Training Manual

Emerging Management Strategies for Climate-smart Agriculture

SCS COLLEGE OF AGRICULTURE
Assam Agricultural University
Rangamati, Chapar, Dhubri 783376

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Emerging Management Strategies for Climate-smart Agriculture

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PREFACE

Climate change is undoubtedly considered as one of the greatest threats faced by entire humanity. Agriculture, on which the survival of humanity depends, bears the maximum burnt of the vagaries of changing climate. Thus, it becomes imperative to device appropriate management strategies to revive the agricultural production system for ensuring the food security. Newer and newer innovations throughout the globe involving various stakeholders have been tried to address this global challenge.

Being an agrarian based economy, India is at the threshold of unprecedented challenge to meet the food and nutritional requirements of ever increasing population. Various stakeholders have been working hand in hand to mitigate the challenge and emerging technologies from different fields have shown the ray of hope for the future.

Agriculture sector in the state is mostly dominated by the resource poor farmers still practicing the conventional production system. The manifold effects of changing climate are much prominent in state like Assam owing to its unique geophysical and socio-economic attributes.

The young professionals are poised to play a pivotal role in bringing the frontier innovations to the agricultural sector. In this context, it is felt necessary for capacity building of the students and faculties in the emerging trends and their adaption in agriculture under changing climate. Considering this, a week-long training programme is proposed for the 4th year (ELP) students and young faculties of SCSCA, AAU, Dhubri.

Content

Impact of Climate Change in Agriculture with special reference to rice cultivation

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Agriculture is immensely influenced by weather and climate. The nature of agriculture and farming practices in any location are strongly influenced by long term mean climatic state. The experience and infrastructure of local farming communities are generally appropriate to a particular group of crops which are known to be productive under the current climatic condition. Changes in mean climatic condition require adjustment to current practices in order to maintain productivity or in some cases optimum type of farming may change.

Changes in ozone layer, GHG and climate change affect the agricultural producers greatly because agriculture, forestry and fisheries depend on specific climatic conditions. Climate change can affect biodiversity, agriculture in multiple ways. Beyond a certain range of temperature warming trends reduce the yield. The climate change refers to major changes in temperature, precipitation, wind pattern, humidity that occur over several decades.

Population explosion and changes in diets are the driving force for demand of food. However, production is not increasing in many parts of the world.

A report published in 2020, indicated that nearly 690 million people or 8.9 % of global population are hungry. The food security problem will only become more difficult, as the world will need to produce 70% more food by 2050 to feed 9 billion people.

The challenge will be intensified by agriculture's extreme vulnerability to climate change. Negative impacts of climate change are already being felt in the form of increasing temperature, weather variability, shifting ecosystem boundaries, invasive pests and more frequent weather aberrations. Climate change is reducing crop yield, nutritional quality of major cereals, lowering livestock productivity.

India is a large developing country with a nearly 700 million rural populations directly depending on climate sensitive sector like agriculture, fisheries, forestry and natural resources like water diversity, mangroves, coastal zones, grasslands etc. for their subsistence and livelihood. Climate change is likely to impact all the natural ecosystem.

The potential impacts of climate change are often diverse and immediately need to address the adverse impact is widely recognized. Different regions have different vulnerabilities to climate change.

Assam is extremely vulnerable to climate change due to both geographical location and poor social economic condition.

Assam has vast network of rivers which is prone to natural disasters like flood, erosion which has a negative impact on the development of the state. The Brahmaputra and Barak has more than 50 tributaries which cause devastating flood in the monsoon period. Moreover, Assam and N.E. India is flood prone zone due to their geographical and topographical region making it one of the highest rainfall zones of the world. Moreover, Assam has a number of major rivers originating from lower Himalayan region which cause devastating flood in the plains of Assam and neighbouring areas.

Rice is the primary staple food crop of Assam and this crop is grown in the region from time immemorial. Rice is well adapted to the climatic condition of the region. However, impact of the global climate change is felt in the region resulting in flood, drought, cloud burst, thunderstorm etc.

Drought and flood are the major constraints arising due to climatic aberrations. July and August are highly prone to flood due to incessant rain in its catchment areas. But due to advancement and prolongation of monsoon rice cultivation gets damaged and the state faces serious problem: a flood severity.

Usually drought is not encountered in month of the lowland rice. But in some years due to weather aberration, intermittent drought prevails in rice and other crops. Similarly, cold affect late sown rice crop in reproductive stage which is detrimental for production and productivity of the crop.

In order to mitigate the ill effect of weather aberrations research is undergoing and with the advancement of molecular techniques the crop improvement programmes are progressing rapidly.

Flood

Assam has encountered the problem of flood in the state of Assam from the time immemorial. Catastrophic floods immediately cause displacement and homelessness of thousands of people. Rice is worst affected due to flash floods that occur more than once in a year. The strategy is so far to develop pre-flood and post flood short duration varieties and submergence tolerant variety. The pre flood rice varieties can be sown/transplanted in February/ March and harvested within 100 days i.e., in April/ May. These short duration varieties can escape the flood prone months i.e., June to August. Similarly, the short duration post flood rice varieties can be grown during September to November.

For flash flood affected region the rice varieties with Sub1 Gene can tolerate submergence up to 14 days and with the help of Marker Assisted Selection it has been possible to introgress Sub 1 gene in mega varieties which is otherwise high yielding and good grain quality. The successes are pouring in from different parts of the country including Assam. In those areas where food inundates beyond two weeks need separate set of varieties with different traits to minimize loss of yield.

Drought

Assam and North east India is located in the high rainfall zone in the country. However, delay in monsoon or insufficient rain sometimes cause drought stress in the crops. Lack of irrigation facilities and other means create stress in the crop like rice, toria and pulses in the years with drought spell resulting in yield reduction in major food crops of the state. Under such situation it is urgent to identify appropriate varieties or improved the existing varieties for drought like situation in the prevailing year. Drought tolerant accessions in the indigenous genetic resources could be exploited in this regard.

Cold

Assam experiences low temperature from the month of November to February which adversely affect the yield of the late sown crops or the crops sown under cold spells. Researches are underway to develop cold tolerant rice varieties in the reproductive stage. Genes have been identified for such situations in rice and other crops with the help of biotechnological tools.

Anaerobic germination

In many of the traditional cultivation practices, direct seeding is followed more particularly in deep water and semi deep water condition. In such practices, seeds are sown before the onset of monsoon rain or flood and subsequently submergence occur in such areas. Due to the early breaking of monsoon the rice fields are entirely submerged and the germination of seeds has to take place under anaerobic condition. However, only a few varieties have the ability to survive under water at the germinating stage hence for a large low-lying area varieties with anaerobic germination ability would stabilize the yield in such stress prone areas. Genes are being explored in the germplasm stock to combat the problem of anaerobic germination.

Varieties for Sand/ Silt deposited areas

Heavy deforestation in the upper stream of the river has loosened the soil which in turn are carried to the downstream with sand and silt when flood occurs due to heavy rainfall. Erosions are also prevalent in the banks of the rivers destroying many crop areas and sand/silt deposits in the downstream. The sand and silt deposits make the cultivable land infertile for many years. Hence, it is very urgent to identify crops suitable for sand and silt deposited areas. Researches are underway with the help of GPS mapping and ground real situation. Crops like niger, linseed, buckwheat etc. are usually not predominant in the north eastern region although they have great potentiality in the market elsewhere. Hence, such crops can be introduced and market channel of the products of such crops should be found out. Potato and pumpkin are yet another potential cash crops in some of the silt deposited areas which needs to be identified and popularized.

Varieties for acid soil condition

Soil acidity is an important factor for crop yield reduction. In many of the areas it is essential to increase the soil pH and identify crops/varieties for cultivation.

Biotic Stresses

Hot and humid climate of Assam and North East India favours harbouring of a number of insect-pests and pathogens. Due to changes in the climatic factors, occurrence of new pests and diseases and upcharge of the insect pest population the crops are affected and there is reduction in crop yield and quality. Hence, it is high time to gather information on the new diseases and pests, their occurrence and their management.

Agriculture provides most of the world's food, fiber and fuel. Agriculture also provides wood for construction and paper products. Climate changes is drastically affecting agriculture by interfering with efficient crop production. It is facing drought, flooding, elevation of sea levels, natural disasters and health hazards of workers and animals. All these factors lead to crop failure that create famines and indirectly the price rise. Changes in rainfall pattern increases the chance of crop failures and production decline. Population in developing world is already vulnerable and suffering from food insecurity and likely to be seriously affected. Hence, it is very essential to quantify the climate change impacts and adapt strategies to mitigate it globally.

Impact of Climate Change in Horticulture - Adaptation and Mitigation Measures

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Introduction

Climate change is the change in average temperature and cycles of weather over a long period of time. Since 1880, scientists have kept thermometer-based records of the global surface temperature. It has been observed that the planet has becoming warmer and the climate is changing. Earth's temperature has risen by 0.14° Fahrenheit (0.08° Celsius) per decade since 1880.

Intergovernmental Panel on Climate Change (IPCC) had concluded in 1990 that the human-caused release of greenhouse gases together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century. In this context it deserves mentioning that in 2007, the IPCC and U.S. Vice-President Al Gore were jointly awarded the Nobel Peace Prize.

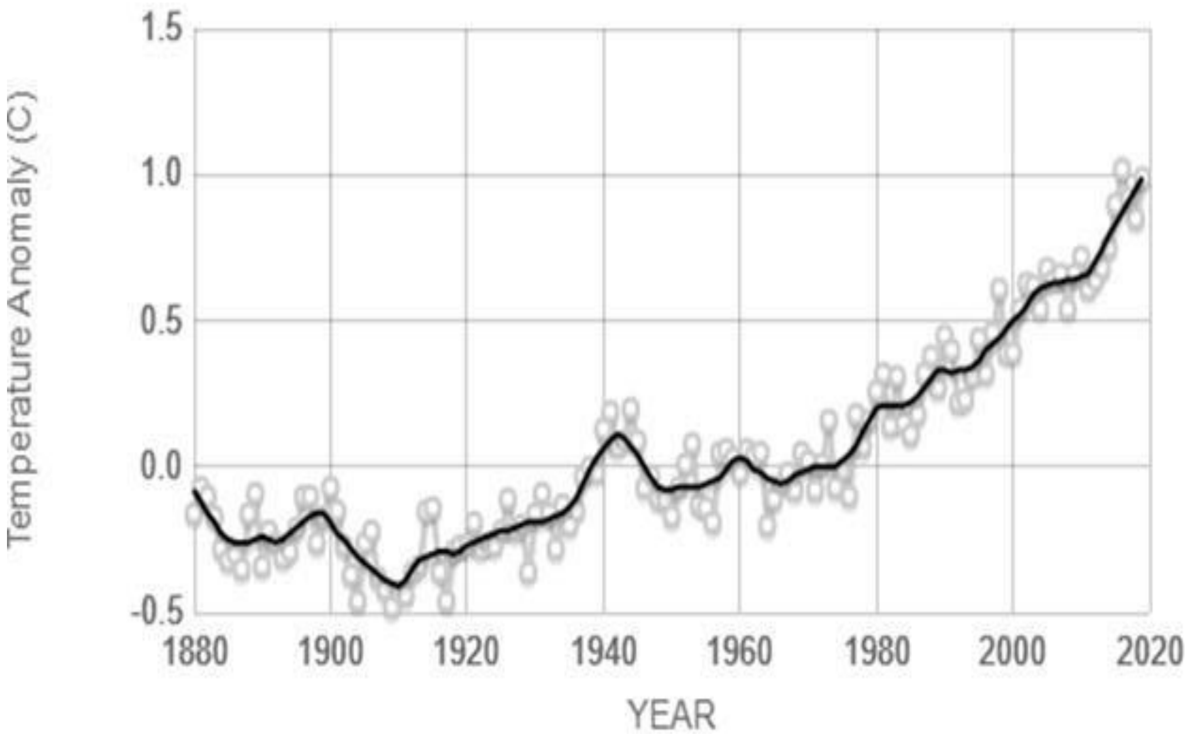

Fig. 1. Trend of temperature change between 1880 and 2020 Source: (NASA/GIS, 2019)

Greenhouse Effect

- The higher the proportion of greenhouse gases in the atmosphere, the more radiation is absorbed.
- This causes a rise in the temperature of the Earth and is known as the greenhouse effect.
- This increase in temperature drives climate change.

Monthly mean carbon dioxide measured at Mauna Loa Observatory, Hawaii, the longest record of direct measurements of CO2 in the atmosphere.

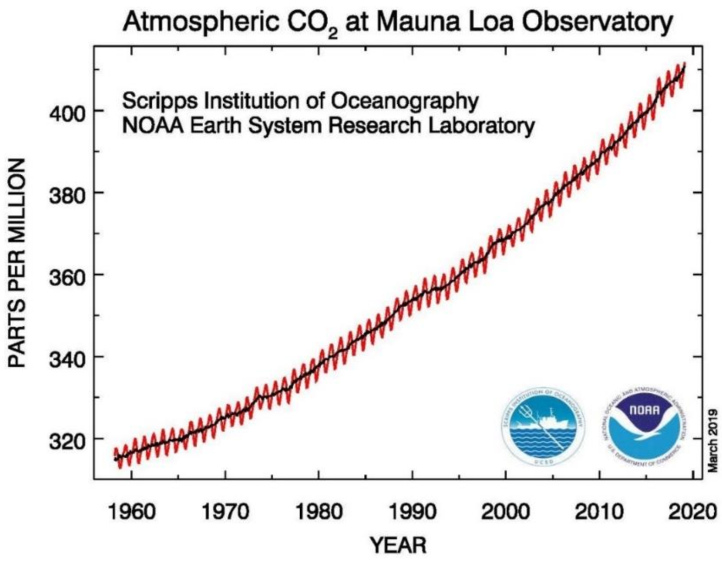

Fig. 2. CO_2 records at Mauna Loa Observatory

- The concentration of carbon dioxide in Earth's atmosphere is currently at nearly 412 ppm and rising.
- This represents a 47 percent increase since the beginning of the Industrial Age (1760 – 1840) when the concentration was near 280 ppm
- 11 percent increase since 2000, when it was near 370 ppm.09-Oct-2019.
- Oct. 24, 2022, 416.37 ppm ; Oct. 23, 2021, 414.30 ppm ; 1 Year Change, 2.07 ppm (0.50%) .

Source: of Greenhouse Gases (Source: IPCC 2014)

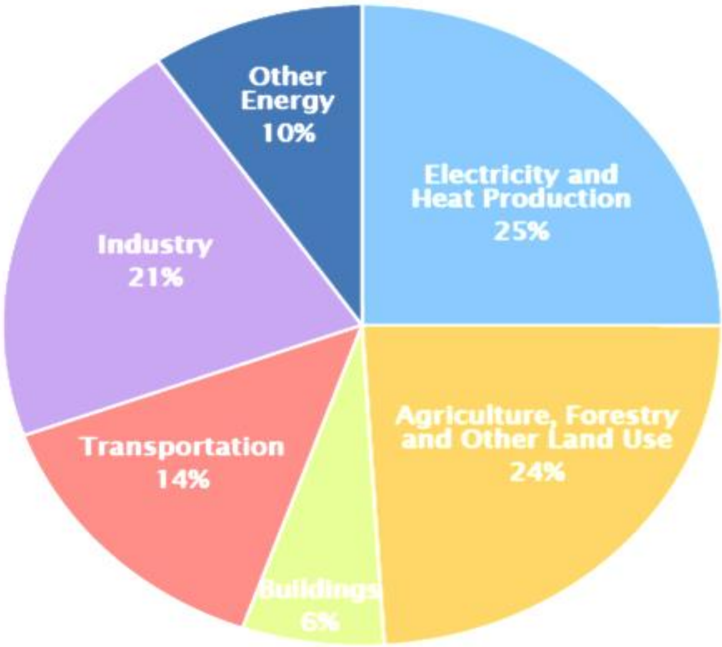

Fig. 3. Global Greenhouse Gas Emissions by Economic Sector

Efforts on Reduction of GHG emission

- Present efforts remain insufficient to limit global temperature rise to 1.5 degree Celsius compared to pre- industrial age (Co2 280 ppm) as per Paris agreement Goal, Legally binding International treaty on climate change) by the end of this century.
- UN-NDC (Nationally determined contribution) synthesis report,2022 combined efforts of 193 countries could limit temperature rise to 2.5 degree Celsius by the end of this century.
- Current commitments will increase emission by 10.6 % by 2030.
- IPCC (2018) report indicated that greenhouse gas emission should be cut 43% by 2030.
- CoP 27 will be held this year at Egypt form 6-18 Nov, 22.
- CoP 1: 28 March to 7 April 1995, Berlin

Highlights

- Each year, human activities release more carbon dioxide into the atmosphere than natural processes can remove
- The global average carbon dioxide set a new record high in 2021: 414.72 parts per million, which is 5th-highest annual increase in NOAA's 63-year record
- The annual rate of increase in atmospheric carbon dioxide over the past 60 years is about 100 times faster than previous natural increases
- The ocean has absorbed enough carbon dioxide to lower its pH by 0.1 units, a 30% increase in acidity.

Challenges to Agriculture

- High temperature stress during critical crop growth stages
- Intermittent and/or terminal drought
- Excess moisture stresses caused by extreme rainfall events
- Incidence of insect pest and diseases
- Emergence of new insect pests and diseases
- A temperature increase of 3-5 ^{0}C could cause yield to fall by 15-35% in Africa & Asia and 25-30% in Middle East (Ortiz *et.al*., 2008)

Fruits: Impact of Climate Change

- Non-receipt of specific chilling requirements in temperate fruits
- Increased requirement of annual irrigation
- Heat unit requirement achieved in much lesser time
- Changing in production timing. e.g. citrus, grape, melons and mangoes will mature earlier by about 15 days.
- Considerable reduction in fruit size
- Premature ripening resulting in improper colour of fruits
- Sunburn and cracking in apples, apricot and cherries
- Fruit cracking and burning in litchi
- Strawberries will have more runners at the expense of fruits
- Fruits to have less storage period in trees and PH storage
- Shifting of major area of potential suitable zones of horticultural crops to higher latitudes
- Anthocyanin production may be affected in apples and capsicum due to thermal sensitivity of biosenthetic gene
- Rain fed cashew crop is highly sensitive climate change, particularly during reproductive phase.
- The Yield reduction in Cashew nut is upto 50 to 65%.
- Consecutive drought reduced the coconut Productivity loss was to the tune of about 3500 nuts/hectare/ year in India
- Fruit trees emerge from dormancy and bloom in the early spring. But if there is an unseasonal late frost at that time the frost can kill the delicate blossoms

Vegetables: Climatic changes will influence the severity of environmental stress specially in vegetable crops

- **Tomato:**
- Adverse effect on Pollination
- Floral abortions, Frequent flower and fruit drop, reduced carbohydrate availability
- Poor quality in tomatoes because of tip burn and blossom end rot
- **Chilli:**
- High post-pollination temperatures inhibited fruit set.
- Wilting, leaf curling and epinasty, leaf abscission
- Decreased photosynthesis, respiratory changes
- Loss of cellular integrity, tissue necrosis.
- **Potato:**
- Reduction of tuber initiation process in potato
- Tuber malformation
- Occurrence of common scab
- Changes in reducing sugars contents
- **Crucifers**
- Bolting in all Brassicas
- **Onion: (photosensitive crops)**
- Mature faster leading to small bulb size.

Tomato, water melon, potato, squash, soyabeans, peas, carrot, beet, turnip etc are more susceptible to air pollution damage. Yield of vegetable can be reduced by 5-15 percent when daily ozone concentrations reach to greater than 50 ppb.

Flower and Spices

- Reduce the chilling requirement for the flowering of many of the ornamental plants Orchid, Tulip , Magnolia, Narcissus
- Poor flowering, improper development floral bud and colour in flowers grown under open field conditions
- Make flower less fragrant due to decrease in phenylpropanoid-based floral scent production
- Decreased productivity in black pepper

Climate Change and Pest and Diseases

- Apple Powdery mildew and Shooty blotches

- Blossom blight in fruits and vegetables
- Downey mildew in vegetables
- Leaf spot in banana
- Fruit fly in banana
- Increase in Insect vectors
- Feeding habit of insects shall be changed

Adaptation

- Development climate smart varieties. Pineapple being a CAM plant has remarkable adaptability to different climatic regimes
- Change in the sowing time
- Use of efficient technologies like drip irrigation, soil and moisture conservations measures, fertilizers management through fertigation, change of crop/alternate crop, increase in input efficiency
- Novel irrigation methods, like partial root zone drying (PRO), could be adapted.
- Efficient pre and post harvest management of economic produce
- Certain physiological and morphological adaptations to withstand adverse effects of 'water stress'
- Improvement of skin color in grapes by girdling and appropriate fruit load
- Plastic mulching and drip irrigation (fertigation) in citrus orchard

Mitigation Measures: process in which the emission of green house gases are either reduced or sequestered

- ➢ Reduction of green house gases
- Improved crop management practices due to reduced dependence on energy needs e.g. INM,IPM, OM
- Afforestation, Pro-forestation and Reforestation
- Biofuel
- ➢ Eco-friendly disease management
- Resource conservation techniques and organic farming
- ➢ Carbon sequestration by coconut and other spp
- perennial horticultural crops for sequestering carbon dioxide
- TTC

Carbon Trading

- Carbon trading is the process of buying and selling permits and credits that allow the permit holder to emit carbon dioxide. It has been a central pillar of the EU's efforts to slow climate change. The world's biggest carbon trading system is the EU ETS
- Allow richer countries to cut their emissions by paying for the development of carbon lowering schemes in poorer nations
- If a company curbs its own carbon significantly it can trade the excess permits on the carbon market for cash. If it's not able to limit its emissions it may have to buy extra permits
- Trading is set to begin in 2014 in India covering eight sectors responsible for 54 per cent of India's industrial energy consumption. India has pledged a 20 to 25 per cent reduction in emission intensity from 2005 levels by 2020

Conclusion

The Government of India launched National Action Plan on Climate Change (NAPCC) on 30thJune, 2008 outlining eight National Missions on climate change, which includes National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Eco-system (NMSHE), National Mission for a Green India, National Mission for Sustainable Agriculture and National Mission on Strategic Knowledge for Climate Change (NMSKCC). In the context of changing climate, the concept of 'Lifestyle for the Environment (LiFE)' was introduced by Prime Minister Narendra Modi at COP26 in Glasgow on 1st November, 2021. Modi requested the global community of individuals and institutions to drive LiFE as an international mass movement towards "mindful and deliberate utilisation, instead of mindless and destructive consumption" to protect and preserve the environment. LiFE puts individual and collective duty on everyone to live a life that is in tune with Earth and does not harm it. Those who practice such a lifestyle are recognised as Pro Planet People under LiFE.

Role of controlled release fertilizer on climate smart agriculture

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The current world population in 2022 is 7.9 billion and is expected to reach 9 billion people by the end of 2050. With the growing population food demand is also increasing and 60% more food is required than existing food demand worldwide. To achieve the global food demand, fertilizers (contribute 50% of today's food production) are essential source of nutrients for crop growth. Most of the plant nutrients required for crop growth are generally found in limited supply in the soil. To get targeted yield and crop demand, growers often use large quantity of synthetic fertilizers, especially nitrogen fertilizers like urea (widely used), ammonium nitrate, sodium nitrate, potassium nitrate, calcium ammonium nitrate etc. Excessive use of these conventional fertilizers may lead to environmental pollution by volatilization in the atmosphere, leaching to groundwater, surface runoff and denitrification. It is estimated that agricultural sector during different agricultural practices like fertilizer application, cultivation, irrigation *etc.* contributes 25-30% of global greenhouse gas emissions, out of which, fertilizers alone can represent 2.5% and 1.5% of greenhouse gas emission derived from fertilizer application. Sustainable agricultural production with optimum management of water and fertilizer, especially nitrogen fertilizer by adjusting type of nitrogen fertilizer, recycling of organic wastes and addition of soil conditioner get prioritization in agricultural crop research. The main challenge of agricultural sector is sustainable production of food by reducing environmental pollution and preserving natural resources for next generation. Climate Smart Agriculture is the solution to meet the increased food demand of growing world population in midst of the climate change.

Controlled release fertilizer is an integral component of climate smart agriculture. Climate Smart agriculture is an approach that helps to transform agricultural production systems towards green and climate resilient practices. Three main objectives of climate smart agriculture are: enhancement of sustainable agricultural productivity and incomes; adapting and building resilience to climate change; reducing or removing greenhouse gas emissions. Climate smart agriculture follows the FAO Strategic Framework 2022-2031 which is based on four betters: better production, better nutrition, a better environment and a better life for all living being. Climate smart agriculture practices are mostly governed by socio-economic, environmental and climate change factors. The World Bank Group recently committed with different countries to adapt technologies in agriculture in climate adaptation and mitigation. Correct and balanced use of plant nutrients is very much important in climate smart agriculture and International Fertilizer Association is dedicated to disseminate the Climate smart agriculture practices all over the world.

Controlled release fertilizers are granular fertilizer particles which are coated or encapsulated with polymer or resin or coating materials that restricts moisture contact and functions gradually to release nutrients from fertilizer core and enhances the availability of nutrients for comparatively longer time. These fertilizers are also known as controlled availability fertilizer, delayed release fertilizer, slow acting fertilizer. Nitrogen based fertilizers are usually controlled release fertilizers. Controlled release fertilizers can provide more economical and efficient way to regulate release of nutrients at desired rate or controlled level and hence sustain the nutrients in soil for a longer period of time. Thereby CRFs help to enhance nutrient use efficiency by less frequent application and also decrease environmental pollution by reducing nutrient removal rate from soil by rain or irrigation water.

In 1936, controlled release nitrogen fertilizer, methylene di urea, was first produced by combining urea with formaldehyde and commercialized in the year 1955. In 1961, in the US, Tennessee Valley Authority National Fertilizer Development Centre, Alabama started development of sulfur coated urea as coated fertilizer. Sulfur was used as a coating material because of its value as a secondary nutrient, insolubility in water and low cost. Later on, with development of technology, many inorganic, organic and advanced engineering materials were used to produce controlled release fertilizers.

There are many differences between controlled release fertilizers and slow release fertilizers. Though the nutrient release pattern of slow release fertilizers are slower than water soluble fertilizers, but the nutrient release pattern and time required for release of nutrients is less predictable than controlled release fertilizers. In controlled release fertilizers, the rate, pattern and duration/time required for nutrient release can be predicted within a certain limit in controlled environmental conditions. The nutrient use efficiency of controlled release fertilizers are better as they are designed to supply nutrient demand for crops based on the growth cycle. In controlled release fertilizer manufacturing, fertilizer material *i.e.,* the nutrient is used as a core material which is protected by resin or polymer coating or coating materials and hence core nutrient is released in a controlled manner. Different factors such as the type of coating material, thickness and air temperature effect the rate of release of nutrients in controlled release fertilizers. Higher the air temperature enhances the rate of release of nutrients from the controlled release fertilizers. Polymer coated urea and polymer coated sulfur coated urea are expected to release > 80% of nutrients between 28-46 days as compared to uncoated urea, in which nutrient releases within a few hours of application (Ransom *et al,* 2020). As compared to the conventional fertilizers, controlled release fertilizers can significantly decrease the total amount of green house gas emissions. Controlled release fertilizers reduces nitrous oxide emission by 15.5% than conventional fertilizers. One of the green house gases, methane emission in paddy soil due to application of nitrogen fertilizers can be reduced by use of controlled release fertilizers. The main objective of use of controlled release fertilizers is to increase nutrient use efficiency, reduce nutrient loss, minimization of environmental hazard by preventing nitrate leaching and nitrogen (nitrous oxide and ammonia) emission to the air. By adding organic matter to fertilizer, the emission reduction ability of controlled release fertilizers can be improved. Use of controlled released fertilizers in agriculture is considered as a best management practices tool in climate smart agricultural practices.

Advantages of controlled release fertilizers

Use of controlled release fertilizers have a long term positive impact on the environment due to decrease release of nitrous oxide and ammonia. Optimum yield can be achieved by 20-30% decrease application of controlled release fertilizers than recommended dose of fertilizer because controlled release property of these fertilizers help in synchronized uptake of nutrients by the crop. Decrease application of controlled release fertilizers reduce labour cost. Release of nutrients from controlled release fertilizers generally do not depend on weather condition. Application of controlled release fertilizers protect crops from chemical damage/toxicity because of reduced high soil ionic concentration from quick dissolution of nutrients.

Disadvantages of controlled release fertilizers

Coatings of controlled release fertilizers are usually made from non degradable polymers such as polyurethane, polyethylene *etc.* which leads to accumulation of microplastics in agricultural soil (Katsumi *et al*., 2021). Microplastic accumulation in soil is harmful to soil microbes, plants and causes soil pollution. Temperature, moisture and soil biological activity can change the properties of controlled release fertilizers. These unpredictable changes can modify nutrient release pattern and cause harmful effect of crops. Controlled release fertilizers are costly than conventional fertilizers. Therefore, its application in the field is scanty. Sulfur coated controlled release fertilizers may reduce the soil pH leading to deficiencies of Ca^{2+}, Mg^{2+} etc. in soil.

Nutrient release mechanisms

The controlled release rate of controlled release fertilizers depends on type of material used for coating. Release of nutrients take place in three stages: i) lag phase, ii) constant release and iii) decay period. In lag phase, fertilizer granules come in contact with water and water penetrates through the outer core of granules and dissolves some fractions of fertilizer. Vapour pressure gradient governs the release of nutrients and a steady state condition is established between water and released nutrients. In second stage of constant release, an equilibrium is established between penetrating water (inside the granule) and fertilizer solute. Surrounding environment affect the coatings of controlled release fertilizers leading to damage and cracking of the coatings. In case of polymer coated controlled release fertilizers, crack development does not occur and water enters through the microscopic pores of the coatings. Factors such as soil pH, temperature, soil moisture, salinity and microbial activity significantly affect nutrient release pattern of controlled release fertilizers. In this phase, environmental factors like moisture and temperature play crucial role as they may cause damage of coating layer and may cause failure of fertilizer. In the decay phase, fertilizer diffusion occurs. Complete diffusion of fertilizer granule will leave only the polymer made microcapsule of the granule, non biodegradable polymers remain in soil and cause plastic pollution.

There are five types of mode of release mechanisms. They are i) diffusion, ii) swelling, iii) osmosis, iv) biochemical reaction and v) erosion or degradation. Diffusion is the uniform distribution of nutrient released from fertilizer granule. Fertilizer solubility, membrane conductance, soil moisture content and plant nutrient uptake controls diffusion. In swelling, uptake of water by fertilizer coating increases the volume of coating. It occurs only in case of fertilizers having hydrogel formulation (hydrophilic polymer that can hold a large quantity of water). Soil solution, ionic strength, particle size and pH effects swelling. Osmosis can be defined as flow of water from higher concentration to lower concentration through a semipermeable membrane. In controlled release fertilizer, fertilizer coating acts as the semipermeable membrane and soil solution concentration will be higher than fertilizer granule.

Hence, soil solution water will flow into the fertilizer granule through semipermeable coating and dissolve the nutrients. Diverse group of microbial species and chemical species present in soil may cause release of nutrients from controlled release fertilizers. Biochemical interaction may lead to loss of nutrients in soil or atmosphere and environmental factors can degrade coating layer of controlled release fertilizers and cause erosion of nutrients in soil.

Factors affecting release of nutrients from controlled release fertilizers

Several physical, chemical and biological factors such as temperature, soil moisture, pH, biological activity and soil affects the release of nutrients from controlled release fertilizers. Intrinsic parameters like coating thickness, nutrient composition, shape of granule and diameter of controlled release fertilizers affect nutrient release.

Temperature: Temperature is one of the important environmental factors that influence nutrient release of controlled release fertilizers and can reduce release duration. If the temperature increases from 10^0 to 20^0 C, nutrient release rate doubles nearly. When fertilizer is applied to soil, direct exposure of the fertilizer granule to high surface temperature reduces the longevity of coating polymer material by affecting the outermost layer of the fertilizer granule. Cracks develop on the surface and diffuse nutrients from the granule to the outer environment. The nutrient release rate is also affected by quick release of nutrients from granules.

Soil moisture: Soil moisture is an important parameter for nutrient release of controlled release fertilizers as water infiltrates into fertilizer granules. Maximum release of nutrients or urea hydrolysis occurs at 50% water holding capacity. Mineralization and conversion of ammonium to nitrate occur with increased soil moisture (Agehara and Warncke, 2005). In presence of water, controlled release fertilizer granules can absorb enough water and nutrient release occurs through swelling.

pH: Soil pH directly affects solubility and availability of nutrients by swelling of controlled release fertilizer granules. Most of the release of soil nutrients from controlled release fertilizer granules occur at 6.0-7.0 pH range and too high or too low pH can reduce swelling and availability of nutrients. Use of sulfur coated urea can reduce soil pH leading to deficiencies of Ca^{2+} and Mg^{2+}.

Biological activity: Soil microorganisms and enzymes can affect the degradation of fertilizer coating materials of controlled release fertilizer granules. The coating material of controlled release fertilizers are made either from natural or synthetic polymer. These polymers may have different biodegradability in soil. Polyurethane, polydopamine, chitosan, polycaprolactone, ethylcellulose, starch/PVA/PLA, polyethylene/paraffin etc. are common controlled release fertilizer coating materials. Degradation of polymers are enzyme specific. Eg. Degradation of chitosan-based polymers occur by chitosanases enzyme produced by *Streptomyces* spp. or *Kitasatospora* spp.

Soil texture: Soil microbial activity, water and nutrient retention capacity, cation exchange capacity and organic matter content of soil depend on soil texture. In clay soil, due to high CEC and organic matter content, adsorption of NH_4^+ on clay particles prevent rapid pH change and loss of NH_3 is reduced. On the other hand, NH_3 volatilization and loss of nutrient occurs in sandy soil because of lower CEC, low soil organic matter content, low water retention capacity and high magnitude of pH change. The nitrification rate of loamy soil is more than sandy soil which can reduce NH_3 loss.

Coating materials for controlled release fertilizers:

Coating materials for controlled release fertilizers can be classified into four groups. They are: i) Inorganic materials, ii) Organic materials (biochar, sewage sludge, agricultural residues), iii) Polymers (synthetic and naturally occurring), iv) Miscellaneous materials (advanced engineering materials, *eg.* graphene, nanomaterials).

Inorganic materials: Inorganic materials are usually used for coating of fertilizer granules due to their low cost, availability and ease of agricultural application. Sulfur, gypsum and minerals are commonly used inorganic coating materials of controlled release fertilizers. Various polymers like wax, gum acacia, polyethylene etc. are used to make the outer layer of sulfur coated urea to increase the longevity. Gypsum is also used as a coating material of controlled release fertilizers which supply both calcium and sulfur to soil. Polymers like paraffin or polyethylene wax is used for coating of gypsum coated urea to prevent surface cracking of granule and improve nutrient release pattern. Minerals such as zeolite, hydroxyapatite, bentonite *etc*., natural clays like hectorite, laponite etc. and synthetic clays like montmorillonite can be used as coating material in controlled release fertilizer granules.

Organic materials: Organic materials like agricultural residues, animal litter etc. contain high organic matter and decomposition of these material can enhance soil health. Biochar produced by thermochemical treatments can improve water holding capacity of soil, reduce soil heavy metal pollution by immobilization of the metals and can sequester carbon. By integrating biochar, humic acid, bentonite and biodegradable polymer can be used as coating material of controlled release fertilizers.

Polymers: In controlled release fertilizers, the fertilizer core and inorganic or organic materials coated on the fertilizer granules can be protected by using polymer coating material. Use of polymer coated controlled release fertilizers can improve nutrient use efficiency, reduce water pollution and decrease nutrient loss to the environment. Three types of polymers are widely used in fertilizer coatings are: i) synthetic polymers, ii) semi-synthetic polymers and iii) natural polymers.

Synthetic polymers: Synthetic polymers are man-made polymers produced artificially in laboratory. Polyurethane, polyvinyl alcohol, polylactic acid, polyacrylamide, polysulfone, and resins are synthetic polymers used in controlled release fertilizers preparation.

Semi synthetic polymers: Semi synthetic polymers are derived from chemical modifications of naturally occurring polymers. Epoxy-based, methylcellulose and ethylcellulose are semi synthetic polymers used in coating production of controlled release fertilizers.

Natural polymers: Natural polymers are directly derived from materials widely available in nature or extracted from plants or animal based materials. Starch, cellulose, lignin, alginate, natural rubber, and chitosan are natural polymers used in preparation of controlled release fertilizers due to their low cost, biodegradability, and eco-friendly source.

Miscellaneous materials: Advanced engineering materials such as graphene and other nanomaterials (copper, zinc, iron, silicon, magnesium) can be used in preparation of coatings of controlled release fertilizers. These advanced engineering materials and nano particles are commonly used in research only.

Conclusion

To accomplish increased food demand and sustainable development goals, climate smart agriculture practices are need of the hour. Use of controlled release fertilizers can reduce environmental problems, enhance longevity of nutrients in soil and high nutrient use efficiency for longer time. Besides supplying nutrients use of controlled release fertilizers can improve soil fertility by adding organic matter, enhance moisture retention capacity of soil and maintain optimum soil pH for plant growth. Based on location, weather, soil characteristics and plant nutrient requirements selection of controlled release fertilizers vary.

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Application of ICT and AI based management strategies in changing agricultural scenario

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Agriculture is facing new and severe challenges with advancement of time. Gradually rising food prices have pushed over Millions of people into poverty and more effective interventions have become essential in agriculture. Global population with it's ever increasing trend is expected to become 9 Billion by 2050, has heightened the demand for food and putting pressure on already stressed agricultural production system. As per estimates, feeding that population will require over 70% increase in food production (Anon., 2009). Agriculture faces a range of modern and serious challenges, particularly in developing countries exposed to price fluctuations, climate change, deficiencies in agricultural infrastructure etc. Because of climate change many of natural events related to agriculture have become unpredictable or less predictable with age old practices. Variability and shifting as well as unpredictability of rain for planting, probability of frost, duration of dry intervals that spare the crops from various diseases etc are gradually reducing agricultural production and productivity. Severe climatic condition leads to migration from rural areas and from agriculture to non farm activities in urban areas.

Information and Communication Technology (ICT) and Artificial Intelligence (AI)

Information and Communication Technology (ICT) considers all the uses of digital technology that exist to help individuals, businesses and organizations use information to make decisions. ICT covers any product that will store, retrieve, manipulate, transmit or receive information electronically in a digital form. Information and Communication Technology (ICT) has been defined by World Bank as "any device, tool or application that permits exchange or collection of data through interaction or transmission". It includes anything ranging from radio to satellite imagery to mobile phones or electronic money transfer.

ICT is an umbrella term that includes any communication device or application encompassing- radio, television, cellular phone, computer and network, hardware, software, satellite systems, videoconferencing and distance learning etc.

Artificial Intelligence (AI) is based on the principle that human intelligence can be defined in a way that a machine can easily mimic it and execute tasks, from simplest to complex. The goals of artificial intelligence include learning, reasoning and perception. With advancement of science and technology, artificial intelligence has been used in various information and communication technologies (ICT) to maximize the effectiveness of the targeted tasks. AI Enabled technologies are extensively used to predict weather condition, analyse crop sustainability, and evaluate farms for the presence of diseases or pests, as well as status of plant nutrients, using data such as temperature, precipitation, wind speed, and solar radiation in conjunction with machine learning algorithms and images captured by satellites and drones.

Use of ICT in Agriculture

Under risky and uncertain situations farmers take decisions every day. These decisions will have to be made with the knowledge and information available with them at that point of time. Access, efficiency and affordability of agricultural information continue to be a major impediment for raising agricultural productivity among smallholders in the developing countries. It is in this arena that ICT can play a very crucial role by disseminating information to farmers to help them make better well informed decisions. In the context of globalizing agriculture, information is vital. Smallholders, who still produce a significant portion of food for the entire world need information to upgrade and update their work just as much as industrial scale producers.

Information and communication technology can help overcome various constraints in agriculture, such as:

i. There is lack of extension facilities
ii. Issue of low literacy rate among farmers
iii. Limited capability of farmers to compete with corporate
iv. Wide gap between traditional practice and modern technologies
v. Lack of market linkage and other latest information to farmers

Information and communication technology can help us meet the demand for food, by collecting and sharing timely and accurate information on weather, inputs, markets, and prices, by feeding information in to research and development initiatives, by disseminating knowledge to farmers, by connecting producers and consumers , and through many other avenues. ICT services provide critical access to knowledge, information and technology that farmers require to improve the productivity and thus improve the quality of their lives and livelihoods. This would retard the migration of farmers to non-farm activities in urban areas.

Five main driving force in adoption of ICT for small farmers are- low cost and widespread connectivity, adaptable and affordable tools, advances in data storage and exchange, innovative business models and partnerships, accessibility of information including open access sources and social media.

Studies on impact of ICT application in agriculture

Researchers have studied impacts of various ICT tools on agriculture including production and marketing system under various circumstances, some of which are mentioned below:

Traditionally, farmers in developing countries have obtained much information from personal visits, radio and to a lesser extent landlines and newspaper. Mobile phones, by contrast, can reduce cost of obtaining this information as compared to other modes.

Purchase of mobile phones in Philippines increased the growth rate of incomes in the range of 11-17 percent significantly as evident from World Bank study (Labonne and Chase, 2009). This is due to stronger bargaining position of the farmers in the existing trade relationships for additional connectivity to other markets. Another study found that purchase of mobile phones in Morocco increased the average income by 21 percent (Ilahiane, 2007).

Aker (2008) found that mobile phones reduced grain price dispersion across markets by a minimum of 6.4 percent and reduced intra-annual variation by 12 percent. Mobile phones have a greater impact on price dispersion for market pairs that are farther away and those with poor road connectivity.

Climate Change Adaptation and ICT Project (CHAI, 2014) was implemented as a solution for issues faced by Ugandan farmers. A study involving 640 households showed that the dissemination of timely and locally relevant adaptation information reduced crop loss and damage by 67 percent.

Casaburi et al. (2014) reported that sending SMS messages with agricultural advice to smallholder farmers increased yield by 11.5 percent relative to a control group with no messages.

ICTs have transformed how businesses, people and government work. Large scale adoption and integration of ICTs have reduced information and transaction cost, improves service delivery, created new jobs, generated new revenue streams and saved resources (Anon., 2017).

Aker and Mbiti (2010) reported a reduction in search cost by 50 percent in rural Niger when the agricultural price cost was disseminated through mobile phones. Svensson and Yanagizawa (2009) reported that dissemination of price information in Uganda resulted in 15 percent rise in farm-gate price of maize.

Syiem and Raj (2015) reported mobile phone as the most frequently used ICT tool. According to them, the mobile phones were used by the farmers for social communication, contacting middle men for marketing of produce and contacting experts on real time basis for getting agricultural advisories. Major issues in use of ICTs by the farmers were lack of confidence in operating ICTs, erratic power supply, low network connectivity and lack of awareness on benefits of ICTs.

De Silva and Ratnadiwakara (2008) stated the possibility of dramatic reduction in transaction costs with the use of ICT. This was due to reduction in information costs to enable greater farmer participation in commercial agriculture as opposed to subsistence farming that continue to exist in developing countries.

Major barriers for adoption of ICT based extension services were lack of training, poor infrastructural development and poor network connectivity. While the major drivers of adoption of ICT based extension services were easy to adopt, up to date nature of the ICT based extension service, no requirement of physical presence of expert, useful content of the services, timeliness of the information, and relevancy of the information. Major consequences of non adoption of ICT based extension services were- loss of contact with timely information, loss of production, loss of competitiveness etc., (Naik, 2014).

Way forward

- Currently the ICT initiatives are meeting the selected portions of the population and they have to be popularized to meet the large sections of the community
- Use of mobile application is very limited among the farmers. This needs to be analysed and promoted extensively amongst the farmers. e-literacy schools need to be established for this purpose.
- The number of messages sent is very limited, particularly given the cost factor. So steps need to be taken to increase the number of messages sent.
- Alternative modes of communication need to be established in places where power and internet connectivity turns out to be barriers.
- There has to be dynamism in the way, package of Practices is utilized for information dissemination
- Periodical studies need to be undertaken to evaluate the ICT initiatives undertaken for further expansion
- Given the potential of youth in utilization of ICT, proper training amongst them will be a great boost for agriculture development.
- Development of infrastructure is crucial for the widespread dissemination of ICT benefits.

It is expected that extensive use of ICT and AI enabled technologies by smallholder farmers will improve overall agricultural situation in the coming years to meet the desired increase in food production at global scale along with industrial producers.

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Nano Fertiliser- Past, Present and Future

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Introduction

Food Security, Sustainable Agriculture & clean Environment/climate are major concern nowadays worldwide. Human population is constantly on the rise making it a must to produce more food. As per UN estimates, planet Earth will inhabit about 9.6 billion people by 2050 AD (UNDESA, 2015). This rising world population calls for commensurate increase in agricultural productivity to satisfy the food needs of its inhabitants.

Conventional fertilizers offer nutrients in chemical forms that are not often fully accessible to plants leading to low utilization of added macronutrients. These problems make it imperative to go in for the repeated use of fertilizers. Heavy use of Nitrogen (N) and Phosphorus (P) fertilizers has became the major anthropogenic factor leading to world-wide eutrophication problems in freshwater bodies and coastal ecosystems (Correll 1998; Conley et al. 2009). To deal with such situation, it is very important to develop smart materials that can systematically release nutrients to specific targeted sites in plants which could be beneficial in controlling their deficiencies in agriculture, while keeping intact the natural soil structure. Nano fertilizers possess unique features which enhance plant's performance in terms of ultrahigh absorption, increase in production, rise in photosynthesis and significant expansion in the leave's surface area. Replacement of traditional fertilizer by nano fertilizer is beneficial as upon application, it releases nutrient into soil steadily and a controlled way, thus preventing the water pollution (Naderi and Danesh-Shahraki-2013; Moaveni and Kheiri-2011).

The Green Revolution was initiated in India in the 1960's to increase food production and feed the millions of malnourished people throughout the nation. The technology of the Green Revolution involved bio-engineered seeds that worked in conjunction with chemical fertilizers and heavy irrigation to increase crop yields (Ameen and Raza, 2017). The revolution transformed India in a very better way to feed the exceedingly large and growing population of the developing nation. Indian farmers adopted the use of chemical fertilizers from this revolution and made India self-sufficient in food, feed, fodder and fibre production. But, the excess level of use of these chemical fertilizers and pesticides create major hazard on environment, soil, animal and human beings. In addition to it, urea is prone to losses due to leaching and volatilization causing a problem of eutrophication and reduction in fertilizer use efficiency. The nitrogen use efficiency (NUE) is very low (only 50-70%) in case of nitrogen applied to the soil using conventional nitrogen fertilizer *ie.* urea. A major portion of the applied nitrogen is owed to leaching in the form of water soluble nitrates, emission of gaseous ammonia and nitrogen oxides and long-term incorporation of mineral nitrogen into soil organic matter by soil microorganisms (Derosa *et al.*, 2010). Numerous attempts to increase the NUE have so far met with little success, so it is the need of hour to solve the lacunas of previous approaches where nanotechnology seems to be a promising area. Nutrient particles in nano form can be absorbed directly by the pores in leaf surface preventing nutrients from interacting with soil, water and microorganisms, and releasing nutrients only when they can be directly internalized by the plant. Owing to a high surface area to volume ratio, the effectiveness of nanofertilizers may surpass the most conventional fertilizers.

IFFCO Nano Nitrogen

The world's largest and wholly owned by cooperatives, Indian Farmers Fertiliser Cooperative ltd (IFFCO) has introduced Nanotechnology-based product i.e. Nano-N, Nano-Zn and Nano-Cu.

Out of this three products Nano- N is in the form of NANO UREA(Liquid) 500 ml bottle is now commercially available across the globe. Complex fertilizer like DAP, NPK will also be available in NANO form with in short time. Field trials on Nano- DAP is going on in different crops and locations. NANO urea(liquid) has been included in FCO, 1985 by GOI.

Nanotechnology based Nano urea (liquid) has been developed by scientist of IFFCO-Nano Biotechnology Research Centre (NBRC), Kalol, Gojarat after years of rigorous research. Proprietary and patented Nano urea (liquid) contains 4% nano nitrogen particles. It has been tested on more than 90 crops across 11,000 locations in collaboration with ICAR-KVKs, Research Institutes, State Agriculture Universities and progressive farmers in India.

Reduction in the demand of Chemical Nitrogen (urea) by 50% or more, hence there is a reduction in the input cost for the farmers.

Rapid plant growth, development and pigment formation in the plants.

Expand the root hair network and improve soil biological heath.

Applicable to all crops.

Nano nitrogen is most effective when applied through foliar spray during tillering and flowering stage.

Nano nitrogen is eco-friendly, it prevent rapid de-nitrification, leaching and volatilization.

- NANO urea (liquid) contains 4.0% total nitrogen(w/v) evenly dispersed in water.
- NANO nitrogen particle size varies from 20-50 nm.

Mode of Action

- When sprayed on leaves, Nano urea easily enters through Stomata and other openings and is assimilated by the plant cells.
- It is easily distributed through phloem from source to sink inside the plant as per its need.
- Unutilized nitrogen is stored in the plan vacuole and is slowly released for proper growth and development of plant.

Rate, Time and Method of Application

- Mix 2 -4 ml of Nano urea in 1 litre of water and spray on crop leaves at active growth stages.
- For best results apply 2 foliar sprays—

  # 1^{st} spray at active tillering/branching stage (30-35 DAG or 20-25 DAT)

  # 2^{nd} spray 20-25 days after 1^{st} spray or before flowering in crop.

Note: Don't cut nitrogen applied through DAP or complex fertilizer at basal stage, reduce only top dressed Urea applied in 2-3 splits; spray number can be increased or decreased depending upon crop and its nitrogen requirement.

Application Instructions

- Shake well the bottle before use.
- Use flat fan or cut nozzles for spraying on the leaves.
- Spray during morning and evening hours avoiding dew. If rain occurs within 12 hours of spray of nano, it is advised to repeat the spray.
- Nano urea can easily be mixed with bio- stimulants, 100% water soluble fertilizer and few agrochemicals. It is always advised to go for jar test before mixing and spraying for compatibility.

Safety & Precautions

- Nano urea has been tested for bio-safety and toxicity as per the guidelines of department of Biotechnology (DBT), Government of India and OECD international guidelines.
- Nano urea is safe for user, safe for flora and fauna and non-toxic. However it is recommended to use face mask and gloves while spraying on the crop.
- Store in dry place avoiding high temperature and keep away from reach of children and pets.

Impact of climate change on agriculture in the Brahmaputra valley of Assam

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Introduction

Climate change as clearly manifested by each decadal warming of the earth's surface is posing challenges to sustain the food security. Increased anthropogenic greenhouse gas (GHG) emission is the primary driver of a warming planet. Global mean surface temperature during this period was observed to be 1.09°C higher than the average over the period 1850-1900 and a rise of 1.5°C is anticipated between 2030 and 2052 even in the best case scenario (IPCC, 2021). The study also predicts that average global temperatures will continue to rise and could rise by 5.7°C by the end of the century compared to 1850-1900. Carbon-dioxide (CO_2), one of the major GHGs contributing to climate change, reached its highest concentration during the period 2011-2020 in the last 2 million years, attributed mostly to human activities. The impacts of global warming are already felt in the form of increased frequency of extreme weather events like floods and droughts, changes in rates and patterns of precipitation, retreating snowlines, ocean acidification, increased frequency of powerful cyclones, etc. Since climate is the key determinant of a successful harvest, there is rising concerns with respect to crop production under the event of climate change. In India, around 70% of the total working force depends on agriculture and allied activities for their livelihood, where majority of agricultural land area is under rainfed farming (about 56%) contributing to about 40% of country's food production. In the context of recent climate variability, erratic as well as extreme weather events are emerging as a potential threat to crop production, thereby affecting food security and sustainable livelihood of the farming community.

The Brahmaputra, one of the largest braided river systems, is the seventh largest river in the world (Tandon and Sinha, 2007) and has created an extensive flat floodplain in the state of Assam. On account of its strategic location and fragile geo-environmental setting, the Brahmaputra valley is highly prone to natural and man-made disasters. Agriculture in the valley is primarily rainfed, supporting the livelihood of about 75% of its inhabitants. More than 83% of the farmer families are small and marginal with an average operational holding as low as 1.15 hectares (Agricultural Census of Assam, 2006). Rice is the most dominant crop of the Brahmaputra valley. Tea, rapeseed and mustard, potato green gram, black gram, jute, sugarcane, maize etc are other important crops grown in the valley. Besides, the status of horticultural crops such as sweet potato, banana, papaya, chilies, turmeric cabbage, cauliflower, brinjal, lemon, orange and pineapple, have also improved in the valley with respect to acreage and production, even though less than one per cent of the cropped area is being used for cultivating each of them. Since, agricultural activities form an integral part in shaping the economy, any significant fluctuations in the spatial and temporal pattern of the climatic parameters would affect the livelihood security of its inhabitants.

Climate of the Brahmaputra valley

The Brahmaputra valley of Assam has a sub-tropical monsoon type of climate characterized by hot and wet summer and mild to moderately cold dry winter. The valley experiences high rainfall and high humidity which is mainly influenced by both the south-west monsoon from the Bay of Bengal and the surrounding hills. Mean annual rainfall in the Brahmaputra valley is about 2352 mm distributed over 120 days (Deka *et al.*, 2016). Highest rainfall is received during the monsoon months amounting to 61-72% of total annual rainfall scattered over 18-20 days in a month. Rainfall during post-monsoon and winter season varies between 7-10% and 1-5% respectively. A rainshadow belt comprising Karbi Anglong and Nagaon districts extending partly to Golaghat district in the east is found, where the annual rainfall is around 1000 mm, which then gradually increases towards the upper and the lower Brahmaputra valley zones. The valley experiences a mean annual temperature of 23.0 to 24.0°C. August is the hottest month and January is the coldest month in the state.

Observed changes in rainfall

The climatic parameters of the Brahmaputra valley have changed significantly over the years with decreased rainfall and rising temperature. Deka *et al.* (2016) studied the trends and fluctuations of rainfall regime in the Brahmaputra and observed that annual as well as monsoon rainfall showed long-term decreasing trends in the Brahmaputra valley. They also reported a decrease in mean annual rainfall by 7.4 mm/decade and monsoon rainfall by 21.2 mm/decade in the Brahmaputra valley during the period 1901-2010. A notable decline in yearly total rainfall over a 30-year period between 1981 and 2010 was also observed. Gharphalia *et al.* (2018) also reported that the annual as well as monsoon rainfall in the Brahmaputra valley decreased by 66.6 mm/decade and 53.4 mm/decade, respectively during 1986-2015. During the monsoon season, rainfall showed significant decreasing trends in Golaghat (88.7 mm/decade), Barpeta (127.7 mm/decade), Dhubri (561.9 mm/decade), Nagaon (118.5 mm/decade) and Tezpur (118.6 mm/decade) due to significant decrease in July and September rainfall. Rainfall during pre-monsoon, post-monsoon and winter seasons have also showed a declining trend in the state by 12.4 mm/decade, 17.9 mm/decade and 8.6 mm/decade, respectively during 1989-2018. Table 1 shows the trend of monthly rainfall in different locations of the Brahmaputra valley (Gharphalia *et al.,* 2018).

Table 1. Monthly rainfall trend (mm/decade) in different locations of Assam during 1985-2015

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dibrugarh	-1	-16	-9	7	21	8	-36	8	-68	-20	1	-1
Jorhat	-3	-5	2	4	25	25	-1	20	-24	-16	-3	-1
Lakhimpur	-6	-16	-2	-2	25	2	-39	34	-50	-24	1	1
Tezpur	-2	-8	3	19	5	0	-34	-25	-35	-22	1	1
Nagaon	-4	-14	-16	-31	-28	-3	-45	-22	-45	-13	4	0
Guwahati	-1	-5	-7	-7	3	15	-42	-21	-18	-10	-1	0
Barpeta	-2	-6	0	30	7	-31	-79	-6	-12	-34	0	0
Dhubri	0	-4	9	-4	-20	-81	-167	-98	-59	-24	-2	0

(Shaded box indicates statistical significance at 5% level)

Observed changes in temperature

An increasing trend in temperature in the Brahmaputra valley was reported for the period 1986–2015 by Tamuly *et al.* (2019). They also reported that the annual average maximum temperature increased from 24.3°C to 26.4°C from late 1980s to 2015 in the Brahmaputra valley of Assam while the average minimum temperature decreased from 14.8°C to 13.8°C during the same period. The Brahmaputra valley has also warmed up by 0.90°C during the period 1986-2015, with increase in annual maximum temperature (0.41°C/decade) being double than that of minimum temperature (0.20°C/decade), leading to increase of warmer days and reduction of cooler nights in the valley.

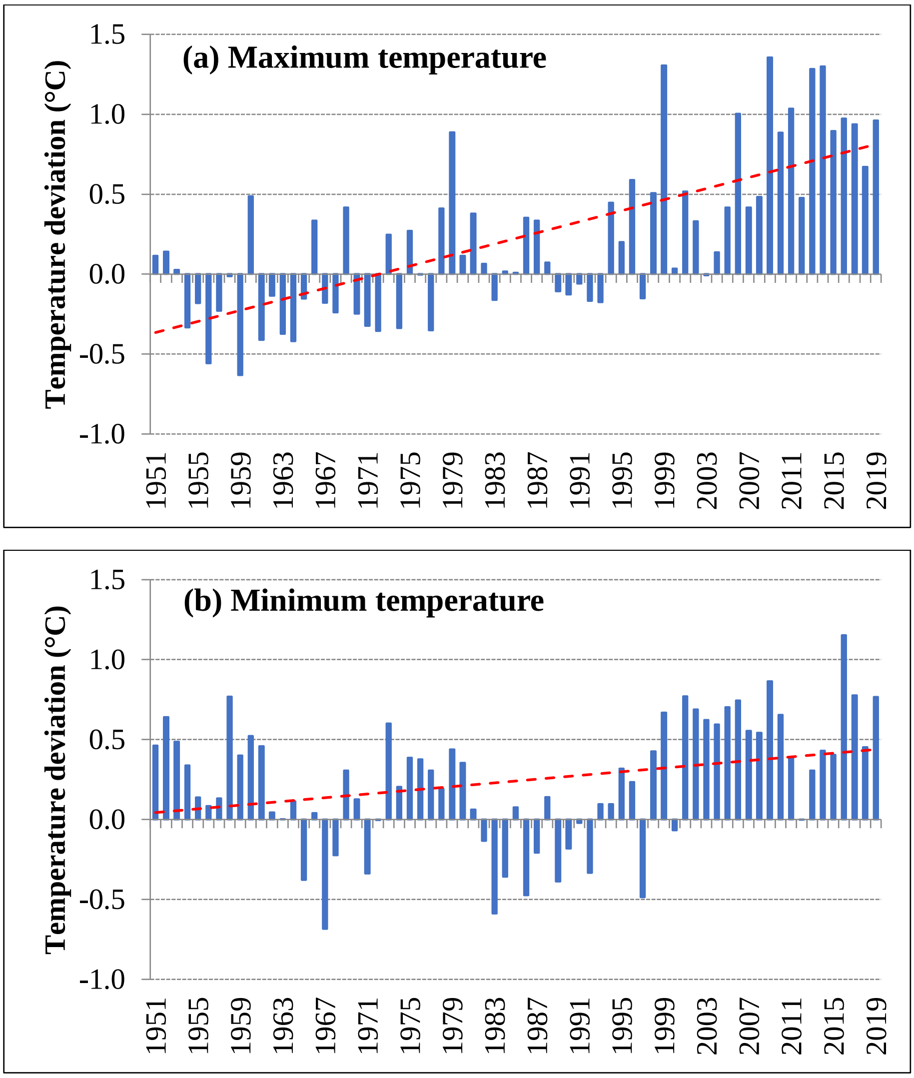

Fig. 1. Inter-annual variation of temperature during 1951-2018 relative to the overall mean of 1961-1990

The trends of temperature in different months are showed in Table 3 and 4. Significant increase in maximum temperature during February, March, September, October and November in 4, 5, 4 and 5 locations of the Brahmaputra valley of Assam was observed (Table 3). Increase in minimum temperature at Dhubri during all the months and its decrease at Lakhimpur was prominent (Table 4) and the reasons for such anomaly are difficult to explain. Decreasing trend of maximum temperature and increasing trend of minimum temperature at Dhubri might be due to increase in night time cloud cover (Revadekar *et al.*, 2012). On the contrary, increase in maximum temperature and decrease in minimum temperature at Lakhimpur might be due to occurrence of massive siltation in agricultural lands from late 1990s which altered the normal diurnal temperature range.

Table 2. Trend of maximum temperature in the Brahmaputra valley during 1985-2018

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dibrugarh	+	+	+	+	+	-	+	+	+	+	+	+
Jorhat	+	+	+	+	+	-	+	+	+	+	+	+
Lakhimpur	+	+	+	+	+	+	+	+	+	+	+	+
Tezpur	+	+	+	+	+	+	+	+	+	+	+	+
Nagaon	+	+	+	-	+	+	+	+	+	+	+	+
Guwahati	+	+	+	+	+	+	+	+	+	+	+	+
Dhubri	-	-	-	-	-	-	-	-	-	-	-	-

(Shaded box indicates statistical significance at 5% level)

Table 3. Trend of minimum temperature in the Brahmaputra valley during 1985-2018

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dibrugarh	+	+	+	+	+	-	+	+	+	+	+	+
Jorhat	+	-	+	+	+	-	+	+	+	+	-	+
Lakhimpur	-	-	-	-	-	-	-	-	-	-	-	-
Tezpur	-	-	+	+	+	+	+	+	+	+	+	+
Nagaon	+	+	+	+	+	+	+	+	+	+	+	+
Guwahati	-	-	+	+	+	+	+	+	+	+	-	+
Dhubri	+	+	+	+	+	+	+	+	+	+	+	+

(Shaded box indicates statistical significance at 5% level)

Impacts of climate change on Agriculture

As agriculture in the Brahmaputra valley is predominantly rain-fed and most of the farmers have extremely limited adaptive capacity against any unfavorable impact, the observed changes in rainfall and temperature regimes are expected to harm the agricultural sector. Erratic rainfall distribution, recurring floods accompanied by soil erosion due to surface run-off during the rainy season, more so aggravated by global warming, has been a major cause of slow growth of agricultural productivity in the Brahmaputra valley. Decrease in the amount of rainfall in the absence of proper irrigation might have a detrimental influence on crop yields, as rising temperature can have both positive and negative effects depending on the temperature sensitivities of a particular crop. Decrease of monsoon rainfall leading to frequent short dry spells may negatively affect winter rice production and necessitates contingent plans during *kharif* season. For example, the winter rice crop in the valley experiences a mean temperature between 28°C and 29°C during vegetative, 21.7°C during reproductive and 22.2°C during ripening phase. It is observed that the prevailing mean temperature during different phases of rice crop were much below the optimum cardinal temperature requirement. The observed trend of mean temperature during 1986-2015 is not likely to impact any of the phases of winter rice crop negatively in near future. But under deficient and aberrant rainfall situation which was observed during monsoon months (corresponding to vegetative phase), mean temperature may be higher than the normal growing season temperature (Tamuly *et al.,* 2018). Under this scenario, development of high yielding varieties (HYVs) tolerant to abiotic stresses as well as adaptation strategies especially adjustment in transplanting time to avoid the high temperature episode during sensitive growth periods, methods of crop establishment like dry seeding, system of rice intensification (SRI), rain water harvesting for irrigation during stress periods and proper use of weather forecasts and other agro-climatic information to plan management practices may prove to be crucial to increase productivity of winter rice. Similarly, during *rabi*, the potato crop experiences a mean temperature of 22.2°C, 18.3°C, 16.9°C and 19.3°C during vegetative, tuber initiation, tuber bulking and maturation respectively over the Brahmaputra valley. Negative impacts of observed trend of temperature are likely during vegetative growth period. Due to accumulation of required thermal unit in less number of days, reduction in crop duration may occur. Moreover, higher temperature during crop establishment period will increase the evapotranspiration rate. Some of the feasible adaptation strategies to sustain crop productivity in potato crop in the valley are: moisture conservation practices like use of organic mulch, adjustment (delay) of planting time to avoid the affect of high temperature during vegetative phase, irrigation at critical growth stages by harvesting rainfall during monsoon and from ground water, growing of suitable varieties (late planted) and proper use of weather-based advisories (Tamuly *et al.,* 2018). Likewise, the flowering of horticultural crops like mango, jackfruit, litchi may be earlier and the fruit set may be poor. In terms of livestock production, increasing air temperature along with high relative humidity (>90%) can result in heat stress in dairy cattle especially during monsoon season (Das *et al*., 2020), which may affect their health and biological functioning leading to poor milk yield.

Possible adaptation strategies

Since the changing climate affects natural resources that impart a negative impact on crop productivity and food security, it is imperative to identify area specific adaptation strategies to ensure food security. Considering the observed changes in rainfall and temperature as well as their extremes, on farm adaptation strategies must be designed in a timely fashion, backed by strong climate research and application oriented outputs. Development of location specific interventions by identifying the available resources is a significant factor that would reduce the impact of risks associated with climate variability or climate change. Some of the adaptation and mitigation options for the Brahmaputra valley of Assam could be:

- ✓ Growing of climate resilient crop varieties such as submergence tolerant and post-flood varieties, heat and drought tolerant, pest resistant varieties of the major crops etc. Cultivation of flood tolerant varieties in flood prone areas and preference of high yielding varieties over traditional varieties are seen among the farmers of the valley.
- ✓ Identification of economically feasible farming systems with the ability to adjust to or recover from negative impacts and take advantage of positive impacts of the current climate variability. This needs identification of appropriate mixes of production activities like establishing crop/livestock mixed systems; efficient mix of crop

species/cultivar types; combining less productive drought resistant crops with high yielding water-sensitive crops.

- ✓ Mid-season drainage/alternate wet and dry method of irrigation is reported to reduce methane emissions from rice fields. Techniques such as adjustment of sowing time, double transplanted rice, direct seeded rice, aerobic rice, and System of Rice Intensification (SRI) are found to be effective in sustaining rice production in a changing climate
- ✓ Development of new agronomic practices that avoid the concentration of sensitive growth stages in the same period of the year (*e.g.*, different season lengths, sowing dates). Changes in cropping pattern (shift from rice-rice cropping system to other favourable crop mix) may be adopted in vulnerable areas. Moreover, expansion of areas under pulses in riverine areas and oilseeds in mono-cropped areas is needed.
- ✓ Nutrient management techniques such as the application of neem coated urea, nano fertilizers, Azolla compost and biochar mixed with farm yard manure were found to mitigate nitrous oxide and methane emissions from crop fields while enhancing the yields by improving nitrogen use efficiency and soil carbon sequestration.
- ✓ Rainwater harvesting, soil conservation measures and suitable cropping patterns for maximum *in-situ* retention of rainwater to avoid terminal drought conditions.
- ✓ Developing Decision Support System (DSS) combining databases (crop, soil, climate) and modern information tools to establish drought/flood alerts, monitor the vegetation condition, develop crop yield forecasts, identify best agronomic practices and to define land use suitability classes.
- ✓ Development of contingency plans for temperature and rainfall related risks and weather based pest and disease forecasting systems.

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Crop Adaptability in Changing Climatic Scenario

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Climate change has already affected Indian agriculture through changes in rainfall patterns, characterised by strong inter-annual rainfall fluctuations, increased frequency of rainfall extremes and prolonged droughts. Agriculture in India is predominantly rainfed and thus highly vulnerable to climate change and variability, making crop production uncertain. Uncertainty about future crop production creates uncertainty for the food system, with consequences for economic, health and socio-cultural systems. To prepare the food system for future challenges, it is important to project potential crop production changes under different climate and field management scenarios to inform adaptation planning. Crop models can be used to estimate changes in future crop production based on the simulated response of crops to field management, weather and soil processes. However, projected crop yields vary considerably between crops and locations and are strongly influenced by a wide range of potential climate and field management scenarios. In addition, crop yield projections are influenced by uncertainties from model parameters and representation of biophysical processes in different crop models. However, in a global review of climate change impact studies demonstrated the importance of considering adaptation strategies, which significantly increased projected crop yields. Similarly, many projections for India see the possibility of increased agricultural production under climate change, especially if appropriate adaptation measures are taken. In addition, many case studies in India have concluded that common farming practices, which respond to environmental change, can significantly reduce the negative impacts of climate change. The effects of farming practices are highly location and context-specific. Practices that reduce negative climate change impacts on rainfed agriculture respond to shifts in precipitation and temperature, which can vary greatly in India.

India is a large emerging economy with a great variety of geographical regions, biodiversity and natural resources. However, the country is one of the most vulnerable to climate change risks worldwide. More than half of India's population of over 1 billion people lives in rural areas and depends on climate-sensitive sectors like agriculture, fisheries, and forestry for their livelihoods. Natural resources and the environment are already under pressure as a result of rapid urbanisation, industrialisation and economic development.

Practically, adaptation to climate change means doing things differently because of climate change. Most often, it does not mean doing completely new things, but rather purposefully modifying development interventions. Adaptation itself is not a development objective, but necessary for safeguarding beneficial outcomes. Adaptation measures may be compared with a baseline of 'doing nothing', resulting in bearing losses and not making use of opportunities. Bearing losses occurs particularly when those affected have no capacity to respond in any other way or where the costs of adaptation measures are considered to be high relative to the risk or expected damage.

With the increase of the Earth's temperature, the climate undergoes severe alterations and becomes abiotically stressful. Environmental changes are very damaging and pose various threats to naturally prevailing crop species. Under field circumstances, drought and heat are the most predominant stresses and have a significant influence on plants. It is reported that plants require an optimum temperature for their normal growth and blooming. Plant physiology is heavily influenced by temperature fluctuations. As heat stress affects the grain production and yield, cold stress results in sterility, and drought stress negatively influences the morpho-physiology of plants. These climatic problems severely distress plant development and yield, produce enormous responses, comprising molecular, biochemical, physiological, and morphological modifications. Overall, global warming and climate change both have some negative and positive effects on agricultural crops as well as on humans.

In this context, understanding the stress-resistance processes in plants has emerged as a very difficult task for plant scientists in order to develop stress-resistant plants. The chief cereal crops around the world, such as maize, rice, and wheat, are crucial to meet the daily food demand. Out of them, wheat was the leading staple crop which has been cultivated on a large scale. Wheat is harvested on 38.8% of total agricultural land worldwide and provides a considerably high concentration of proteins: 15% per gram as compared to maize or rice which only supplies 2 to 3%. Regardless of large growing land globally, its productivity has been predominantly less than the maize and rice. Reasonable reduction was anticipated in wheat productivity with a 2 ^{0}C increase in temperature. Related research on environmental variability expected a 6% reduction in wheat yield. It is described that due to the increase in temperature, the grain filling phase decrease is the major reason of crop productivity reduction in changing climatic conditions. Therefore, sustaining crop yield is an important task in current agriculture, and to produce stress-tolerant crop plants.

For sustainable agriculture and food safety for an increasing population of the world, it is necessary to grow stress-tolerant plants and understand their responses under different stress conditions. In relation to various climatic stresses, the response of plants varies in the expression of genes, physiology, and metabolism. It was reported that plants have the ability to sense any variation in surrounding environmental signals but in spite of many studies, only some reputed sensors have been recognized. Due to different stresses, the organs and tissues of the plants are damaged and they respond accordingly, for example, transcriptional responses against various stresses are different in specific cells or tissues of roots. Stress-responsive protein creation, high levels of associated solutes, and more elevated antioxidant ratios are the cellular signals which are produced due to salinity, drought, and chemical effluence. These stresses are regarded as primary stresses and they generate secondary stresses like oxidative and osmotic stress.

Under drought conditions, high level of CO_2 in leaf causes the initiation of reactive oxygen species (ROS) which trigger the multiple stresses in crops. With locked stomata, movement of CO_2 inside the leaf is clogged, and ROS are produced due to enhanced levels of oxygen under drought conditions. The frequency of plant development, photosynthesis, and respiration are disturbed by membrane breakdown due to ROS production. Several cell building materials like carbohydrates, lipids, proteins, and nucleic acid are impaired by ROS in drought stress. In recent studies, it was observed that Osmo-protectants have been produced under the combined stress conditions of heat and salinity in tomato plants, but do not appear in individual stresses. Another experiment demonstrated that the combined effect of heat and salt stress leads to diverse metabolomic profiling which was established with molecular and physiological statistics. For plant development, ROS has a significant role and it is considered as a crucial secondary signal for cellular metabolism: an elevated level of ROS prompts cell apoptosis. Therefore, a gentle equilibrium among ROS creation and their decontamination may occur in every oxygenated organism.

With great environmental variability, plants are suffering from unique climatic conditions that limit the plants' ability to adapt successfully in a range of ways. Due to more spells of rainfall and warmth, plant relocation is not to be the solution to this problem. However, modifications in plant physiology have been beneficial in unique climatic conditions, but environmental variability can be risky for plants. Morphological, biological, and biochemical mechanisms of plants have been severely affected by abiotic stresses. Although for expected weather conditions in the future, plant physiology reactions are predicted to propagate quickly, with minor variation in fruiting and flowering. The ideal temperature for plant development is in the range of 10 to 35 ^{0}C. Elevation of the temperature to a specific point will permit plants to generate excess energy but a larger increase in temperature retards the plant growth and the photosynthesis rate abates to deadly levels. Turgor pressure is limited by the drought stress and therefore delays cell development. Water shortage impacts the photosynthesis enzymes actions and decreases the metabolic competency and ultimately destroys photosynthetic machinery. Because of environmental changes CO_2 levels proliferate and retard respiration in plants and enhance temperature level. Respiration rates of the plant were elevated when the temperature was raised from 15 to 40 ^{0}C, disturbing morphological features of some crops. During the process of photosynthesis, the enzyme Rubisco is associated with carbon fixation and translation of CO_2 into a complex energy-rich compound. Rubisco is activated by the Rubisco activase at an optimum temperature by abolishing secondary metabolites. A minor elevation in temperature resulted in the deactivation of Rubisco enzyme leading to the generation of xylulose-1,5-bisphosphate which is supposed to be an inhibitory compound. At an increased temperature, Rubisco did not work properly because of the Rubisco activase breakdown and was unable to activate Rubisco. ROS containing OH, H_2O_2, and singlet oxygen are derivatives of metabolisms and are regulated by antioxidant defence mechanism. ROS are mostly formed in minimum amount under optimum conditions but with the increase in concentration environmental stress triggered.

Under different abiotic stresses, hormones are very crucial for regulating many signalling pathways and responses such as salicylic acid (SA), abscisic acid (ABA), and ethylene. The major role is played by ABA in the regulation of stress responses by the interactions with some other hormones. The most important and vital hormone for regulating the climatic stresses in the plant is ABA. ABA plays a major role in different stages of plant development particularly in stomata opening and closing, drought stress, seed germination, and dormancy. Under drought conditions, the plant growth is severely retarded and it increases the ABA concentration in cells. ABA accumulation during drought stress controls transpiration and inhibit stomatal disclosure. ABA also triggers many physiological mechanisms in plants such as water scarcity, regulates stomata to close down, and produces many stress-responsive genes in this period.

Variation in the environment has a long-lasting influence on agriculture and food security globally. Food security and safety are threatened by the severe weather conditions and it is not a recent problem. Therefore, to cope with these weather variations is the most urgent demand worldwide. For crops to adapt to changing environmental stresses subsequent approaches are required.

Cultural Methodologies: There are many useful approaches adopted by farmers, including abiotic factors such as altering planting and harvesting time, a collection of crops with short life cycles, crop rotation, irrigation techniques, and variation in cropping schemes. Under climatic stress conditions, all of these approaches are very beneficial for crop adaptability. Modification in sowing time, application of drought resistant cultivars, and the cultivation of new crops are some important strategies to lessen the climatic variability danger and provide better adaptability to crop plants for assuring food safety and security.

Another plant adaptability approach is by means of crop-management techniques that have the ability to enhance crop development under various environmental stresses. The choice of sowing time, planting density, and optimum irrigation practices are crucial techniques to tackle weather stresses. Fertilizers are also very vital to reduce the effect of global warming and support the plant for better adaptability. It provides substantial energy to plants and is beneficial to maintain the fertility of the soil and increase productivity. Hence, the importance of fertilizer in nourishing the world is undeniable.

Conventional Techniques: Under various environmental stresses, plant breeding shows dynamic techniques in crop development and betterment. It gives a way to potentially guarantee food security and safety under harsh weather variations and help plants escape from various stresses through a crucial phase of plant growth by developing stress resistant cultivars. Genetic divergence analysis is used for polymorphism, inbreeding, assessment, assortment, and recombination to attain plant perfection, and is amongst the main aspects for defining accomplished inbreeding. Genetic divergence analysis is considered a very important method for the development of new cultivars based on genetic distance and similarities.

Genetics and Genomics Strategies: In many crops, the breeding program is coupled with genomic approaches to achieve great heights in molecular breeding and to screen elite germplasms with multi-trait assembly. Different molecular markers are studied in population genomics across the environment in many individuals to find out novel variation patterns and help to find if the genes have functions in significant ecological traits. Biotechnology is an influential approach for genetic manipulation of the genome for the betterment of human beings. The genetic modification through biotechnology is a powerful strategy to develop stress-resistant crop cultivars.

Climate change has devastating effects on plant growth and yield. Abiotic stresses are the major type of stresses that plants suffer. To understand the plant responses under different abiotic conditions the most pressing current need is to explore the genetic basis underlying these mechanisms. Some bottleneck molecular and physiological challenges present in plants need to be resolved for better plant adaptation under abiotic conditions. Temperature fluctuations and variations in rainfall spells are a very crucial indicators of environmental stresses. Weather variations collectively have positive and negative outcomes but the negative effects are more thought-provoking. It is very difficult to overcome the imbalance in agriculture by climate change. How to tackle this problem and what strategies we should apply are still ambiguous. Hence, researchers need to focus on optimizing plant growth and development in abiotic stresses. For crop resistance against biotic and abiotic stresses, propagating novel cultural methods, implementing various cropping schemes, and different conventional and non-conventional approaches will be adopted to save agriculture in the future.

Recent development in insecticide research

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Infestation of insect-pests cause enormous crop losses. In ancient times, neem, pyrethrum, rotenone, nicotine, ryania, sabadilla and a number of lesser known botanicals were used to protect agricultural crops from ravages of insect and non-insect pests in different parts of the world. Botanical pesticides were prepared from the roots, stems, leaves, flowers and oils of various plants. These botanical pesticides were followed by inorganic synthetic insecticides like paris green, lead arsenate, calcium arsenate etc. In 1867, Paris green was successfully used for the control of Colorado potato beetle in USA. Lead arsenate was first used against Gypsy moth in USA in 1892. Inorganic compounds containing mercury, tin or copper were also used as stomach poisons during this period. In early 1900s, sodium fluoride and cryolite replaced some arsenicals because of lower phytotoxicity. With the development of these insecticides, the focus of research in entomology slowly shifted from ecological and cultural control practices to chemical control during the period 1920-1945.

By World War II, only about 30 pesticides were existed. Research during the war yielded DDT (dichloro-diphenyl-trichloro-ethane), which had been synthesized in 1874 but wasn't recognized as an insecticide until 1942. The impact of DDT on pest control is unmatched by any other synthetic substance and Paul Muller was awarded Nobel Prize in 1948 for discovering the insecticidal properties of DDT. Other strong pesticides soon followed, such as chlordane in 1945 and endrin in 1951. Poison gas research in Germany yielded the organophosphorus compounds, the best known of which is parathion. These new pesticides were very strong. Further research yielded hundreds of organophosphorus compounds and carbamate group. Later synthetic pyrethroids entered in pesticide market during nineteen eighties and used successfully for crop pest management, followed by a number of neonicotinoids and fermented pesticidal products isolated from soil bacteria, which are presently in use. Conventional pesticides are still foremost option for the farmers in India to manage the crop pests even though there are problems related to environmental pollution, residual toxicity, pesticide resistance and pest resurgence.

Until the 1800s, when people began to spray personal gardens using fairly large machines, pesticides were generally applied by hand. Airplanes were not used until the 1920s, and slow, well-controlled, low-level flights were not implemented until the 1950s. The first aerial spraying of synthetic pesticides used large amounts of inert materials, 4000 liters per hectare. This quantity was rapidly reduced to 100 to 200 liters/hectare and by the 1970s the amount had been reduced to 0.3 liter per hectare of the ingredient itself applied directly to the fields. Now-a-days experimentation being conducted for use of drone for application of insecticides in crop fields of India.

Today, some 900 active chemical pesticides are used to manufacture 40,000 commercial preparations. In recent years, compounds that are not classified into nicotinic and diamide insecticides and have or seem to have a variety of novel modes of action have been under development. This is useful in terms of resistance management. It has taken approximately ten years and $ 250 million to discover and develop one insecticide out of approximately 100,000 compounds. Due to the high costs and unique requirements for developing a pesticide, only a handful of companies in the world can afford to continue pesticide research and development (R/D) in the $70 billion pesticide market. To be a successful pesticide researcher nowadays needs to be knowledgeable and skillful in multiple disciplines. Pesticide Research and Development is a high-risk yet high-rewarding business.

Nutri-cereals in Climate-smart Agriculture

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Introduction

With the increase in Global population, climate change and change in dietary habits of today's generation, it has resulted in the reintroduction of millet crops in Agricultural Scenario. In different parts of the World, the level of crop production is plummeting due to factors like declining soil fertility, climate change and deteriorating quality of water. It was reported that nearly 690 million people or 8.9 percent of the global population are hungry, and will be nearly 60 million in five years. The food security challenge will only become more difficult, as the world will need to produce about 70 percent more food by 2050 to feed an estimated 9 billion people (https://www.worldbank.org/en/topic/climate-smart-agriculture).

The challenge is more intensified by extreme vulnerability to climate change. Climate change refers to the rise in average surface temperatures on Earth Increasing average global temperatures are reported to have a direct impact on crop productivity and overall sustainability of food systems. These impacts may be in the form of variability in weather, shifting of agro ecosystem, invasive crops and pests. Extreme weather events are frequently being observed in many parts of the world. Climate change has not only resulted in reducing crop yields but also the nutritional quality of major cereals. Furthermore, most of the scientific community across the world agrees that the current rates of global warming and emissions of greenhouse gas would significantly reduce the overall crop productivity. The agricultural sector is considered as one of the primary contributors to greenhouse gases such as methane into the atmosphere. Currently agriculture activities generate 19–29% of total greenhouse gas (GHG) emissions. Moreover, one third of food produced globally is either lost or wasted. Addressing food loss and waste is critical to helping meet climate goals and reduce stress on the environment.

Climate Smart Agriculture

Climate SMART (Sustainable Management of Agricultural Resources and Techniques) Agriculture is an approach of food production system, which deals with the management of available agricultural resources, with latest management practices and farm machinery, under a particular set of edaphic and environmental conditions. Its main objective is to enhance the achievement of national food security and sustainable development goals. Climate Smart Agriculture (CSA) is location specific, and tailored to fit the agro-ecological and socioeconomic conditions, of a location. CSA may be defined as, "agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances achievement of national food security and development goals." Therefore, implementation of CSA at right time with required resources, techniques and knowledge in a particular typological domain, will lead towards food security, while improving adaptive capacity and mitigating potential for sustainable agriculture production.

CSA aims to simultaneously achieve three outcomes:

1. *Increased productivity*: There is need to produce more and better food to improve nutrition security and boost incomes, especially of 75 percent of the world's poor who live in rural areas and mainly rely on agriculture for their livelihoods.

2. *Enhanced resilience*: Exigencies to reduce vulnerability of agriculture to drought, emerging pests & diseases and other climate-related risks and shocks demand improve capacity to adapt and grow in the face of longer-term stresses like shortened seasons and erratic weather patterns.

3. *Reduced emissions of GHGs*: There is also need to lower emissions of green house gases for each calorie or kilo of food produced, avoid deforestation from agriculture and identify ways to absorb carbon out of the atmosphere.

Need of Nutri-cereals

Climate change poses a serious threat to environment and food. Millet was the staple food since ages. Due to change in lifestyle pattern, food consumption pattern of people has changed and it has lead to low demand for millet and millet processed foods. Changes in climatic conditions have motivated people to try and utilize the natural resources in a sustainable way. There is only one way to use the natural resources in a sustainable way by means of cultivating millets, which are also known as Nutri-cereals. Nutri-cereals are cereals which provide most of the nutrients required for normal functioning of human body. Millets are group of small grained cereal food crops which are highly nutritious and can grown under marginal/low fertile soils with very low inputs such as fertilizers and pesticides. These crops largely contribute to food and nutritional security of the country. Most of millet crops are native of India and are popularly known as Nutri-cereals as they provide most of the nutrients required for normal functioning of human body along with several health benefits. Millets also have high fodder value. Millets are rain fed crops and are grown in regions with low rainfall and thus resume greater importance for sustained agriculture and food security. Based on area grown and its grain size the millets are classified as major millet and minor millets. The major millets include sorghum (jowar) and pearl millet (bajra). The finger millet (ragi/mandua), foxtail millet (kangni/Italian millet), little millet (kutki), kodo millet, barnyard millet (sawan/jhangora), proso millet (cheena/common millet), and brown top millet (korale) are categorized under minor millets. In certain countries of Africa, other millets such as fonio and tef are grown. Millets were the first crops to be domesticated by the mankind in Asia and Africa which later on spread across the globe as critical food sources to the evolving civilizations. All these millets have shorter growing duration complete their life cycle in 2-4 months, fit wide range of cropping systems and also adapt themselves to the changing environmental conditions especially during vagaries of monsoon

Millet as climate change compliant crops

Cereal crops are major source of macronutrients such as carbohydrates, fats and proteins. They also have a significant global warming potential. Among all the major cereal crops, wheat has the highest global warming potential of around 4 tons CO_2 eq/ha followed by rice and maize (around 3.4 tons CO_2 eq/ha). (Jain *et al.,* 2016). Despite their higher emission rates, they are widely cultivated and are primary sources of nutrition for the global population. However, the carbon footprints of millets are comparatively lower. Thus millet cultivation can play the role of an alleviator that could reduce carbon footprint in the world (Prasad and Staggenborg, 2009). Millets are known for its climate compliant characteristics with adaption to a variety of climatic changes, can be grown under less irrigation facilities, less dependent on fertilizers and pesticides and tolerant/resistance to pest and diseases.

Water table in India is decreasing due to increased cultivation of paddy and wheat by farmers (Bhattarai *et al.*, 2021). Increased millet cultivation will help recuperate the depleting water table in India. The General Global Environment Change's report of 2017 has claimed that in comparison with wheat and paddy, millets consume very less water. Millets being C_4 crops; are efficient users of water and nutrients for growth. They are highly tolerant to warmer temperatures and to some extent to flooding. Their tolerance to salinity results in germination and seedling stages results in very good plant stand. As millets possess physiological mechanisms for rapid recovery from abiotic stresses like drought and heat, they are most promising sources for food during climate change. Therefore in the present scenario Millet is being considered as a smart crop. Climate resilient traits of the millet crops are presented in Table 1.

Table 1. Climate resilient traits of the millet crops

Millets	**Crop duration (days)**	**Climate resilient traits**
Pearl millet	80-95	Highly resilient to heat and drought, come up in very poor soils, but responsive to high input management
Sorghum	100-125	Drought tolerant, excellent recovery mechanism from stresses, highly adapted to wide range of soils, altitudes and temperatures, responsive to high input management
Finger millet	90-130	Moderately resistant to heat, drought and humidity, adapted to wide altitude range
Foxtail millet	70-120	Adapted to low rainfall, high altitude
Kodo millet	100-140	Long duration, but very hardy, needs little rainfall, comes up in very poor soils, good response to improved management
Barnyard millet	45-60	Very short duration, not limited by moisture, high altitude adapted
Little millet	70-110	Adapted to low rainfall and poor soils- famine food; withstand water logging to some extent
Proso millet	60-90	Short duration, low rainfall, high altitude adapted
Fonio	75-120	Shorter duration, Adapted to poorly fertile sandy and stony soils, low rainfall
Tef	60-120	Short duration, drought and flood tolerant, high altitude adapted, fit in diverse cropping systems
Brown top millet	60-80	Short duration, adapted to poor soils with less rainfall

There are a number of biotic and abiotic stresses affecting crop productivity. Drastic changes in climate have led to major losses of arable land used for crop production and imposing abiotic stresses such as drought, extreme temperature (cold, frost and heat), flooding, salinity etc. during critical plant growth and development stages causing yield losses. Millets possess numerous morpho-physiological, molecular, and biochemical properties that confer better tolerance to such type of stress than major cereals. Among all major abiotic stresses, increased drought and heat due to climate change adversely affect current crop production and alone cause more annual losses. The different models of climate change predict that drought stress would continue as a major abiotic limitation for food production (Simmons *et al*., 2020). Numerous reports has documented indirect relationship between drought and the rise in malnutrition rates, poor health, hunger, starvation, food and water insecurity (Ye and Fan, 2021). Millets, being naturally drought tolerant, stands as the best alternative in the semi-arid and arid environments. Several studies on millets showed that drought impacts include growth, yield, membrane integrity, pigment, osmotic adjustment, water relations, and photosynthetic activity and also modulates the root-associated microbiome structure and activity (Gupta *et al*., 2017; De Vries *et al*., 2020; Simmons *et al*., 2020). Millets possess different morpho-physiological, biochemical and molecular traits that make them more resistant to drought than major cereals. The rainfall requirement of pearl and proso millet is 20 cm, which is many folds lower than rice, as it requires more than 120–140 cm (Kumar et al., 2018). The life-cycle of millets is short (10–12 weeks) as compared to other major crops (20–24 weeks), which helps them to mitigate stress conditions. Several morphological characters such as short stature, small leaf area, thickened cell walls, and dense root systems also help them survive under the stress (Bandyopadhyay *et al*., 2017). Furthermore, they have a C_4 (Hatch and Slack Pathway) photosynthetic system that is highly advantageous for surviving in high temperatures and low moisture stress conditions. Millets have enhanced photosynthetic rates at warm conditions and confer immediate water and nitrogen use efficiency, which is 1.5 to 4 times higher than other crops having C_3 photosynthesis (Wang et al., 2012). For instance, Foxtail millet requires just 257 g of water to produce 1g of dry biomass, whereas maize and wheat require 470 and 510 g, respectively (Nadeem *et al*., 2020). Additionally, C_4 photosynthesis also provides some secondary benefits to millets, including better growth and performance in warm temperatures, enhanced flexible dry matter partitioning and reduced hydraulic conductivity per unit leaf area (Lundgren *et al*., 2014). The above mentioned distinctiveness offer opportunities for the promotion of these crops to a higher level of production in the changing climate scenario. Despite this, several studies have reported some physiological properties of millets for stress adaptation and mitigation behavior. Bidinger *et al*. (2007) reported on the adaptation of pearl millet flowering phenology to rainfall patterns. Compared to maize, pearl millet can modify their membrane dynamics better for water permeability to manage better water status during osmotic stress (Bandyopadhyay *et al*., 2017). Several biochemical events like regulation of reactive oxygen species (ROS), enhancement of ROS scavenging enzymes and other stress-related proteins, accumulation of antioxidants and osmolytes have been reported in response to abiotic stresses in millets (Ajithkumar and Panneerselvam, 2014). These characteristics of millets make them a suitable model system for research into stress-responsive traits and the mechanisms of stress at the physiological, biochemical, and molecular levels.

Millets can be grown in adverse conditions and thus will be able to save farmers and the agri-food industry. It can be grown in dry soil. Thus, tillage practices can be avoided, reducing the duration of cultivation as well as promoting carbon sequestration (Zarnkow *et al.,* 2010).

Varieties of millets with short growing duration can be incorporated into multiple cropping systems under irrigated and dry farming conditions. Moreover, millets can be stored for a considerable amount of time under appropriate storage conditions, therefore making them "famine reserves" (Michaelraj and Shanmugam, 2013).

Special features of individual millets which make them resilient towards climate change are described below:

1. Sorghum (*Sorghum bicolor L.*), also known as Jowar, can tolerate drought conditions because of its deep root system, waxy leaves, and the presence of mortar cells in the stem. It is more suitable than any other nutri-cereal crop in dryland conditions as it can withstand higher temperatures at any stage of its growth. Sorghum is regarded as a climate-smart crop because of its extreme tolerance to higher temperatures (up to 42^{o}C temperature, drought and salinity (Chaturvedi et al., 2022).

2. Pearl millet (*Pennisetum glaucum L.*), also known as Bajra, can grow on poor sandy soils and is well suited for dry climates due to its ability to use moisture efficiently compared to sorghum or maize. However, unlike sorghum, it cannot resist drought or water stress conditions, but in such conditions it can shorten its life cycle and come to flowering earlier. This is known as the drought escaping mechanism. It can sustain and produce a significant amount of grain even in drought-prone areas receiving an average annual rainfall of less than 250 mm (Nambiar *et al.,* 2011). The crop performs better than other cereals like wheat, maize, rice, sorghum and barley because of its distinctive characteristics like the C_4 plant having high photosynthetic efficiency, the capacity to produce more dry matter production and survive under adverse agro-climatic conditions with fewer inputs and more economic returns (Nambiar et al., 2011). As a C_4 plant, pearl millet can account for 30% of global terrestrial carbon fixation along with other C_4 plants such as maize and sorghum (Choudhury et al., 2020). Due to its inherent capacity to endure high temperatures up to 42^{o}C during the reproductive stage of growth, the crop is suitable for growth in extremely hot summers, thus making it a climate-resilient crop.

3. Finger millet (*Eleusine corocana L.*), also known as Ragi, was earlier considered a minor millet, but presently it's wider adaptability makes it much more popular among other nutri-cereals. It has the best ability to tolerate salinity among cereals.

4. Foxtail millet (*Setaria italica L.*) has a fast ripening mechanism and a high photosynthetic efficiency; hence, it is perfectly suited to be used as a catch crop. It can provide a good yield with only a single pre-sowing precipitation. The crop is more water efficient compared to maize and sorghum (Zhang *et al.*, 2007).

5. Proso millet (*Panicum miliaceum L.*) is a relatively short-duration emergency or quick-season irrigated crop with low moisture requirements. It is a relatively low-demanding crop with no known diseases. Proso millet is well suited for many soil types and climate conditions.

Proso millet is highly drought-resistant, which makes it of interest to regions with low water availability and longer periods without rain. Compared to all other millets, proso millet is a short- season crop, reaching maturity in 60 to 75 days after planting.

6. Barnyard millet (*Echinochloa frumentacea L.*) is a type of millet that is considered a minor cereal and is grown widely in India, China, Japan, Pakistan, Africa, and Nepal. It is a drought-tolerant crop and can be grown in marginal lands with a rapid maturation rate and possesses high nutritional qualities (Wallace et al., 2015).

7. Kodo millet (*Paspalum scorbiculatum L.*) is considered as the coarsest cereal in the world. It is said to possess the highest drought resistance among all minor millets and believed to give a good yield with a growing period lasting 80–135 days (Ravi, 2004), can thrive well in both shallow and deep soil.

8. Little millet (*Panicum sumatrense L.*) matures quickly and withstands both drought and water logging. The grains are similar to those of rice. Its high fibre content makes it a healthy replacement for rice packed with the goodness of B-vitamins, minerals like calcium, iron, zinc and potassium.

Nutritional and health benefits of nutri-cereals

They are a rich source of various nutritional components and possess various beneficial properties. Millets are nutritionally superior compared to other major cereals in their calcium, iron, potassium, magnesium, and zinc content, including other essential molecules such as vitamins, amino acids, and fatty acids (Muthamilarasan and Prasad, 2021).

They are rich in antioxidants (quercetin, curcumin, ellagic acid, and other useful catechins) and are considered an immunity booster. Further, millets aid in detoxification by eliminating harmful toxins, free radicals, and neutralizing enzymes in the organs, eventually preventing various health issues such as cancer and heart disease. Many vitamins (A, B_6, B_{12}, C, D, E, and folate) and trace elements (zinc, copper, selenium, and iron) have been proven to have key roles in supporting the human immune system and reducing the risk of infections.

Millets contain a variety of health-promoting nutrients, including proteins, dietary fibers, phenols, and a low glycemic index, making them ideal for diabetics. Consuming millet products can decrease fasting glucose by 32% and remove insulin resistance by 43% (Muthamilarasan and Prasad, 2021).

High levels of dietary fibre also make them ideal for lowering cholesterol by eliminating toxic "bad cholesterol"(LDL) from the system while supporting the effects of "good cholesterol" (HDL). High fibre and minerals in millet can help to eliminate problems like constipation, excess gas, bloating, and cramping (Rodríguez et al., 2020). They possess a higher nutritional value compared to other cereal crops such as rice and wheat (Awika, 2011).

Conclusion

Climate is the primary determinant of agricultural productivity with a direct impact on food production across the globe. The agriculture sector is the most sensitive sector to climate change because crop cultivation is directly reliant on climate. Food production systems are extremely sensitive to climate changes like changes in temperature and precipitation, which in turn have a direct impact on factors like outbreaks of pests and diseases, thereby reducing harvest and ultimately affecting food security. In such a dire situation, millets can provide a solution for ensuring the food security of a rapidly growing population. Millets are adaptable almost everywhere, right from dry regions with clay soils to wet lowlands or in alluvial lands. Their root systems are powerful, able to descend very quickly to a great depth of soil (sometimes up to 2 meters), which helps to extract water and minerals from deep inside the soil. This characteristic partly explains their quality of hardiness and drought resistance, as well as their high adaptability and resilience to climate change. The U.N. General Assembly recently adopted a resolution, sponsored by India and supported by more than 70 countries, declaring 2023 as the International Year of Millets. The resolution is intended to increase public awareness of the health benefits of millets and their suitability for cultivation under tough conditions marked by climate change. In India, the Assam Millet Mission was also introduced by the Govt. of India to increase the awareness of millet cultivation among the farmers.

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Remote Sensing and GIS as Tool for Mitigating Adverse Effects of Climate Change in Agriculture

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Climate change is very likely to affect food security at the global, regional, and local level. It can disrupt food availability, reduce access to food, and affect food quality (USDA, 2015). Projected increase in temperatures, changes in precipitation patterns, changes in extreme weather events, and reductions in water availability may all result in reduced agricultural productivity. Increases in the frequency and severity of extreme weather events can also interrupt food delivery, and resulting spikes in food prices after extreme events are expected to be more frequent in the future. Mankind is in a critical phase where we are already witnessing the climate change phenomenon and its disastrous impacts. Global temperatures and sea levels are rising, emerging as our planet's most important concerns. The Earth is now about 1.1°C warmer than it was in the late 1800s. The last decade (2011-2020) was the warmest on record. Climate change is commonly defined as a significant fluctuation in average weather conditions over a few decades or more, such as conditions becoming warmer, wetter, or drier. Climate change is distinguished from natural weather variability by its longer-term trend. Effects of climate change are intensifying as the planet continues to warm. Climate change is already affecting every region on Earth, in multiple ways. According to NASA, the average surface temperature of the Earth has risen by about 1.62 degrees Fahrenheit since the 19th century, which is directly attributed to the discharge of carbon dioxide and other greenhouse pollutants into the atmosphere causing severe weather events, sea-level rise, and shrinking ice sheets and glaciers. Major climate risks are temperature and precipitation variability, Drought, flooding and extreme rainfall, Cyclone and storm surge, Sea-level rise, environmental health risks etc. Scientists can closely monitor these threats using remote sensing and GIS techniques. Changes in temperature, atmospheric carbon dioxide (CO_2), and the frequency and intensity of extreme weather could have significant impacts on crop yields. For any particular crop, the effect of increased temperature will depend on the crop's optimal temperature for growth and reproduction. In some areas, warming may benefit the types of crops that are typically planted there, or allow farmers to shift to crops that are currently grown in warmer areas. Conversely, if the higher temperature exceeds a crop's optimum temperature, yields will decline.

Remote sensing refers to the acquisition of data and information about a phenomenon or an object without a direct contact with it. Remotely sensed data with high spatial resolution, along with topographical data processing techniques, provide a very effective tool for understanding and managing natural resources. It offers real-time and precise knowledge about various geographical formations, and landforms and helps to recognize ecosystems that are altered by the natural forces of human activity (Kumar *et al.*, 2010). It is alternative to in-situ observation. Remote sensing techniques are used in numerous fields, including geography, hydrology, ecology, meteorology, oceanography, glaciology, geology, as well as for military scope, intelligence, commercial, economic, planning, and humanitarian applications. Remote sensing technologies can be satellite or aircraft-based and are able to detect and classify objects and characteristics of the Earth system through propagated signals (e.g. electromagnetic radiation). In addition, the use of drones is emerging due to the high-resolution data that can be collected in a short time for real-time monitoring. Recently, remote sensing has been used for improving understanding of the climate system and its changes. It enables to monitor the Earth surface, ocean and the atmosphere at several spatio-temporal scales, thus allowing climate system observations, as well as to investigate climate-related processes or long and short term phenomena, as for example deforestation or El Niño trends. Geographic Information Systems (GIS) using satellite technology can be used for developing early warning and forecasting systems to reduce and manage climate-related disaster risk (i.e. preparing better prediction of cyclone and flood tracks, drought events, fire occurrence).

Researchers are using GIS for climate change information in a variety of ways, including:

- Locating areas where temperatures are unusually high or irregular in comparison to the global average.
- Determine the natural atmospheric processes that affect global warming.
- Developing models to demonstrate how a warming climate might affect the ecology of different regions
- Investigating the relationship between climate change and changes in land cover, such as tree removal.
- Expanding forests and halting deforestation are simple and quick methods to lower CO_2 in the surrounding air and reduce global warming. Monitoring carbon content requires the use of GIS techniques. GIS technology can be used to map forest carbon.
- Software-based GIS mapping and assessment are effective in geographic planning, identifying changes in the environment, and integrating action plans.
- Utilizing GIS data, climate mapping, and estimation for predicted future climate changes.
- GIS climate change simulations can also be used to determine the impact on specific locations.

Carbon emission, through different sources, is a casual factor for global warming, which is the most dreaded problem across the world. Over the past century, human activities like burning of fossil fuels, deforestation and urbanization have resulted in high concentration of CO_2 and other greenhouse gases in the atmosphere (USGS, 2002). Some laboratory experiments suggest that elevated CO_2 levels can increase plant growth. However, other factors, such as changing temperatures, ozone, and water and nutrient constraints, may counteract these potential increases in yield. Though rising CO_2 can stimulate plant growth, it also reduces the nutritional value of most food crops. Rising levels of atmospheric carbon dioxide reduce the concentrations of protein and essential minerals in most plant species, including wheat, soybeans, and rice. This direct effect of rising CO_2 on the nutritional value of crops represents a potential threat to human health. Carbon sequestration is a phenomenon for the storage of CO_2 or other forms of carbon to mitigate global warming. Through biological, chemical or physical processes, CO_2 is captured from the atmosphere. Carbon sequestration is a way to mitigate the accumulation of greenhouse gases in the atmosphere released by the burning of fossil fuels and other anthropogenic activities. Agricultural crops can also act as micro-sinks and cannot be ignored while modelling carbon balance in a region.

Likewise in livestock sector, heat waves, which are projected to increase under climate change, could directly threaten livestock. Heat stress affects animals both directly and indirectly. Over time, heat stress can increase vulnerability to disease, reduce fertility, and reduce milk production. Climate change may increase the prevalence of parasites and diseases that affect livestock. The earlier onset of spring and warmer winters could allow some parasites and pathogens to survive more easily. In areas with increased rainfall, moisture-reliant pathogens could thrive. Climate change would also affect the Aquatic species. Many aquatic species can find colder areas of streams and lakes or move north along the coast or in the ocean. Nevertheless, moving into new areas may put these species into competition with other species over food and other resources.

Flood is the most common of all major disasters that regularly affects the population and results in extensive damages to properties, infrastructure, natural resources, and even loss of lives. Remote sensing and Geographic Information Systems (GIS), have enabled the acquisition and analysis of data about the Earth's surface for flood mitigation projects in a faster, more efficient and more accurate manner. Remote sensing and GIS have emerged as a powerful tool to deal with various aspects of flood management in prevention, preparedness and relief management of flood disaster. GIS facilitates integration of spatial and non-spatial data such as rainfall and stream flows, river cross sections and profiles and river basin characteristics, as well as other information such as historical flood maps, infrastructures, land use, and social and economic data. Such data sets are critical for the in depth analysis and management of floods. The flooding problem is further intensified by inappropriate land use and environmental degradation in areas that are vulnerable to erosion, rapid water runoff, and slope failure. Poor land-use practices (e.g., slash and burn agriculture, quarrying, deforestation, and rapid urbanization and development) lead to heavy sedimentation in river channels, thus, reducing their carrying capacity. In parallel, the removal of vegetative cover leads to much shorter lag times between rainfall and the water reaching the waterways causing the already reduced channels to overflow, leading to massive floods (Ramlal and Baban, 2008). The required physical information includes topography and terrain, soil types, watershed /catchments, land cover and forestry, and the intensity of the triggering factors. Ultimately, flood risk management requires socio-economic data (housing location, valuation data, demographic structure, census information) as well as land use information, administrative boundaries, development pressure, and environmental constraints. Advances in remote sensing technology and new satellite platforms such as ALOS sensors widened the application of satellite data. One of the many fields that these technologies can be applied is to validate flood inundation models. For a long time flood extent from flood inundation models were validated using the ground truth surveys. The most promising application of remote sensing is its use for risk analysis as a function of hazard and vulnerability assessments. The mapping of areas affected by floods is essential for both planning and the assessment of incurred damages as a result of the disaster. Achieving this will require mapping flooded areas before and after flood waters recede. Satellite and aerial remote sensing provides a suitable alternative to traditional field surveying techniques for producing flood inundation maps. Besides, they offer the possibility of validating the output of developed models by comparing the observed extent of the flood with the modelled prediction (Alkcma, 2004; Wilson and Atkinson, 2003). Moreover, the flood prone areas can be mapped and suitable technology can be devised accordingly. For eg. Recently developed stress tolerant rice varieties such as Ranjit sub 1, Bahadur sub 1 and Swarna sub 1 can withstand complete submergence for a period of 14 days. Through flood mapping those areas can be identified where flash flood occurs and flood water remains for almost two weeks and the stress tolerant rice varieties can be advocated. And for the areas where flood water remains for more than a month, deep water rice varieties could be advocated to the farmers for better productivity and profitability.

Conversely, water resource scarcity is also one of the most important challenges for agricultural water management, especially in arid and semi-arid areas all over the world. Due to drought associated with climate change, agricultural water resources has been reduced, hence, it is necessary to achieve maximum production per unit of applied irrigation water. Currently, crop water stress can be detected based on soil moisture content, crop physiological characteristics (e.g., stomatal conductance, leaf water potential) and remote-sensing technology. On-site measurements of soil water content and crop physiological characteristics are time-consuming, laborious and costly, and do not take into account the spatial variability of soil and crops (Li *et al.,* 2010). Measurements of canopy temperature or canopy reflectance based on remote-sensing technology have the advantages of being easy, non-destructive and of low labor intensity (Li *et al.* 2010). Drought is one of the highest natural disasters globally (Paulo *et al.,* 2012). The events are often associated with severe economic losses, reduction in growth domestic product (GDP) growth, crop failure and impact livestock rearing and mortality (FAO, 2006). Drought is one of the most frequent climate-related disasters occurring across large portions of India, often with devastating consequences for the food security of agricultural households (Tadesse, 2018). There is a firm conviction that the use of Satellite Remote Sensing data and Geographical Information System (GIS) can effectively facilitate the detection, identification and mapping of drought risk prone areas. And accordingly suitable water management strategies can be formulated in drought prone areas. Integration of remote sensing, GIS, and simulation modeling for drought early warning further facilitates the process. GIS provides capabilities for mapping and anomaly detection. Integration provides framework for early warning systems. Furthermore, increased availability and higher resolution remote sensing data provides opportunities for near real-time assessment of drought for risk management decision making.

Another use GIS and remote sensing is for the study of environmental sensitivity to desertification. GIS and remote sensing is being used to assess the environmental sensitivity area to desertification. The thematic layers of soil, vegetation, climate, and extent of sand movement are the main data required for estimating the desertification sensitivity index. And prior mitigation measures could be adopted.

In conclusion, it has been clear for decades that the Earth's climate is changing, and the role of human influence on the climate system is undisputed. Stabilizing the climate will require strong, rapid, and sustained reductions in greenhouse gas emissions, and reaching net zero CO_2 emissions. Remote sensing and GIS can act as an important tool for devising proper and prior strategies for combating the effect of climate change on agriculture and allied sector.

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Role of Nutrient Film Technique and Hydroponics in Climate Smart Agriculture

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The average of the weather conditions that is prevalent at a particular point of the earth is termed as "Climate". Normally climate is interpreted in terms of temperature, rainfall and wind conditions based on historical data. Now, a change in the average climate or climate variability that persists over an extended period is called as "Climate Change" (Riedy, 2016).

Interestingly, the Earth's climate has been changing over the years and is often considered as a natural phenomenon then why this hue and cry about climate change. Changes in the Earth's orbit, volcanic activities, the geographic movement of the Earth's land masses and the other internal or external factors has influenced climate. This long-term change in climate is often referred to as "natural climate change" by the scientists. As a consequence of natural climate change, the Earth has gone through a lot of changes from cold periods (or ice age) in the past to the current period which is comparatively warm and stable that has been lasting since many centuries. This period is known as the Holocene by the geologists and is the period where human civilization has flourished.

If this natural climate change was to take place, then it would not have been any concern to the scientists. Contrarily, this is not so because the change in climate is taking place at a much faster rate due to human activities which is termed as "Anthropogenic Climate Change". Human activities like burning fossil fuels, clearing forests for farming and cities, rearing of livestock and releasing of greenhouse gases into the atmosphere are few among the reason. These greenhouse gases have resulted in the greenhouse effect giving rise to Global Warming. The climate change taking place but the magnitude can be felt only over a period of years which has made people reluctant to care for our environment promptly.

Causes of Climate Change

Anthropogenic changes have led to the release of carbon dioxide into the atmosphere leading to its concentration in the atmosphere (Montzka *et al*., 2011). This change in atmospheric CO_2 concentration can effect the microbial activities of the soil, along with changes in soil water content and therefore an increase of atmospheric CO_2 (463-780 ppm) can result in stimulation of nitrous oxide and methane emission from upland soil and wetlands (Groenigen *et al*., 2011). Greenhouse gas emission to the tune of 15% is emitted by agricultural activities which includes primarily methane and nitrous oxide. Another cause is the changing consuming preference towards high value foods such as milk and meat which will lead to even higher rate of emissions. The emission can be decreased either through technological intervention or by changing the consumption pattern towards reduced meat consumption (Popp *et al*., 2010). Livestock being the major contributor of greenhouse gases in agriculture can contribute upto 18% of GHG emissions based on life cycle analysis (Omara, 2011).

The main sources of greenhouse-gas emissions by the livestock sectors include enteric fermentation, N_2O emissions, liming, fossil fuels, organic farming, and fertilizer production (Lesschen *et al.*, 2011). The use of nitrogenous chemical fertilizers also leads to greenhouse-gas emissions (Kahrl *et al.*, 2010). With better management of crop production, N fertilizer use can be lowered by 38%. Better crop management also leads to consumption of 11% less input energy with 33% increased yields, leading to a reduction in greenhouse-gas emissions by 20% (Soltani *et al*, 2013).

Agriculture in relation to climate change

Agriculture is the most vulnerable sector to climate change, owing to its huge size and sensitivity to weather parameters, thereby causing huge economic impacts (Mendelsohn, 2009). The changes in climatic events such as temperature and rainfall significantly affect the yield of crops. The effect of rising temperatures, precipitation variation, and CO_2 fertilization varies according to the crop, location, and magnitude of change in the parameters. The temperature increase is found to reduce the yield, while the precipitation increase is likely to offset or reduce the impact of increasing temperature (Adams *et al*, 1998). As influenced by climatic variables when witnessed in Iran, crop productivity depends on adaptation abilities and crop type, climate scenario, and CO_2 fertilization effect (Karimi *et al.*, 2018). The net revenue of farmers is found to decrease significantly with a decrease in precipitation or increase in temperature in Cameroon. This factor and poor policy-making have led to low demand for Cameroon's agricultural exports, thereby causing fluctuations in national income (Molua and Lambi, 2007). Statistical evidence shows the temperature affects coffee yield in Veracruz, Mexico. It was also found that coffee production may not remain economically viable for the producers in the coming years, as there is an indication of a 34% reduction in current production (Gay *et al.*, 2006). The effect of climate change on the crop yields vary according to the area and irrigation application. Crop yields can be increased by expanding irrigated areas, which can have a detrimental effect on the environment (Kang *et al*., 2009). The rise in temperature is likely to reduce the yield of many crops by reducing their duration (Mahato, 2014). The aggregate production of wheat, rice, and maize is expected to decrease if both the temperate and tropical regions experience a warming of 2 °C (Challinor *et al.*, 2014). Climate change in general has more impact on tropical regions, as tropical crops remain closer to their high-temperature optima, and thereby experience high-temperature stress during elevated levels of temperature.

Hydroponics to mitigate effects of climate change

The sustained increase in global population implies that countries have to increase their food production to support the increase in demand for food. Although the world continues to embrace technology to help meet the rising global food demand, several factors namely climate change, increased demand for land resources, water and energy hamper the world's efficiency in increasing food production (Godfray *et al*., 2010). In particular, volatile climatic conditions impair the ability of farmers to optimise their food production, mainly because of the variability of rainfall patterns. Low volumes and length of rain could lead to drought while increased rainfall volumes and duration could cause floods all of which have adverse effects on the crop production. Similarly, changes in temperatures could also impact negatively on the growth and maturity of the crops. Overreliance on rain fed agriculture further increases vulnerability to climate change as variances in rainfall patterns as a result of climate change is likely to have a devastating effect on the production (Kabubo-Mariara and Kabara, 2018). The combination of these factors have impaired the global capacity to meet the demand for food using the traditional methods of food production, thereby providing an incentive to devise more efficient food production and farming methods.

According to Kang *et al*. (2009) food security in the global sphere is contingent to stable and reliable climactic conditions, mainly because these conditions affect water resources. Water is a primary factor in food production. Consequently, a decline in the volume of water available for agriculture impairs the efficiency of the food production process, with the outcome being food insecurity. Agriculture has been a major casualty with huge losses to crops and livestock occasioned by the frequent climate change induced droughts (Kang *et al*., 2009). These droughts have led to water scarcity posing even a greater threat to the livelihoods of the population whose survival is contingent upon availability of water for irrigation and for consumption by livestock.

Impaired natural resources in turn lead to a decline in agricultural productivity. Views presented by (Ong'are and Omambia, 2019) point to the effect that weather variations and climate change-induced droughts are the leading causes of vulnerability and socio economic threats. It is, therefore, important to develop means to mitigate these vulnerabilities. To that end, one of the proposed measures is to have a means of crop production that is little affected by the climate change induced droughts and constant weather variation. Hydroponics has been identified as one such solution. Lee (2015) notes that climate change does not impose significant effects on the plants produced under hydroponic system and this makes the system sustainable and reliable for an all year production regardless of the weather conditions. Butler and Oebker (2006) note the fast growth rate of hydroponics farming in agricultural production and intimates that it could be the dominant food production system in future. Van os *et al*., (2002) hints on the effectiveness of adopting new technologies to do farming in harsh climates noting that despite Israel having dry and arid climate, it has been highly successful in the production of citrus, bananas, and berries all of which production could have been impossible using conventional farming methods in Israel's climate. Kenya is a developing country that has over the years been unable to ensure adequate agricultural productivity to enhance food security across all the counties, specifically in the rural areas.

Therefore, embracing the use of technology in farming would present a major opportunity to improve agricultural productivity and ensure food security. Hydroponics farming being one such technology would thus cushion from the adverse consequences of climate change.

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Enhancing working Efficiency and drudgery reduction through smart mechanization in agriculture sector

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India being a developing economy with GDP shared 18% in agriculture sector and annual growth rate of 7-9%. Agricultural and its allied sector received a major emphasis as it employed 60% of population. Indian agriculture system is often looked as an industry rather than an activity for food of which mechanization is an utmost important component.

Farm mechanization has shown direct correlation with crop productivity; it not only saves time and labor but also reduces drudgery. In India, both the gender has significant contribution towards the farming sector. Women contribute 70% of major farm work and constitute 60% of the farming population. (NSWF, 2014). Keeping in view of mechanization and efficient agriculture practises along with safe and minimum drudgery of both the genders, scientific and ergonomic approach must be incorporated in all practises starting from small to heavy agricultural practises. Thus, to achieve better performance and efficiency along with higher comfort and safety to the operator, it is necessary to design tools, equipment's and workplaces keeping in view of the anthropometric data of the agricultural workers.

Importance of Ergonomics

Ergonomic is simply Law of Work (Ergon- Work and Nomos- law). Ergonomics is the process or methodology for arranging or designing workplaces, Products, and Systems of a working environment so that they are best fitted for the PEOPLE who work there. Appropriate ergonomic design is necessary to prevent repetitive strain injuries and other musculoskeletal disorders (MSDs), which can develop over time and can lead to long-term disability of both female and male workers.

In agriculture, tools and equipment being manufactured by local artisans and small-scale manufacturers without application of ergonomic principles are low in working efficiency and often failed to reduce the drudgery of operation. The proper matching of machine requirements with the human capabilities is necessity for optimizing performance of man–machine system.

Problems arise while agricultural practises: Fatigue, injury, stress, MSDs, etc.

These problems arise due to forceful gripping, kneeling, lifting, squatting, bending, vibrating machines, twisting, dust, noise etc.

The implementation of ergonomics in system design should make the system work better by eliminating aspects of system functioning that are undesirable, uncontrolled, or unaccounted for, such as-

- Inefficiency – when worker effort produces sub-optimal output.
- Fatigue – in badly designed jobs people tire unnecessarily.

- Accidents, injuries, and errors – due to badly designed interfaces and/or excess stress either mental or physical.
- User difficulties – due to inappropriate combinations of subtasks making the dialogue/interaction cumbersome and unnatural.
- Low morale and apathy.

Design consideration using Anthropometric dimension

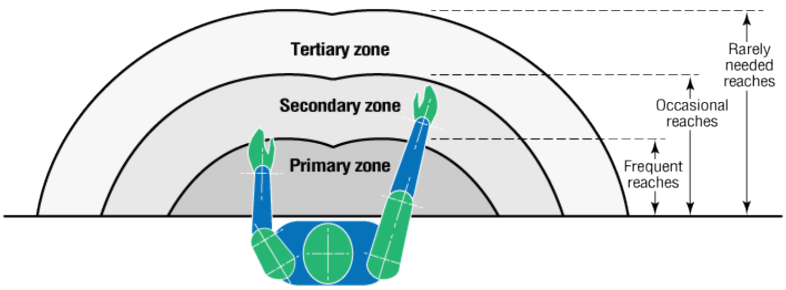
Anthropometric dimension- Anthropometric measurements are those that characterize human body dimensions (size and shape). Human body is a complex system and the force exerted by body parts is called muscle strength which varies from person to person depending upon many factors such as gender, ethnic origin, body dimensions, age and muscular built-up

Virtual simulation

Digital Human Modeling (DHM), the process of CAD representation of human body form or its parts for virtual ergonomic evaluation of human-product compatibility, is being used popularly and effectively all over the world. Application of DHM has been proved to be beneficial for considerable reduction of project timescale; design and manufacturing cost; occupational hazards; and for improvement of quality, productivity and efficiency in diverse industrial sector. Rapid Upper Limb Assessment (RULA) index is one of the most cited and commonly used tools for evaluating ergonomic risk of work-related MSDs. RULA is a subjective observation method for posture analysis that focuses on the upper part of the body with the particular attention to the neck, trunk and upper limbs.

Work Reach envelope

The working reach envelope, with regards to ergonomics, is that area in which a human can comfortably reach. The working reach envelope includes only that space that a worker can reach while maintaining minimal deviation from a neutral arm position.



The working reach envelope should be based on the 5th percentile (the 5% of workers with the smallest reach) so that 95% of workers can reach items in the workspace.

Subjective Assessment

Physiological cost: Physiological cost of human refers to energy expenditure in doing specific work. There is a linear relationship between heart rate, oxygen consumption and the physical work performed by a person. This relationship makes it possible to measure the physiological cost of human work.

Heart rate: Heart rate (HR) is one of the primary physiological parameters identified to increase with physical workload and energy demands. Over moderate work intensities, HR will be measured using polar heart rate monitor (Polar RS800CX, Finland). Most of the agriculture operation required physical engagement so there is adverse effect of heart rate on physiological workload.

Oxygen consumption rate: The oxygen consumption rate (OCR) of subject on their measured WHR will be estimated based on general equation as given by Singh *et al*. (2008):

$$OCR=0.0114\times AWHR-0.68$$

Where, OCR=Oxygen consumption rate, l/min and AWHR= Average working heart rate

Energy expenditure rate: The entire heart rate will be recorded in Heart rate monitor. Energy expenditure rate (EER) will be measured indirectly by measuring oxygen consumption using the formula given by Varghese.

$$EER\ (kJ/min) = 0.159 \times HR - 8.72$$

Classification of Workload (Varghese, 1994)

Physiological Workload	Energy Expenditure (Kj/min)	Heart Rate (beats/min)
Very light	<5.0	<90
Light	5.1-7.5	91-105
Moderately heavy	7.6-10.0	106-120
Heavy	10.1-12.5	121-135
Very heavy	12.6-15.0	135-150
Extremely heavy	>15.0	>150

Work Rest Cycle for worker

For every strenuous work in any field requires adequate rest to have an optimum work out put.

Better performance results can be expected from both the operator and the worker only when proper attention is given for the work rest schedule for different operations. The actual rest time taken for each subject was found from the heart rate response curves of respective operations.

The rest time was measured from the cease of the operation till the heart rate of the subject reaches resting level. The rest pause to the subject was calculated using the following formula as given by Pheasant (1991):

$$R = \frac{T(E-A)}{E-B}$$

Where, R = Resting time (min), T = Total working time/day (min), E = Energy expenditure during working task (kcal/min), A = Average level of energy expenditure considered acceptable (kcal/min) (standard is 4 kcal/min), B = Energy expenditure during rest (kcal/min)

Maximum Aerobic Capacity

The aerobic capacity, i.e., maximal oxygen consumption (VO_{2max}) sets the limit of an individual's cardio-respiratory fitness or capability to give maximum performance. Oxygen uptake, therefore, is an expression of the rate of energy output or rate of work, also expressed as percentage of the individual's maximum aerobic power, i.e., how much of individual's maximum aerobic power has to be taxed in order to complete the work with exhaustion. Since aerobic capacity is higher in men than women, So work efficiency also differs. Weighted average workload for the whole working day, the bodily strains in farm tasks were less than 0.4 times the VO_2 max in the case of men and 0.3 times the VO_2 max in the case of women. The absolute VO_2 max, was less than 2.5 l/min in the case of men and 1.5 l/min in the case of women

Musculoskeletal Disorder (MSD)

Farming is a physically arduous occupation, and this places farm workers at potential risk of musculoskeletal disorders such as osteoarthritis (OA) of the hip and knee, low back pain (LBP), neck and upper limb complaints, and hand–arm vibration syndrome (HAVS). Lifting and carrying heavy loads; work with the trunk frequently flexed; risk of trips and falls on slippery and uneven walkways, exposure to whole-body vibration (WBV) from farm vehicles and hand-transmitted vibration (HTV). MSD is a subjective assessment by using Nordiques questionnaire.

Discomfort Assessment

It is a subjective assessment of subject engaged in farming sector. Basically, of two approach- Body Part discomfort score (BPDS) and Whole-body part discomfort or overall discomfort score (ODR). Assessment of postural discomfort included overall discomfort rating (ODR) and body part discomfort score (BPDS). For this assessment**,** a Borg CR 10-point rating scale (0–no discomfort, 10 - extreme discomfort) will used which is an adoption of Corlett and Bishop (1976) technique.

NASA TLX index assessment

Workload is defined here as the cost incurred by an individual, given their capacities, while achieving a particular level of performance on a task with specific demands. The NASA TLX is a multi-dimensional rating procedure that provides an overall workload score based on a weighted average of ratings on six subscales *viz*.

- Mental Demands- Measure perceptual and mental activity that needed to see, remember, and find something that related
- Physical Demands: Measuring physical activity such as pull, push, etc
- Temporal Demands: Measuring time pressure (slowly or quickly) that can make fatigue
- Performance: Measuring success or failure to complete projects. Score of P that nearly zero score makes a very good categorized.
- Effort: Measuring unsafe, despair, offense, or distraction works while doing the task
- Frustration: Measuring hard work relating to performance level

Vibration

Basically, agricultural machinery such as tractor, power tiller, thresher, grass cutter, chaff cutter etc. produces vibration. Vibration may transmit to the worker engaged with it physically. Vibration is defined as the oscillation of a body about a reference position and can be described, like noise, in terms of amplitude, frequency and phase. The Effects of vibration basically on health, task performance and communication. Vibration may be of two types-hand arm vibration and whole-body vibration. Vibration is measured using accelerometers placed in the workplace or on seats where exposure measurement is required.

- Vibrations in the frequency range 4–8 Hz are particularly hazardous.
- Hand arm vibration- Transmitted from handle to the hands, arms and shoulders causes discomfort and early fatigue during long term exposure to vibration.
- Vehicle operator such as tractor, combine harvester are exposed to whole body vibration which is also an important occupational health risk if its exceed the permissible limit.

Axis	*Frequency (Hz)*	*Effect*
Vertical	0.5	Motion sickness, nausea, sweating
	2	Whole body moves as one Difficulty positioning hands
	4	Vibration transmitted to head Lumbar vertebrae resonate Problems writing or drinking
	4–6	Resonance of gastrointestinal system
	5	Maximum discomfort
	10–20	Voice warbles
	15–60	Vision blurred (resonance of the eyeballs)
Horizontal	<1	Increased postural sway
	1–3	Upper body destabilised
	>10	Backrest is a prime cause of vibration transmission to body

Noise

Agriculture machinery and post-harvest processing machineries are known to produce excessive noise. Farmers/operators are mostly expose to intense noise which may create health issue such as temporary as well as permanent hearing loss. Noise- Typically unpleasant, unwanted or hazardous sound. Sound is an invisible air waves and often referred as Vibrations. It transmitted through ear canal and vibrated eardrum. Our brain then interprets this impulse as sound. Sound has two properties: **Frequency** (How many vibrations occur/second) and **Intensity** (Power or size of sound pressure). Sound or loudness is measured in decibels (dB)- a logarithimic scale that allows small numbers to reflect large numbers. A healthy young person can hear sounds in the range 16–20 000 Hz. The amplitude of sound is evaluated by measuring the sound pressure level (SPL)in dB. The range of SPLs to which the human ear is sensitive is so wide (0.00002 to 20 N/m^2.

The SPL level of agricultural machineries: Tractor-74-112 dB, Combine harvester-80-105 dB, Grain dryer-81-102dB, Power tiller-86-115 dB, Riding mower-79-89 dB, Orchard sprayer-85-106 dB etc.

Duration per day (hours)	**Sound level dB(A) [OSHA limit]**
8	90
6	92
4	95
2	100
1	105
1/2	110
1/4	115

NIOSH recommended exposure limit for occupational noise exposure is 85 dB for 8 hours exposure time. OSHA recommended exposure limit for safe working is 90 dB for 8 hours. If excessive noise level in workplace, the operator should reduce the exposure time. PPE (personal protective equipment) for operator ear can be used where noise level cannot be adequately reduced.

Summery

- ❑ Tools and equipment should be compatible to large target user group
- ❑ Tools and machineries should be user friendly and provision of sufficient adjustment for both the genders to minimize the drudgery, fatigue, and workload
- ❑ To minimize the drudgery and increase the work efficiency, a proper work cycle as well as rest cycle should be followed
- ❑ Keeping in mind the farmers safety, designer should consider the vibration, noise, dusty environments, and climatic control for worker as well as workplace design.
- ❑ Use sufficient protective aids wherever necessary.

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Course Schedule

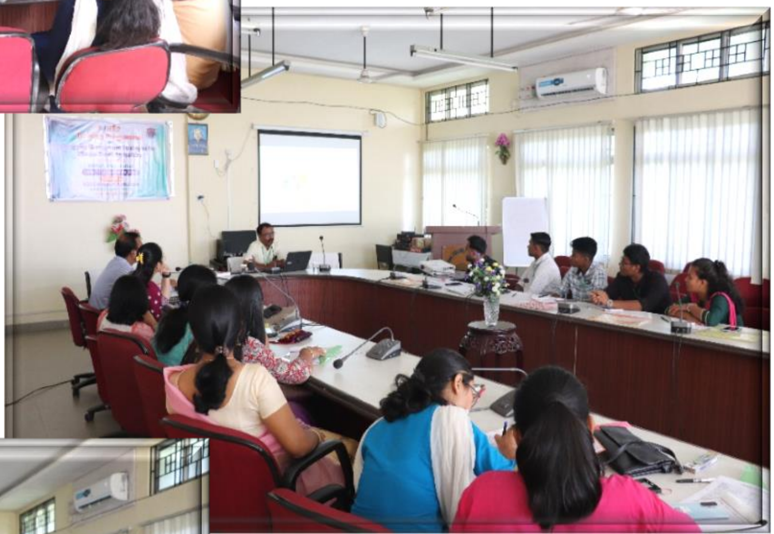
Particulars	Time	Speaker
DAY 1 (*07.11.2022*)		
Registration	09.00 am - 09.30 am	
Inaugural Session	09.30 am -10.30 am	
Pre-training Evaluation	10.30 am -10.45 am	
Tea & Refreshment	10.45 am -11.00 am	
Technical Session		
Impact of climate change on horticultural sector and its mitigation strategies	11.00 am - 12.00 noon	Dr. R. Sarma Associate Dean, SCSCA, AAU, Dhubri
Smart crop varieties for changing climate	12.00 noon- 01.00 pm	Dr. K. K. Sharma Prof. and Head, PBG and Nodal Officer, NAHEP, AAU, Jorhat
Lunch break	**01.00 pm - 02.00 pm**	
Nano fertilizer: Past, present and future	02.00 pm – 03.30 pm	Mr. Binod Saikia Manager, IFFCO
Recent development in insecticide research (Virtual Mode)	03.30 pm –05.00 pm	Dr. K. Saikia Principal Scientist, RRLRRS, Gerua, Assam
DAY 2 (*08.11.2022*)		
Bioremediation: A viable alternative for chemical treatment	10.00 am – 11.30 am	Dr. G. K. Upamanya Assistant Professor, Deptt. of Plant Pathology, SCSCA, AAU, Dhubri
Profit maximization in changing farm scenario (Virtual Mode)	11.30 am – 01:00 pm	Dr. Kishor Goswami Professor, IIT, Kharagpur
Lunch break	**01.00 pm - 02.00 pm**	
Breeding for climate smart agriculture	02.00 pm - 03.30 pm	Mr. Nabajyoti Bhuyan Junior Scientist, RARS, Gossaigaon
Impact of pesticide residue in agricultural produce	03.30 pm - 05.00 pm	Dr. V. Upadhyay Junior Scientist (PP), RARS, Gossaigaon
DAY 3 (*09.11.2022*)		
Role of nutrient film technique and hydroponics in climate smart agriculture	10.00 am – 11.30 am	Dr. S. Saha Assistant Professor, Deptt. of Horticulture, SCSCA, AAU, Dhubri
Remote sensing and GIS as tool for mitigating adverse effect of climate change in agriculture.	11.30 am – 01:00 pm	Dr. Rituporna Saikia SMS (Soil Science) KVK, Kamrup
Lunch break	**01.00 pm - 02.00 pm**	
Impact of agrochemicals on animal products	02.00 pm - 03.00 pm	Dr. F. U. A. Ahmed Senior Scientist and Head, KVK, Dhubri

Role of controlled release fertilizer for climate-smart agriculture	03.00 pm - 04.00 pm	Dr.(Ms.) Aradhana Baruah Assistant Professor, College of Horticulture & FSR, Nalbari
Brain storming session	04.00 pm – 05.00 pm	Dr. H. K. Kalita Prof., SCSCA
DAY 4 (*10.11.2022*)		
Enhancing working efficiency and drudgery reduction through smart mechanization in agriculture sector	10.00 am - 11.30 am	Mr. S.M. Khayer Asst. Professor, Deptt. of Agril. Engg., SCSCA, AAU, Dhubri
Crop adaptability in changing climatic scenario (Virtual Mode)	11.30 am – 01.00 pm	Dr. Dipul Kalita Principal Scientist, NEIST, Jorhat
Lunch break	**01.00 pm - 02.00 pm**	
Emerging trends in aquaculture for adaptation in climate resilient intensive farming system	02.00 pm - 03.00 pm	Mr. Julfikar Ali Fisheries Development Officer, Dhubri
Impact of climate change on agriculture in the Brahmaputra valley of Assam (Virtual Mode)	03.00 pm -04.00 pm	Dr. R. L. Deka Professor, Deptt. of Agrometeorology, AAU, Jorhat
Brain storming session	04.00 pm – 05.00 pm	Dr. D.K. Mazumdar Prof., SCSCA, AAU, Dhubri
DAY 5 (*11.11.2022*)	**Field Visit**	
DAY 6 (*12.11.2022*)		
Nutri-cereals in climate-smart agriculture	10.00 noon – 11.30 am	Dr. P. Ahmed Assistant Professor, Deptt. of Agronomy, SCSCA, AAU, Dhubri
Application of ICT and AI based management strategies in changing agriculture scenario	11.30 am -- 01.00 pm	Er. Benjamin Kaman SMS (Agri. Engg.) KVK, Goalpara
Lunch break	**01.00 pm - 02.00 pm**	
Valedictory session	02.00 pm – 05.00 pm	

List of Participants

Sl. No.	Name	Gender	Designation	Contact No.
1	Dr. Britan Rahman	Male	Assistant Professor	7896052060
2	Dr. (Ms.) Pompy Deka	Female	Assistant professor	8822316241
3	Mr. Bhaskarjyoti Sarma	Male	Assistant Professor	9435092275
4	Dr. (Ms.) Padminee Das	Female	Assistant Professor	8471820791
5	Dr. (Ms.) Barnali Saikia	Female	Assistant Professor	8812062345
6	Dr. (Ms.) Pranamika Sharma	Female	Assistant Professor	8876765383
7	Dr. (Ms.) Sanchita Brahma	Female	Assistant Professor	8753984271
8	Ms. Gitali Handique	Female	Assistant Professor	9401079466
9	Mr. Kishor Kumar Roy	Male	Assistant professor	7002321343
10	Dr. Billal Hoque Choudhary	Male	Assistant Professor	9678491026
11	Mr. Arpan Lahon	Male	4th Year Student	9126873989
12	Mr. Debasish Sarma	Male	4th Year Student	6001339683
13	Mr. Arindom Kalita	Male	4th Year Student	8638737638
14	Ms. Anwesha Barman	Female	4th Year Student	8486020865
15	Mr. Ramijur Rahman	Male	4th Year Student	9365955156
16	Ms. Naina Pegu	Female	4th Year Student	6002981931
17	Mr. Raktim Bharadwaj	Male	4th Year Student	6901930959
18	Ms. Ananya Kashyap	Female	4th Year Student	9435940647
19	Ms. Madhudwisha Chetia	Female	4th Year Student	9957079094
20	Ms. Jenipha Phukan	Female	4th Year Student	6303860295
21	Mr. Sorjoy Kemprai	Male	4th Year Student	6003694824
22	Ms. Liza Gogoi	Female	4th Year Student	9954028207
23	Mr. Bikramjit Deuri	Male	3rd Year Student	7002621885
24	Ms. Ananya Bora	Female	3rd Year Student	7086572386
25	Ms. Prayashi Das	Female	3rd Year Student	7896548398
26	Mr. Samar Jyoti Kakoti	Male	3rd Year Student	8822602997
27	Mr. Raktim Jyoti Deka	Male	3rd Year Student	6000521265
28	Ms. Dhritisikha Rajbongshi	Female	2nd Year Student	9101042935
29	Mr. Rupjyoti Das	Male	2nd Year Student	7578082358
30	Ms. Jahnabi Baishya	Female	2nd Year Student	6001262772

GALLERY




Pompy Deka
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