2017	187	LB	Odisha, WB, Assam	MR-ShBl, BS,ShR;. 4.4 t/ha
66.	CR Dhan 506	Semi-deep	2017	165	MS	Assam, AP, Karnataka.	MR-ShBl, BS,ShR;. 4.4 t/ha
67.	CR Sugandh Dhan 908 (Aromatic)	Irrigated Late	2017	145	MS	Odisha, West Bengal and UP	MR-LB, NB, BLB, BS, SB, LF and WBPH, 5.0 t/ha
68.	CR Dhan 909 (Aromatic)	Irrigated Late	2017	140	MS	Assam, Bihar, UP, Maharashtra	MR- LB, NB, BLB, BS, SB, LF, and WBPH ; 5.0 t/ha
69.	Gangavati Ageti (Aromatic)	Upland	2017	85	LS	Karnataka	R- BS, MR-BL; R-GM-1,SB,; MR-GM4,5, LF
70.	CR Dhan 309	Irrigated	2018	115		Assam,	R-SB,LF,WM

						Chhatisgarh, Uttar Pradesh	
71.	CR Dhan 801	Rainfed shallow lowland	2019	140	SB	AP, Odisha, UP and WB	For submergence and drought prone areas
72.	CR Dhan 802 (Subhas)	Shallow lowland	2019	142	SB	Bihar, Madhya Pradesh	Submergence and drought tolerant, R-SB,LF,BPH, MR-BLB,ShR,RTV
73.	CR Dhan 510	Semi deep	2019	160	SB	WB and Odisha	MR-BL, BB, SBR & LF
74.	CR Dhan 511	Semi-deep	2019	160	SB	WB, AP	MR-BL, NBL, BLB, SB, WBPH and LF

Grain: LS - Long Slender MB -Medium Bold, MS -Medium Slender, SB-Short Bold, MB-Medium Bold; Resistance: BL-Blast, NBL-Neck blast, BLB - Bacterial Leaf Blight, BPH - Brown Plant Hopper, BS -Brown Spot, GB -Gundhi Bug, GM -Gall Midge, GLH - Green Leaf Hopper LF -Leaf Folder RTV -Rice Tungro Virus, SB -Stem Borer Sh.B - Sheath Blight, Sh.R -Sheath Rot, WBPH - White Back Plant Hopper, SB -Stem Borer.

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Crop –Livestock and Agroforestry-based Integrated Farming System: A Climate Smart Technology forSmall and Marginal Farmers in India

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Summary

Indian Agriculture is quite vulnerable to climate change like rising temperature, drought, flood etc. The Climate Smart Agriculture technology needs to be developed with provision of rationalization of farm resource with energy-efficient, climate resilient and sustainable agricultural practices. Crop-livestock-agroforestry-based integrated farming system (CLAIFS) will provide holistic approaches of farm management in respect to soil health, water harvesting and storage, judicious utilization of farm resources, enhancement of farm income, rural employment generation, food and nutritional security. Climate smart interventions coupled with crop diversification embedded with CLAIFS make system climate resilient. Climate smart technology based interventions enhanced water productivity, sustainability in production, carbon sequestration, energy conservation which enhances farming system sustainability particularly for small and marginal land holding farming community in India.

Keywords: Crop-livestock-agroforestry, Integrated farming system, Climate smart technology

1. Introduction

Climate change (CC) threatens the global food and nutritional security and is one of the most important challenges to meet the food security for growing population in 21st century. Climate change has already caused significant impact on water resources, agricultural productivity and food security of the country. Agricultural intensification and specialized mono-cropping intends to enhance the production, however massive application of synthetic inputs (fertilizer, pesticides, irrigation and machines etc.)results in environmental and ecological degradation which ultimately affects and endangers biodiversity and disregards the ecological integrity of land, forests and water resources. Since, integrated farming system (IFS) is a multi-enterprise agri-system which promotes higher income, minimizes risk of crop failure, creates ecological harmony and restores the sustainability of the agricultural system and can be a best bet for climate smart agriculture (CSA). The agriculture sector is particularly vulnerable to CC mainly because of its dependence over consistent temperature ranges and water availability. The CC also enhanced vulnerability to plant pests and diseases and will likely increases the incidences. The impact of CC on crop yield is both positive and negative i.e. productivity of some crops in some areas increases, while others elsewhere suffer - negative impacts which outweigh the positive impacts (IPCC 2014). It is estimated that CC impacted /reduced global yield of wheat by 5.5% and of maize by 3.8% (Lobell et al. 2011) and projected to have 8-24% loss of total global caloric production from maize, soybean, wheat and rice by 2090 (Elliott et al. 2015).Therefore, CSA technology needs to be developed and adopted to cope up with the future food production strategies.

2. What is climate-smart agriculture?

Climate smart agriculture may be defined as an approach for transforming and reorienting agricultural development under the new realities of climate change (Lipper et al. 2014). According to FAO, CSA is defined as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) wherever possible, and enhances helps in achieving national food security and development goals". The principal goal of CSA is to provide food security and development; while productivity, adaptation, and mitigation are the three interlinked pillars for achieving this goal (FAO 2013; Lipper et al. 2014).

The CSA has three objectives: sustainably increasing agricultural productivity to support equitable increase in income, food security and development; increasing adaptive capacity and resilience to shocks at multiple levels, from farm to national; and reducing greenhouse gas emissions and increasing carbon sequestration wherever possible. Since local conditions vary, the CSA identify the impacts of agricultural intensification strategies on food security, adaptation and mitigation in location specific manner. The practices include strong adaptation and food security benefits that can also leads towards reduction of GHG emissions or increased carbon sequestration. Therefore, CSA programmes include capacity development for local stakeholders to assist them in tapping the sources of funding for agricultural and climate-related investment.
The different elements of CSA system includes:

- Management of farms, crops, livestock, aquaculture and capture fisheries to balance food security and livelihoods needs along with adaptation and mitigation options.
- Ecosystem and landscape management to conserve ecosystem services that are important for food security, agricultural development, adaptation and mitigation.
- Services for farmers and land managers to enable better management of climate risks/impacts and mitigation actions.
- Changes in the wider food system including demand-side measures and value chain interventions that enhance the benefits of CSA.

The CSA aims to strengthen livelihoods and food security, especially small and marginal farm holders through improving the management and judicious use of natural resources through adoption of appropriate technologies and methods for production, processing and marketing of agricultural goods.

In brief,

CSA = Sustainable Agriculture + Resilience – Emissions.

In agricultural sector the CSA can be achieved through the under mentioned practices, system approach and enabling future environmental improvements.

Practices	System approaches	Enabling Environments
Soil management	Landscape management	Index based insurance
Crop productivity	Value chain	Climate Information services
Water management		Infrastructure
Livestock management		Policy engagement
Forestry and agroforestry		Institutional arrangements
Fisheries and aquaculture		Gender and social inclusion
Energy management		

3. Case study

The developments of IFS consisting of crop-livestock-agroforestry components will provide holistic approaches of farm management in respect to soil health, water harvesting and storage, judicious utilization of farm resources, enhancement of farm income, employment generation, nutritional and environmental security. In this context, we have developed a rice-fish based crop-livestock-agroforestry based IFS (CLAIFS) model for enhancing livelihood security of the small and marginal farmers (Nayak et al. 2018a), which is presented in this article.

The rice-fish based CLAIFS model was developed during 2004 at ICAR-National Rice Research Institute (NRRI), Cuttack, India (85^{0}55'E, 20^{0}25'N; elevation 24 m) (Fig. 1). The designed system comprises of water refuge area (15%), rice cultivation (65%area) and complete bunding on four sides (20% of total area). The system designed with suitable land shaping using ecological engineering concepts of soil, water conservation, nutrient and farm waste recycling etc.with components of crops, seasonal vegetables, horticultural plants (banana, papaya, mango, guava, coconut), livestock (fish, duckery, poultry, goatry), fodder grass and agro forestry etc. In this system, climate smart characteristics and resources interventions are discussed below:

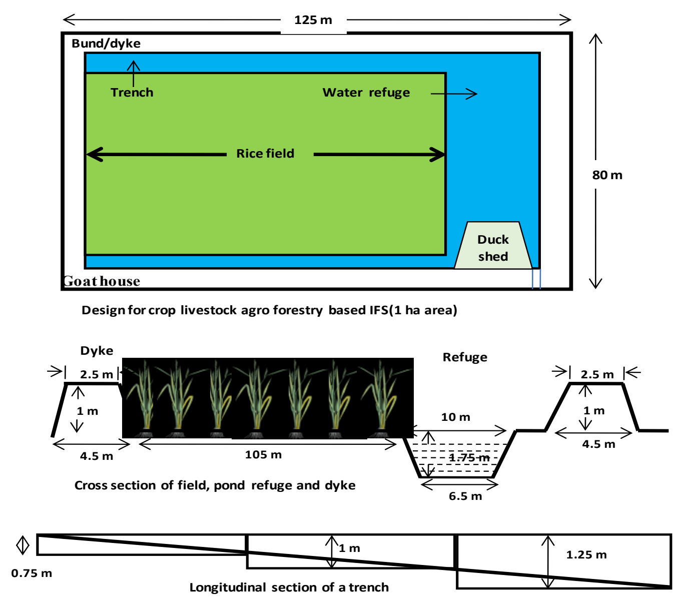

Fig. 1.Rice-fish based CLAIFS model developed at NRRI, Cuttack

a. Climate Smart Interventions in Integrated farming system

Production smart: The production, processing and marketing of agricultural goods are central to food security and economic growth. The system (1 ha.) produces about 19.0 – 20.0 t of food and fodder (bio-mass), including 0.6 - 09 t of fish and prawn, 0.7 t of meat, 0.9 t of horticultural crops including vegetables, in addition to fuel wood and other crops residues. The CLAIFS significantly increased rice equivalent yield *(*REY, 27.72 t/ha*)* as compared to the conventional rice farming *(CS*, 7.3 t/ha*)*. In CLAIFS system the output value to the cost of cultivation ratio *(*OV-CC ratio*)* was 1: 2.86.

Water Smart: Smart water management practices aims to enhance efficiency and productivity of water. The CLAIFS developed at NRRI have the provision of water harvesting structure where rain water can be stored and used for life saving irrigation purpose to meet the crop demands. The system also included fish as a component. This system has potential to conserve and save about 40-50% of rain water for timely agricultural use, and resulted in enhancement of water productivity (WP) by 2.23 times, gross water productivity (GWP) by 2.27 times and net water productivity (NWP) by 5.88 times higher as compared to conventional system (CS).

Carbon Smart: Carbon sequestration is defined as the capture and secure storage of carbon that would otherwise be emitted to or remain in the atmosphere. Increasing carbon content in the soil may reduce the atmospheric carbon dioxide concentration and improve soil quality. Tremendous potential exists in IFS to act as carbon sink by storing carbon in the eco-system because *(*a*)* agro-forestry and horticultural trees are major components in the system, *(*b*)* integration of livestock (raised within system) provides organic manures which enhances soil organic matter and carbon storage *(*c*)* external input like chemical application (reduced fertilizers, pesticides and herbicides) are minimized hence reduced GHG emission, and *(*d*)* less amount of fossil fuel is used in farming. In the small holder integrated farming system, the carbon content in soil increased significantly. Additionally, presence of duck and fish in the rice fields substantially reduced the GHG emission potential (Nayak et al., 2018a: Xu et al 2017). Since system is already having components and provision of agroforestry, livestocks and their manure managements, diversified land use system and crop residue management hence, the system can considered as carbon sink along with enhancing productivities.

Nitrogen Smart: In CLAIFS, climate resilient crops like pulses can be cultured during dry season which improves nitrogen concentration in the soil through nitrogen fixation. Use of nitrogen fixing Azolla with rice cultivation added substantial nitrogen requirement for rice which is also used as animal feed supplements in the IFS. Further, manure from fish, duck, goat and poultry etc. added substantial amount of organic fertilizer i.e. nitrogen to the system, there by reduced the plant requirements for the inorganic nitrogen fertilizer. Precision agriculture can also be practiced through use of right source of nitrogen in right time and right places and right dose in IFS. Farmer must use leaf colour charts, crop sensor and other nutrient-decision-making tools to decide appropriate dosages of nitrogen fertilizer for climate smart interventions.

Energy Smart: Indiscriminate use of chemical fertilizers and pesticides/herbicides and increasing mechanization for agricultural operations is progressively making the modern agriculture system less energy efficient. The direct energy use in various agricultural operations includes fuels and electricity mostly required for performing various tasks related to land preparation, irrigation, harvest, postharvest processing, transportation of agricultural inputs and outputs etc. and indirect energy is the energy consumed in the manufacture processes, packaging and transport of fertilizers, seeds, machinery production and pesticides etc. In a pilot study, the IFS comprising of the rice-fish-duck)RFD (system was found to be more energy efficient as compared to CS rice farming. IFS utilized more renewable energy)52841.3 MJ/ha, 70.62 (%and lesser non-renewable energy)21975.6 MJ/ha; 29.37 (%as reversed in CS system of rice farming and utilizes less renewable energy)15690 MJ/ha; 44.4 (%and higher non-renewable energy)19938 MJ/ha :55.96 (%(Nayak et al., 2018b). Additionally, installation of biogas systems through manure slurry in the IFS is another energy smart approach.

Knowledge Smart: In this system, there is blending of both modern scientific knowledge with local and indigenous traditional knowledge, as CLAIFS utilizes the combinations of science with local knowledge by exploiting the locally available resources of crops and livestock's resulted in a resilient and low risk system. Plantation of agroforestry, fodder for animal etc. can meet the further requirement for wood and fodders for animals at time of scarcity. ICTs, Gender empowerment and capacity building are main frame work system in CLAIFS as the diversified system demands knowledge specific management skills.

4. Conclusion

The CLAIFS is a sustainable farming system having resource (water, carbon, nitrogen and energy) based climate smart intervention which makes system climate resilient with reduction of GHG emissions. The agroforestry component significantly reduces the effects of global warming. The rice-fish based integrated farming system is an eco-efficient land management practices with integration of crop-livestock-agro-forestry system having judicious use of farm resources and waste recycling with lesser dependence of non-renewable resources. CLAIFS (mixed farming systems) enhance resilience and reverse soil degradation, providing nitrogen-rich residues and increasing soil organic matter. The CLAIFS enhances the farm and water productivity; diversifying farm income, increase carbon sequestration and energy efficiency and sustainability in agricultural systems. The system have potential for climate change resiliency and mitigation strategies and thus enables the farmer's participation in climate risks managements for building a climate resilient production system for national as well as global food security.

5. Way forward

- Agro-ecological-based temporal and spatial models to be developed coupled with resource based climate smart intervention.
- Integrated impact assessment of CLAIFS may be evaluated on varied ecological framework for improving agricultural production system's efficiency.
- Impact of risk, vulnerability in extreme weather conditions in respect of CLAIFS requires more attention.
- Mobile applications related to crops, weather predictions and early warning system may be developed with local perspectives.
- Provisioning of subsidies for adoption of CSA technologies for different agricultural production systems.
- Newer adopted species may be evaluated with favourable policy interventions.
- Infrastructure and institutional framework to be built up along with suitable policy framing and implementing network systems.

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Rice straw management: Challenges and Opportunity

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Summary

Rice is a staple food for South-East Asia as well as India. In India itself around 110 million tonnes of paddy is produced each year which generates a substantial amount of straw. On an average 21.86, 97.19 and 10.68 Mt of rice straw is produced in Thailand, India Philippines, respectively. Management and proper disposal of rice-straw has become a burgeoning problem. As a consequence farmers prefer to burn the straw in field itself. Rice straw management is an important issue as it also contains plant nutrients that enhance the productivity of the soil-plant systems. The burning of rice-straw not only pollutes air, environment and at the same time degrades soil. Further, open-burning of rice straw significantly contributes to global warming through greenhouse gases (GHGs) emissions. However, several initiatives have been taken to tackle the problem and managing the straw in a sustainable manner. In this deliberation, we are aimed to assess the environmental consequences of rice straw burning and evaluate the potential of different rice straw management options.

1. Introduction

Globally, the rice production system contributes the highest crop yields. In virtue of that, it also generates the by-product in the form of straw which is becoming difficult to manage day by day. Rice is the staple food for India as well as for tropics. On an average 600 million tons of rice straw is being produced globally. However, 60-80% of them contribute to GHG emissions through burning and other ineffective management practices. Presently, more than 60% of the total rice straw produced annually is burnt by farmers within 3-4 weeks during October–November in India. Rice straw burning is a major practice not only in India but also in whole world (Chen et al., 2017) despite having counterproductive effects on quality of air and health of human.

Rice straw burning enhances the emissions of miscellaneous air pollutants which includes greenhouse gases (GHGs), which have a vital role in changing the chemistry of atmosphere worldwide (Ravindra et al., 2016). However, rice straw burning is still a prevailing practice in South-Asian countries. Lack of field preparation time for next season's crop, high cost of carrying of straw from field to outside, spreading of chopped straw on the field after combine harvester use, weeds removal problem, and so called less diseases and pests infestation in succeeding crops are the major reasons mentioned for rice straw burning in the field.

The unrestricted burning of rice straw leads to emissions of miscellaneous pollutants like carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), oxides of nitrogen (NOx), ammonia (NH_3), non-methane volatile organic compounds (NMVOCs), methane (CH_4), particulate matter (PM_{10}, $PM_{2.5}$), organic carbon (OC), elemental Carbon (EC (Oanh et al., 2018). Emissions and dispersion of pollutants differ according to seasons, climatic condition and type of residue. Moreover, the declining quality of atmosphere due to rice straw burning and its dissemination in surrounding areas are of great concern due to its harmful effects on the environment and human health (Ravindra et al., 2016). Several studies show that rice straw burning is the main factor for loss of major nutrients in soil, like nitrogen (100% loss), phosphorous (25% loss), potassium (20% loss) and sulphur (5-60% loss) (Table 1) (Dobbermann and Fairhurst 2002).

Table 1: Nutrient removal comparisons between grain, straw and burning straw

	Plant Nutrient Removal (in kg t^{-1} of production/ burnt)					
Rice	**Nitrogen**	**Phosphorus**	**Potassium**	**Magnesium**	**Calcium**	**Silicon**
Grain	10.5	4.6	3.0	1.5	0.5	2.1
Straw	7.0	2.3	17.5	2.0	3.5	11.0
Straw-Burning	7.0	0.6	3.5	1.0	2.9	0.2

(Source: Dobermann and Fairhurst, 2002)

2. Environmental Consequences of Rice Straw Burning

2.1 Depletion of air quality due to trace gas and aerosol emission

Carbonaceous matter present in trace gases and aerosols have important role to play in climate change and may lead to deposition of acid, increase in ozone at troposphere and depletion of the ozone layer at stratosphere (Oanh et al., 2018). One tonne of rice straw releases 3 kg particulate matter, 60 kg CO, 1460 kg CO_2, 199 kg ash and 2 kg of SO_2 , on burning. It also responsible for emission of large quantity of particulates that are made up of heterogeneous organic and inorganic substances. In rice straw, about 70, 7 and 0.7 % of existing carbon is liberated as CO_2, CO and CH_4, respectively, while, 2.1% of nitrogen in straw is released as N_2O during burning (Hays et al., 2005). Comparative assessment of current and future emissions of miscellaneous pollutants from burning of rice straw for India is given in Fig 1.

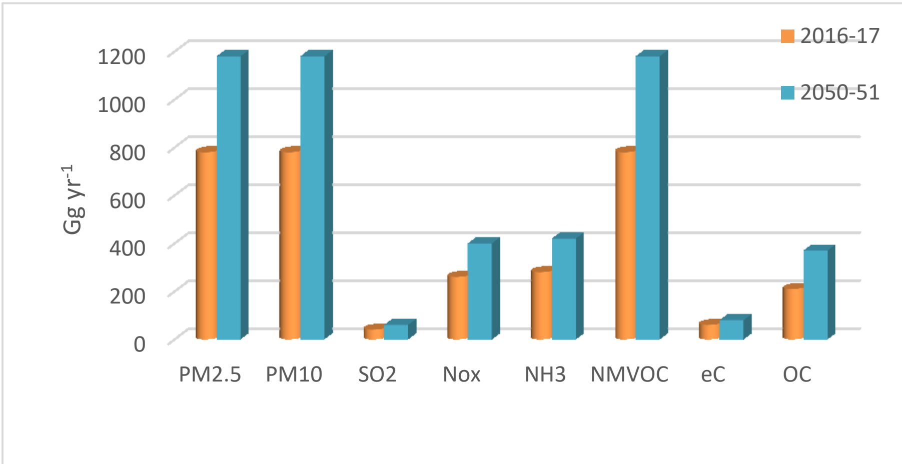

Fig 1: Comparative assessment of current and future emissions of miscellaneous pollutants from rice straw burning for India.

Particulate matter (PM_{10}, $PM_{2.5}$), sulphur dioxide (SO_2), oxides of nitrogen (NOx), ammonia (NH_3), Non-methane volatile organic compounds (NMVOCs), elemental Carbon (eC), organic carbon (OC). (Ravindra et al., 2018)

2.2 Smog formation in the atmosphere and release of soot particles

For the consequence of rice straw burning, liberated particulate matter ($PM_{2.5}$) are highly light in weight and have the ability to stay for a longer period in the atmosphere, produces smog and travel several miles together with wind (Jain et al., 2016). In the air, the particulates are grouped according to their chemical composition and aerodynamic diameter size. Particulate matter (PM) having $PM_{2.5}$ has greater stability-timing in environment as compared to PM_{10} due to the balance between the aerodynamic drag force downward and force of gravity.

2.3 Deleterious effect on health of human, animal and birds

The rice straw burning emits hazardous air pollutants, which have harmful impacts on human health. The diseases could be listed as heart diseases and lung ailments, respiratory problems such as asthma, coughing; highly affecting pregnant women and children (Pathak et al., 2010). Beneficial pests and microorganisms also die due to straw burning.

2.4.Deterioration in soil health and fertility

Repetitive burning in the agricultural field permanently reduces microbial population. Continuous burning reduces total nitrogen and carbon and potentially mineralized nitrogen up to 15 cm soil layer. Burning also kills beneficial soil micro-flora and fauna (Ahmed et al., 2013). Soil temperature could rise up to 33.8-42.2°C at 10 mm depth due to burning of straw. As an effect of rise in temperature about 23–73% of nitrogen is lost and the microbial population is reduced sharply up to 25 mm soil-depth (Kumar et al., 2015).

3. Technological Alternatives of Rice Straw Management: Possibility and Challenges

Management options are broadly classified in to 'on-farm' and 'off-farm'. 'On-farm' management includes straw incorporation, retention, mulching, etc. and 'off-farm' options are energy conversion through biochar, biofuel, paper pulp production, mushroom plantations, etc. A comparative assessment of rice straw management options and GHG emission is presented in Table 2.

3.1 Rice straw retention and incorporation

The retention followed by incorporation of rice straw in agricultural farm is a reasonably eco-friendly alternative to straw burning that enhances soil carbon and nutrient status gradually. Simultaneously, this practice increases weed infestation, soil compactness, and GHG emissions. The incorporation of straw in paddy facilitates methane emission by providing labile carbon substrates to methanogens (Romasanta et al., 2017). The main cause of decrease in N_2O emissions immediately after straw application is due to the reduction of N_2O to N_2.

The amount of GHGs emission and air pollution caused by straw-burning is higher as compared to incorporation of same amount of rice straw in field. Moreover, organic matter content and the organic carbon content in soil increases by incorporation of rice straw. Soil organic carbon acts as an excellent binding agent and play a crucial role to form a stable soil aggregate and improve soil structures.

3.2 Biochar

Biochar is a porous, carbon (C) rich fine-grained product generated by pyrolysis. Pyrolysis refers to the thermo-chemical process of burning at low temperatures in an oxygen-limited environment. Biochar is the mixture of C, hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in various amounts. Biochar application helps to improve soil-water retention and nutrient holding capacity of soil by increasing the effective soil surface area (J. Shen et al., 2014). It has a significant impact and relation with the soil matrix, soil microbes, and plant roots and helps in nutrient retention and triggering a wide range of biogeochemical processes. An increase in pH, increase in number of earthworm and decreased fertilizer usage are reported by several scientists. Rice straw by the process of pyrolysis could be transformed to biochar which has the potential to reduce carbon footprints by 38-49% from rice production and cultivation (Bhattacharyya and Burman, 2018). Hence, use of biochar is a sustainable alternative, which could help to mitigate climate change as it helps in carbon sequestration.

3.3 Straw decomposition

Composting is the decomposition of rice straw for recovery of nutrients and organic components. It is generally done in open natural condition or in an enclosed controlled chamber. The quality of compost depends on condition during composting like, availability of oxygen, moisture content, pH, temperature, and the C: N ratio. Rice straw decomposed slowly and usually will take up to a year to decompose in natural condition. Several simple and rapid composting techniques are developed to convert huge amount of rice straw into valuable compost. The beneficial effect of compost is well known (increase crop yield by 4 to 9%) but the problem is associated with labour availability and prolonged time of composting (Pandey et al., 2014). Recently developed efficient microbial strain with suitable package of practice could decompose the rice straw both in ex-situ and in-situ condition with less than 35-40 days.

Table 2: Comparative assessment of GHGs emission as affected by different rice straw management options

Management practices of rice straw	Reduction in GHGs emission compared to burning (%)			Reason	Reference
	CH_4	N_2O	GWP		
Straw retention	-47.7	17.4	-	Favorable for CH_4 formation as provided more labile carbon in to reduced soil. Reduction of N_2O to N_2 causes less nitrous oxide emission.	*Romasanta et al. ,2017*

Straw incorporation	-12.5	21.74	-	Provides labile carbon to soil, favorable for CH_4 formation. Decrease in N_2O emissions due to higher mineral N immobilization, decreased soil Eh, and increased soil Fe^{2+}content.	*Romasanta et al. ,2017;*
***In-situ* decomposition**	-19.3	57.8	-	The anaerobic decomposition of carbon provides substrates for methanogens, enhanced methane production.	*Romasanta et al. ,2017;*
Biochar	75	-39.1	66.5	Reduced CH_4 emissions due to the stimulation of methanotrophic activity. Increased N2O emissions due to the additional nitrogen input.	*J. Shen et al., 2014;*
Substrate for mushroom production	37.25	47.7	7.3	Comparatively low emissions of CO, CH_4 and NMVOC from mushroom cultivation reduces the air pollution.	*H. Arai et al., 2015*

3.4 Use of rice straw as substrate for mushroom production

Rice straw is an essential component used as a raw matter for rice straw-mushroom culture. Use of rice straw for mushroom production is a win –win situation where, we can convert a waste (burned rice straw to ash) to an asset (substrate for a high value mushroom). Apart from this mushroom cultivation provide good employment opportunity to rural youth and give economic yield to farming community. Moreover, as compared to burning, the same amount of rice straw, GHG emissions due to incorporation is much lesser (straw burning, 1469-2098 g CO_2-eq. kg dry-straw^{-1}; straw-mushroom cultivation, 1362–1461 g CO_2-eq. kg dry- straw^{-1} (Arai et al., 2015). Mushroom beds were conventionally air- dried for several weeks and piled up before the burning was the main cause of less emission (Arai et al., 2015).

3.5 Bioethanol and Bio-energy

Rice straw having lingo-cellulosic biomass is considered a useful substrate for the production of energy and generation through ethanol. Around 205 billion litre bioethanol per year can be produced from rice straw in the world, which may be 5% of total of ethanol required. Rice straw mainly contains cellulose 30-45%, hemicelluloses 15-25%, lignin 6-25% and ashes 18% (Belal, 2013).

Biogas from rice straw in combination with other organic products is a premiere technology in the rice-growing areas. It has several benefits, which adds plant nutrients to the soil. In addition, biogass slurry can be used as soil amendment to mitigate GHGs emission as compared to the addition of raw organic manure. Escalating fuel prices and climate change/environmental issues may re-stimulate its future.

4. Conclusions

Farmers are aware of the deleterious effects of rice straw burning at the field condition but the main constrained is availability of economically viable and acceptable machineries and different alternatives for disposal of huge amount of rice straw. However, rice straw can be best utilized for production of energy and has the potential to meet 10% of current energy demand of India. Rice straws are also of high economic value for biogas, manure, and biochar production And can be used as livestock feed and paper industry raw material.

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Varietal Dissemination to Strengthen Vulnerable Rice Farmers through INSPIRE Model of ICAR-NRRI

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1. Introduction

Development of new approaches in agricultural extension in India and worldwide is a continuous process with its focus on increasing productivity and profitability. Since the Green Revolution during late 1960s, Indian agricultural extension has adopted decentralized, participatory and demand-driven approaches, in which accountability is geared toward the users (Kokate et al. 2009; Sulaiman and Hall 2008; Swanson 2009). While the call for demand-driven agricultural extension has existed for several decades now, new modes of reaching out to farmers could have significant impact in India, as they might better reflect the local information needs of farming communities, especially the more vulnerable farmers in the changing climate scenario. The diverse nature of the Indian subcontinent, with its wide variety of agro-climatic regions and broad range of socio-economic conditions in the rural population, calls for agricultural extension approaches that are context-specific and situation-specific. Extension organizations in general have been using a wide range of methods for reaching individuals, groups and the wider public in rural areas with new information/knowledge. Approaches to extension also vary widely from top-down and supply-led to bottom-up, demand-led and participatory. Approaches also vary depending on the mandate of the organization or the programme. Advances in information and communication technologies (ICTs) have also provided new opportunities for extension to reach more farmers in a short amount of time (Sulaiman et al. 2011). One such innovative extension approach pertaining to fast spread, popularization and adoption of new rice varieties in various agro-ecologies, popularly known as INSPIRE model, has been covered in this chapter. Efforts have been made through the chapter to address various issues and problems responsible for low income of farmers and share innovative ways, means and extension solutions to get rid of those problems. The new ideas could be suitably blended with existing extension models to hasten the extension service delivery in any developing nations.

2. Varietal Development at ICAR-NRRI

The first rice variety from ICAR-NRRI 'Padma' was developed in the year 1968 and so far 132 rice varieties have been developed. The varietal development effort of the ICAR-NRRI has got an impetus after 2010 with the release of an average of over five varieties per year (Table 1). With the reorientation of research focus on rice breeding programmes, production and protection technologies in challenging environments and farm mechanization, the institute has released varieties targeting several situations, requirements of farmers and consumers preference. The scientists have developed varieties targeting both biotic (insects, diseases and weeds) and abiotic stresses (drought, submergence, flash flood, heavy wind, low light intensity, extreme temperatures etc). Some of those include, (i) Aerobic varieties (can be grown with less water without yield penalty), (ii) Climate smart varieties (tolerance to both submergence and drought), (iii) Fortified rice (high protein, zinc and iron), (iv) Hybrid rice (with 7-8 t/h yield), (v) Super Rice/ new generation rice varieties (350-450 grains per panicle with yield potential of 10-12 t/h in farmers' fields), (vi) Quality rice (low GI diabetic rice, aromatic rice, superfine grain, good cooking, milling and marketing quality) and (vii) Varieties suitable for rice-based value added products (puffed rice, popped rice, bitten rice, rice flour, rice noodles etc). But most of these developed varieties are neither in state seed chain nor adopted by farmers of targeted states and ecologies due to their unawareness or some other reasons.

Table 1. No. of rice varieties developed by ICAR-NRRI since its inception

Period	No. of years	No. of variety developed	Average No. of variety developed per year
1946-2000	54	57	1.05
2001-2010	10	28	2.80
2011-2019	9	47	5.22
Total	**73**	**132**	**1.81**

3. Constraints of Technology Transfer and Adoption

A critical review of past studies reveals that the major reasons for slow spread and adoption of new rice varieties by farmers pertain to (i) lack of awareness and publicity among farmers, extension personnel and KVKs, (ii) insufficient minikit trials and demonstration programmes with new varieties, (iii) lack of effort by central and state extension machineries including

KVKs, (iv) non-inclusion of recent varieties in state seed chains, (v) non-receipt of breeder seed indents from the state agriculture departments, (vi) unavailability of sufficient quantity of quality seeds, (vii) absence of suitable seed production and distribution policy etc. It is estimated that a new rice variety takes about 6-8 years to be known or popular by the farmers. But as per the existing government policy, all the subsidies cease for a variety which is older than 10 years and those cannot be promoted through any scheme, with exception in case to case basis. To overcome this problem, the institute has intensified its effort to fast spread and popularize newly released rice varieties in various states through its "**IN**novative extension approach for fast **SP**read of varieties in **R**ice **E**cosystems" (INSPIRE) model since 2017-18. Under this model, district level field demonstrations through minkits of new varieties are carried out in various states with the active participation of various stakeholders like local KVKs, state line departments, local seed growers and farmers to showcase comparative performances with local popular varieties.

4. Research Initiatives and Past Studies on Varietal Spread

Regarding adoption of rice varieties in Bangladesh, Hossain (2012)reported that the number of varieties grown in different seasons were 1091 (Aman-535, Boro–261 and Aus-295). However, only a few varieties covered a large proportion of area. The major varieties according to area coverage in Bangladesh were 'BRRI Dhan 29' (37%) and 'BRRI Dhan 28' (23%) in dry season, while 'BR 11' (27%) and 'Swarna' (12%) in wet season. Similarly, the survey report also encompasses findings from three major rice growing eastern Indian states namely, West Bengal, Odisha and Jharkhand. The survey identified 226 rice varieties in West Bengal, a large proportion of which were traditional varieties mostly grown in the aman season. The most popular variety in the aman season was found to be 'Swarna' (45% of the rice area), whereas in the boro season it was 'IR 36' (27% area). The main source of seed for aman varieties was farmers' own seed, whereas, in the case of improved boro varieties, it was seed traders. In case of Odisha, the number of varieties identified in the wet season was 723, most of which were traditional varieties. On the other hand, the number of varieties in the summer season was 29, all of which were improved varieties grown under irrigated conditions. Variety 'Swarna' (29.3%) was the most popular variety in the wet season, whereas in summer it was 'Lalat' (47.0%). In Jharkhand, altogether, 145 varieties were identified and the highest number was for medium land (71), followed by lowland (55) and highland (19). In the highland, traditional variety 'Gora

Dhan' was found to be the most popular, while in the medium land and lowland, improved varieties namely 'IR 36' and 'Swarna', respectively, were the most popular varieties.

Regarding primary traits for farmers' varietal preferences, he reported that farmers sought high grain yield from limited farm size as the most important trait in a new variety. The responses of the farmers from Bangladesh, West Bengal, Orissa and Jharkhand with respect to this higher grain yield trait were 96%, 100%, 100%, and 73% respectively. Farmers also looked for secondary traits like grain quality for a premium price in the market, shorter maturity duration, lodging resistance, and higher milling recovery. The survey on adoption and diffusion of new varieties in Bangladesh, West Bengal, Orissa and Jharkhand revealed that (i) if varietal performance is substantially better than that of existing varieties, large farmers adopt and small and medium farmers follow; otherwise, the variety is eliminated; (ii) availability of seed of improved varieties is a major constraint for fast-tracking diffusion (70% to 80% of the seeds are from farmers' own harvest or are exchanged with or purchased from neighbors), (iii) Once farmers in a village are convinced of the superiority of a new variety, it takes 3 to 5 years to reach areas suitable for the variety, (iv) However, it may take a longer time to reach a substantial portion of area because of information lag (extension system is not highly effective, radio/television is a minor source of information, input dealers are not targeted as information bearers), and (v) Once a variety is established, it is difficult to dislodge it unless new improved varieties have traits that are substantially superior.

The institute has successfully demonstrated and developed a climate smart model village in a cluster of two rainfed adopted villages in Tangi-Choudwar block of Cuttack during 2012-17 in a participatory and convergence mode. Climate resilient varieties namely, 'Sahabhagidhan' (drought tolerant), 'CR Dhan 202' (aerobic), 'Swarna Sub-1' (submergence tolerant) and 'Varshadhan' (suitable for deepwater and waterlogged conditions) were introduced in the cluster and proved high adaptability and acceptance by the farmers. Other high yielding rice varieties like 'Pooja', 'Ketekijoha', 'CR Dhan 304' and 'Naveen' were also adopted by farmers due to their various motivational traits. Prior to project interventions, they were cultivating HYVs of rice in only about 15% of total rice growing area of the cluster, which increased to about 90% at the end of five years. Farmers were still growing some local varieties due to their special grain and cooking quality for domestic consumption.

For promoting newly released varieties, ICAR-NRRI has been producing breeder seeds of rice as per seasonal indents received from various states through the DAC&FW, Govt. of India and various other organizations. In addition, truthfully labeled (TL) seeds are produced in the research farm as well as in farmers' field in a 'Farmers Participatory and Buy-back mode' for direct sale to farmers through its own sale counter. In addition, limited varietal demonstrations are conducted in selected clusters in the Odisha state. As part of the varietal development programme, all India coordinated rice improvement project (AICRIP) trials are conducted in various states to test the efficacy and adaptability of the varieties. Apart from these, minikit trials are conducted through various research initiatives like institutional research projects, externally funded projects; and various programmes like, Tribal Sub-Plan (TSP), Mera Gaon Mera Gaurav (MGMG), Farmer FIRST, BGREI, NFSM, NICRA, KVKs etc to demonstrate and promote new varieties. The institute also organizes and participates in national and international exhibitions showcasing its latest varieties and rice production technologies. All trainee and visiting farmers coming from various states are also provided with seed minikits of new varieties for their respective local demonstrations and spread, which has partially helped in seed replacement ratio (SRR) as well as variety replacement ratio (VRR).

Results of on-station, off-station and on-farm demonstrations, minikit trials and farmers' feedback on the institute developed varietal performance and their superiority over local popular checks have been very encouraging over the years. Despite all above efforts by the institute, varieties are spreading very slowly and not reaching a wider population as desired. One of the major shortcomings of the institute is production of limited quantity of seed due to availability of limited area of about 30-40 hectares land for seed production. On the contrary, state agricultural universities have been well-placed due to their huge network of regional research stations within respective states with vast area under seed production plan. Apart from superiority of varieties, availability of large amount of foundation and certified seeds is equally essential to fulfill the seed requirements of state machineries to promote through seed chains. Because of this reason, PJTSAU model (previously ANGRAU, Hyderabad) of rice varietal diffusion and popularization through distribution of sufficient minikits during initial 2-3 years of their development has been a very successful model, as was shared by two of its former Breeders-cum-Vice Chancellors namely, Prof. P. Raghava Reddy and Prof. Padma Raju, during the national level Brainstorming

Workshop on "Rice Varietal Diffusion: Estimation, Problems and Prospects" organized by MANAGE at Hyderabad during 19-20 May, 2017, citing examples of mega varieties like Swarna (MTU-7029), MTU-1010, MTU-1001 and BPT-5204.

5. INSPIRE Model of ICAR-NRRI: Varietal Popularization Strategy

The Institute is working on developing mechanisms to shorten the period between varietal development and varietal spread leading to faster adoption and diffusion, which can be simplified in following concurrent activities.

5.1 Preparation of Varietal Matrix: First of all, we need to identify existing popular varieties and farmers' preferencein selected states for testing new and comparable improved varieties through collection of primary as well as secondary data from targeted states. Accordingly, taking all criteria like ecology, duration and preferences farmers, consumers, seed growers and traders into consideration, a 'Varietal Matrix' is prepared for all 'popular but low yielding/ low preferred varieties' vis-a-vis 'new and higher yielding/ highly preferred varieties' for replacement with better alternatives.

5.2 Involving Policy makers in the Beginning: The real field work starts with the discussion and motivation of important state stakeholders and policy makers like, Secretary/Director of Agriculture, GM of National/State Seed Corporation, Seed Certification Agency, Director of Seeds of SAUs, Heads of KVKs, Seed Companies and Food processing industries. They should be well convinced about the superiority of the new varieties over the existing popular varieties though meetings, presentations, literatures and field visits.

5.3 Identification of State Clusters: Ecology wise district clusters should be selected (may be, any one revenue block, depending on the quantity of seed availability, close to the district headquarters and adjacent to a primary village road) and about 10-20 willing farmers per cluster in consultation with local Krishi Vigyan Kendra (KVK), state agriculture department officials and other stakeholders.

5.4 Providing Timely Minikits: Varietal demonstration should be conducted by providing only 3-5 kg seed minikits as critical inputs without altering farmers' own crop management practices at least one month before the start of season. Planning should be done in such a way that all the districts in a state must be covered with the same varietal demonstration in a maximum of 2-3 years.

5.5 **Conducting Participatory On-farm Demonstrations:** These small scale on-farm demonstrations are done for participatory varietal evaluation in consultation and collaboration with all stakeholders like, farm science centres/ krishi vigyan kendra (KVK), state department of agriculture (SDA), state seed corporations (SSC), state seed certification agencies (SSCA), state agricultural university (SAU), regional research institute, farmers interest groups (FIGs), private seed companies and dealers, non-governmental organizations (NGOs) working in agriculture sector, media representatives and both demonstrating and non-demonstrating farmers.

5.6 **Stakeholders' Capacity Building:** Capacity building programmes are conducted with participating stakeholders for detailing them about the package demonstration, telephonic advisory and creating mobile social group for sharing field experiences and resolving immediate issues relating to the new varieties.

5.7 **Monitoring and Technical Backstopping:** Continuous monitoring, technical backstopping,field visits and field days by a team of experts are conducted at various stages of crop growth. These are very much essential to clarify emerging issues with respect to new varieties.

5.8 **Crop Cutting Experiments cum Farmers' Meets:** Farmers' Meet especially in pre-harvesting stage associated with crop cutting experiments of the demonstrated varities, with the principle of 'Seeing is Believing', involving all the stakeholders including non-demonstrating farmers to showcase the superiority of the new varieties. Participating farmers are encouraged in the Meets to share their experiences to motivate fellow stakeholders.

5.9 **Upscaling Strategy:** Best performing new varieties are upscaled through creating demand for breeder seed indents from succeeding years onwards and promoting local seed production by government and private agencies for making timely seed availability to farmers, and creating an institutional mechanism for planning and local production of adequate quantity of seed for making the blocks/districts/state self-sufficient in quality seed.

5.10 Publicity Efforts: Big size and clearly visible road side field boards must be placed on the demonstration sites with details of varietal characteristics and their suitable ecologies in local language. Awareness campaigns are done through local electronic media, print media, ICT tools like mobile apps/ social groups and distribution of extension leaflets in local languages.

5.11 State level Workshops: Apart from field days and farmers meets, state level workshops in the initial years must be conducted involving agriculture ministers, policy makers and senior line development officials to create awareness and convince all the key players about the superiority of newly developed varieties. The non-conventional channels like seed companies, rice millers, traders and food processing industries have to be explored for spread of remunerative varieties. These key players take decisions on the varieties to be selected for state seed chains and quantity of seeds to be produced in forthcoming seasons.

5.12 Promoting Farmer-to-Farmer Spread: For fast spread of varieties, advisory are issued to all participating farmers for not consuming the harvested grains from the demonstrated plots, rather encouraging and ensuring 'farmers-to-farmers' horizontal spread of seeds either through sale or on barter basis for rapid spread and adoption in the state.

5.13 Integrated Feedback Mechanism: Recording of farmers' reactions and feedback on various traits of the new varieties over the comparable popular varieties and overall processes documentation are done for refinement and future research.

5.14 Process Documentation: As part of the process, a good document should be prepared encompassing the workshop/ farmers meet proceedings, action points, demonstration details, crop cutting data vis-à-vis comparative data on local varietal performance, success stories, feedback from farmers and other stakeholders. The document should be widely circulated among important state and central level officials and policy makers and action points should be followed up accordingly.

6. Refinement and Validation of the Model

Since its conceptualization of the model in 2017-18, efforts are being made to develop, refine and validate the model in various states. During kharif 2017, minikit demonstrations were conducted involving 60 farmers in Jharkhand in four districts with varieties 'CR Dhan 202' and

‘CR Dhan 305’; 22 farmers in West Bengal one district with ‘CR Dhan 201’, ‘CR Dhan 203’ and ‘CR Dhan 304’; 4 farmers in Assam in one district with ‘CR Dhan 909’ (aromatic) and over 150 farmers in Odisha in five districts with twenty newly released varieties. Similarly, during kharif 2018, on-farm minikit demonstrations were conducted in farmers’ fields with eighteen newly released varieties benefiting over 225 farmers and covering about 30 ha area in 12 districts in five states, namely Odisha, West Bengal, Assam, Bihar and Jharkhand. During kharif 2019, the efforts have been further intensified, and demonstrations have been conducted in farmers’ fields with twenty two newly released NRRI varieties benefiting over 250 farmers and covering about 40 ha area in 25 districts in eight states, namely Assam, Odisha, West Bengal, Bihar, Jharkhand, Madhya Pradesh, Chhattisgarh and Maharashtra.

The crop cutting results of almost all the demonstrated varieties during kharif 2017 and 2018 showed an average grain yield advantages of about 15-18% (ranging 0-30%) over all the existing popular varieties. A demand for seeds of these varieties has been created among the farmers and participating government organizations. Indents for higher quantity of breeder seed for theses varieties from the all the demonstrated states were received. However, the model needs to be refined and validated in other states of the country and should be replicated in bringing prosperity to the farming communities. To achieve this, there is need to upscale these activities in convergence with other stakeholders in years to come.

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