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EVALUATION OF RKVY PROJECTS

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RAICHUR

“CLIMATE CHANGE AND ITS EFFECT ON IMPORTANT AGRICULTURAL CROPS OF HYDERABAD KARNATAKA REGION”

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CONTENTS

"CLIMATE CHANGE AND ITS EFFECT ON IMPORTANT AGRICULTURAL CROPS OF HYDERABAD KARNATAKA REGION"

EXECUTIVE SUMMARY

The intensified human activities globally have resulted in the use of natural resources which has contributed significantly to the global warming (climate change). Global warming lead to the increase in the concentration of greenhouse gases, namely carbon dioxide, methane, chlorofluorocarbons and nitrous oxide in the atmosphere. On the basis of the increase of these greenhouse gases, climatic models predict a 1.4 ^{o}C to 5.8 ^{o}C average increase in global warming from 1990 to 2100, probably leading to a more rapid increase in temperature at the surface of terrestrial zones and more extreme local variations. Even if the annual flow of emissions did not increase beyond today's rate, the stock of greenhouse gases in the atmosphere would reach double preindustrial levels or 550 ppm CO_2 by 2050 and would continue growing thereafter (Bharath Kumar Neelaboina et al, 2018).

Agriculture is essentially a man-made adjunct to natural ecosystems and is weather and climate dependent. It is also a significant source of anthropogenic emissions of greenhouse gases. Global agricultural reforms are required to deliver the three essential policy objectives of energy, food security and poverty alleviation. Agriculture sector is most vulnerable to climate change due to its high dependence on climate and weather and because people involved in agriculture tend to be poorer compared with urban residents. More than 58 per cent of the population is directly or indirectly relying on agriculture as a source of livelihood in India. Indian agriculture sector is already facing many problems relating to sustainability. Consistent warming trends and more frequent and intense extreme weather events such as droughts, cyclones and hailstorms have been observed across Asia and the Pacific in recent decades (Rohitashw Kumar and Harender Raj Gautam 2014). Indeed, northern parts of Karnatakaare also subjected to such vagaries of climate.

Agriculture is identified within the Convention as particularly vulnerable and particularly critical in terms of global impacts. Agriculture and its allied sectors will inevitably face challenges caused by climate change in future which might lead to both global and local alteration. Enriched atmospheric carbon dioxide (CO_2) and temperature can have various effects at different tropic levels in ecosystems (plants, herbivores, predators and parasitoids).

Indian agriculture faces the dual challenge of feeding a billion people in a changing climatic and economic scenario. Even it is the main source of livelihood for almost 60% of the country's total population. The impacts of climate change on agriculture will be severely felt in India. It has been projected that under the scenario of a 2.5°C to 4.9°C temperature rise, rice yields will drop by 32%-40% and wheat yields by 41%-52% (Anupam Khajuria and N.H. Ravindranath, 2012). This would cause GDP to fall by 1.8%-3.4%. Agricultural productivity is sensitive in two broad classes of climate-induced effects (a) direct effects from changes in temperature, precipitation, or carbon dioxide concentrations and (b) indirect effects through changes in soil moisture and the distribution and frequency of infestation by pests and diseases.

It is against this background, the present project of **"CLIMATE CHANGE AND ITS EFFECT ON IMPORTANT AGRICULTURAL CROPS OF HYDERABAD KARNATAKA REGION"** has been taken up by University of Agricultural Sciences, Raichur at Centre of Agro-climatic studies, College of Agriculture, Raichur. The project was implemented from 2012-13 to 2014-15. The details of the project are as under:

1.	**Title of Project**	**:**	**"CLIMATE CHANGE AND ITS EFFECT ON IMPORTANT AGRICULTURAL CROPS OF HYDERABAD KARNATAKA REGION"**
2.	**Nodal officer and Principal Investigator**	**:**	**Dr. A. G. Sreenivas,** Professor of Entomology and Project Leader on Climate Change, College of Agriculture, University of Agricultural Sciences, Raichur
3.	**Implementing Institution (S) and other collaborating Institution (s)**	**:**	Centre of Agro-climatic studies, College of Agriculture, Raichur
4.	**Date of commencement of Project**	**:**	2012-13
5.	**Approved date of completion**	**:**	2014-15
6.	**Actual date of completion**	**:**	2014-15
7.	**Project cost**	**:**	Rs. 50 lakhs

The objectives of the study are:

1. Collection, compilation, archival and characterization of historical weather parameters of Hyderabad Karnataka Region.
2. To downsize the regional climate change scenarios to local level at a higher resolution of about 50 km on spatial scale as well as daily resolution on temporal scale.

3. To identify and evaluate vulnerable components of various agricultural systems including pests and diseases, and to develop resource management strategies to mitigate climate change impacts.
4. To disseminate the available technologies to the farmers and planners on real time basis through effective communication networking on the adverse effects of climate towards improving the socio-economic status.
5. To identify and develop crop genotypes adaptable to climate change scenarios by utilizing available genetic resources/land races and crop growth simulation models.
6. To develop weather and climate based agro-advisories through GIS medium.

The focus of Evaluation is:

1. to understand the past trends and variability in rainfall, minimum and maximum temperature in Hyderabad Karnataka since the knowledge on the past could provide guidance for the future and also to downsize the regional climate change scenarios to local level at a higher resolution of about 50 km on spatial scale as well as daily resolution on temporal scale..
2. To assess whether vulnerable components of crop growth for adaptation to climate change have been identified for analysis of vulnerability in the face of current climate variability.
3. To examine whether farmers are educated on the resource management strategies to mitigate the effect of vulnerable components on real time basis through effective communication networking besides developing required genotypes to meet the requirements of climate change.

FINDINGS

The focus of Evaluation was to understand the past trends and variability in rainfall, minimum and maximum temperature in Hyderabad Karnataka since the knowledge on the past could provide guidance for the future. However, no serious efforts appear to have been made to understand the past trends and variability in rainfall and temperature. A summary of the past trends as indicated in the report mentions that in the new millennium, Northern Karnataka has faced successive drought years and has also been at the receiving end of many extreme climatic situations, particularly high maximum temperatures in 2004 (more than 40 oC for 10 days during March 2004), lower minimum temperatures in 2007 (5.6 to 8.2oC from November 22-25, 2007), hail storms in 2005 (March 5, 2005), very heavy rainfall on 12th October 2009 (280 mm in Raichur and more in other areas) and unseasonal rains and cloudy conditions during April 2012 (more than 40 mm). The details are very sketchy and need more strengthening in data base.

The studies on crops have shown that, C3 crops like pigeon pea and Bt cotton and C4 crop like maize showed good response to climate change in terms of more growth, yield and yield parameters. However, C3 crops were more benefitted by enriched CO_2.

Biochemically, nitrogen related compounds viz., leaf nitrogen, proteins, amino acids, pigments have decreased while, and the carbon related compounds viz., leaf carbon, C: N ratio, carbohydrates, fatty acids have increased. Hence, these crops may yield more in the changed climatic situations which might be beneficiary to the farmers. Never the less, the studies on insects has given evidence that, climate change in the form of increased CO_2 and temperature have substantial impact on host-herbivore interactions leading to risks of increase in population of some pests and need for management strategies to tackle the problem by breeding resistant genotypes and ensuring that these aberrations do not lead to reduction in crop yields. However, no attempts have been made in this direction.

Studies on climate change provides scientific evidence that, due to climate change, induced stress can alter the endotoxin expression in transgenic crops like Bt cotton (up to 25% and 10 % reduction in endotoxin produced by cry 1Ac and Cry 2Ab2 respectively). This might be one of the reasons for pink bollworm outburst in Bt cotton in recent years in the country. The study needs to be taken up in different regions of the agro climatic zone based on soil type.

In mulberry, the changes in phytochemistry altered the biology of silkworm which was evidenced by decrease in larval weight, increased larval duration, decrease in size, increased pupal duration, decreased cocoon shell, cocoon filament weight, filament length, ERR, productivity, denier in eCO_2 conditions. This shows that in addition to reduction in cocoon yield, there will be increase in rearing period and decrease in quality of cocoons and silk quality.

While all the studies in different crops have revealed impact of yield and quality parameters of different crops, the studies have not identified vulnerable components of climate change and suitable management strategies to mitigate their impact.

To disseminate the available technologies to the farmers and planners on real time basis through effective communication networking, the strategies mainly involved enrolling the farmers in the weather based Agro-services and disseminating the knowledge of daily weather data. Six Automated Weather Stations were installed at all district headquarters of the Hyderabad Karnataka districts. Farmers from all the six districts were enrolled in the weather based Agro-services data base. Daily weather data of the respective districts was communicated to individual farmers of each district by SMS to their mobile phones. These services are reported to have helped to increase the knowledge of the farmers about the farming practices and also get real-time weather information to take up appropriate practices to increase yield and thus increase the monetary benefits. However, the impact of technologies need to be documented.

It is observed that the studies have not been able to identify vulnerable components so that suitable resource management strategies to mitigate the effect of vulnerable components could be developed. In the absence of the strategies to mitigate the effects of climate change, sharing the weather information on real time basis will not help the farmers to take up suitable remedial action to mitigate the impact of climate variability on crop growth. Strategies similar to contingent crop planning could have been developed to ensure that the climate variability does not impact the crop production. Simple strategies such as protective irrigation of crops under prolonged drought periods, sprinkler irrigation to reduce the ambient temperature could have been identified and communicated to farmers. While creation of a huge database of farmers in the Hyderabad Karnataka Area is a welcome and right step in educating the farmers, this database could have been used more effectively in educating the farmers in the area.

REFLECTIONS AND CONCLUSIONS

1. The topic selected for the study is highly relevant to the present-day problems being encountered by farmers in improving their income.
2. The outcome of the project is highly scientific and valuable. However, there is need for convergence of more departments in decision support system as climate change impacts various crop production activities.
3. Good number of technical papers have been published in answering some of the scientific reasons for findings specially in Indian dynamics. The scientists need to be complemented.
4. The study could have made a detailed analysis of past trends in climate variability and made detailed projections on crop production based on future climate variability projections.
5. The study could not downsize the regional climate change scenarios to local level at a higher resolution of about 50 km on spatial scale as well as daily resolution on temporal scale. This could have given a better understanding of the climate variability and helped in development of suitable resource management strategies to mitigate the effects of such variability and also to assess the impact of future projected climate variability and its impact of crop production so that suitable action plan could have been put in place to mitigate its impact.
6. While all the studies in different crops have revealed impact of yield and quality parameters of different crops, the studies have not identified vulnerable components of climate change and suitable management strategies to mitigate their impact.
7. More emphasis should be on C_4 plants response to elevated CO_2 concentration and temperature.

8. There is need for streamlining research in the area of water management and rainfed agriculture more so on climatic variability which is having impact on climate as well as humans.
9. While creation of a huge database of farmers in the Hyderabad Karnataka Area is a welcome and right step in educating the farmers, this database could have been used more effectively in educating the farmers in the area. In the absence of the strategies to mitigate the effects of climate change, sharing the weather information on real time basis will not help the farmers to take up suitable remedial action to mitigate the impact of climate variability on crop growth.
10. Economic impact on crop loss and quality are missing.

ACTION POINTS

1. The topic selected for the study is highly relevant to the present-day problems being encountered by farmers in improving their income. The study could have made a detailed analysis of past trends in climate variability and made detailed projections on crop production based on future climate variability projections. There is need to downsize the regional climate change scenarios to local level to have a better understanding of the climate variability and help in development of suitable resource management strategies to mitigate the effects of such variability. Besides, preparation of vulnerability area index is needed.
2. The outcome of the project is highly scientific and valuable. However, there is need for convergence of more departments in decision support system as climate change impacts various crop production activities.
3. Good number of technical papers have been published in answering some of the scientific reasonings of findings specially in Indian dynamics. The scientists need to be complemented.
4. There is need to identify and evaluate critical vulnerable components of various agricultural systems including pests and diseases, and to develop resource management strategies to mitigate climate change impacts.
5. The observations that induced stress on account of climate change can alter the endotoxin expression in transgenic crops like Bt cotton (up to 25% and 10 % reduction in endotoxin produced by cry 1Ac and Cry 2Ab2 respectively) which might be one of the reasons for pink bollworm outburst in Bt cotton in recent years in the country needs to be validated by a systematic study.
6. While creation of a huge database of farmers in the Hyderabad Karnataka Area is a welcome and right step in educating the farmers, this database could have been used more effectively in educating the farmers in the area by sharing the strategies to mitigate the effects of climate change.
7. Mating Disruption Techniques to control Pink Bollworm infestation in cotton and Direct Seeded Rice technology to save water and reduce methane generation

should be validated and encouraged in all intensive cropping areas of the State, more so in northern parts of Karnataka .

8. There is need for streamlining of research in the area of water management and rainfed agriculture more so on climatic aridity which is having impact on climate as well as humans.
9. Crop diversification in rainfed area and their responses to climate change is needed. Besides, dynamics of soil health status needs to be studied under increased temperature and rainfall distribution through multi-disciplinary approach.

RESEARCHABLE ISSUES

1. Need for research on climate policy on land use changes and long term impact on sustainability of production systems in terms of nutritional quality and economics.
2. Contingent crop planning through diversified farming systems/ cropping systems for climatic aberrations through multi-disciplinary approach.
3. Standardization of agronomic practices for climatic aberrations.
4. Strengthening of breeding strategy for short duration pulses to meet the climatic variations with special reference to biotic and abiotic factors.
5. Documentation of incidence of insect pests and diseases with reference to climatic variations and soil nutritional status.
6. Creation of carbon sink in campus by students.

"CLIMATE CHANGE AND ITS EFFECT ON IMPORTANT AGRICULTURAL CROPS OF HYDERABAD KARNATAKA REGION"

INTRODUCTION

The intensified human activities globally have resulted in the use of natural resources which has contributed significantly to the global warming (climate change). Global warming lead to the increase in the concentration of greenhouse gases, namely carbon dioxide, methane, chlorofluorocarbons and nitrous oxide in the atmosphere. The fourth assessment report of the Inter- Governmental Panel on Climate Change reconfirmed that the atmospheric concentrations of carbon dioxide, methane, and nitrous oxide greenhouse gases have increased markedly since 1750. The report showed that these increases in greenhouse gases have resulted in warming of the climate system by 0.74^{o}C over the past 100 years. On the basis of the increase of these greenhouse gases, climatic models predict a 1.4 ^{o}C to 5.8 ^{o}C average increase in global warming from 1990 to 2100, probably leading to a more rapid increase in temperature at the surface of terrestrial zones and more extreme local variations. Atmospheric concentrations of CO_2 have been steadily rising from approximately 315 ppm in 1959 to a current atmosphere average of approximately 385 ppm. Even if the annual flow of emissions did not increase beyond today's rate, the stock of greenhouse gases in the atmosphere would reach double preindustrial levels or 550 ppm CO_2 by 2050 and would continue growing thereafter. Energy supply and Industry sectors accounts for 26% and 19% of annual GHG emissions respectively (Bharath Kumar Neelaboina et al, 2018).

Agriculture is essentially a man-made adjunct to natural ecosystems and is weather and climate dependent. It is also a significant source of anthropogenic emissions of greenhouse gases. Global agricultural reforms are required to deliver the three essential policy objectives of energy, food security and poverty alleviation.

Agriculture sector is most vulnerable to climate change due to its high dependence on climate and weather and because people involved in agriculture tend to be poorer compared with urban residents. More than 58 per cent of the population is directly or indirectly relying on agriculture as a source of livelihood in India. Indian agriculture sector is already facing many problems relating to sustainability. Consistent warming trends and more frequent and intense extreme weather events such as droughts, cyclones and hailstorms have been observed across Asia and the Pacific in recent decades. To those already daunting challenges, climate change adds further pressure on agriculture adversely affecting the lives of the population particularly the poor farmers.

Climate factors constitute some of the main constraints on crop production. Till recently they have been assumed as exogenous and unchanging. While farming has a history of responding to changing conditions, whether they are economic, social, political or climate related, the potential increase in frequency and intensity of extreme climatic events and other challenges posed by climate change, now gives rise to a need to re-appraise the adaptive capacity of agricultural systems. While the governments throughout the world are assessing the diverse threats posed by climate change, the impacts on agriculture have been identified as potentially the most serious in terms of numbers of people affected and the severity of impacts on those least able to cope.

Agriculture is identified within the Convention as particularly vulnerable and particularly critical in terms of global impacts. Agriculture and its allied sectors will inevitably face challenges caused by climate change in future which might lead to both global and local alteration. Enriched atmospheric carbon dioxide (CO_2) and temperature can have various effects at different tropic levels in ecosystems (plants, herbivores, predators and parasitoids).

The impacts of climate change are likely to be greater on those countries more dependent on primary sector economic activities, primarily because of the increase in uncertainty on productivity on these primary sectors. Impacts include reduction in water availability in already water-stressed areas, changes in the incidence of extreme events such as typhoons and droughts and impacts of sea level rise in low-lying coastal areas (Easterling *et al.,*2007). Modern agriculture has tried to minimise the impacts of climatic and weather uncertainty through irrigation, the substitution of labour with energy-intensive practices and plant breeding for heat or water-stress tolerant crops. Thus, adaptation in agriculture takes places either by farmers individually, by farmers and local institutions collectively, or through national level policy decisions which provide finance, research and development, and knowledge transfer, and property rights or legal frameworks to enable individual or collective action.

The impacts of climate change on agriculture come about through changes in variability, seasonality, changes in mean precipitation and water availability, and the emergence of new pathogens and diseases (Fischlin *et al.,* 2007). Each of these mechanisms is likely to become more significant with higher rising temperatures and clearly the overall impacts of climate change in agriculture depends on the interactions between these mechanisms. The range of projections of climate change by 2100 (1.4-5.8°C by 2100) as per the *Fourth Assessment Report* (AR4) of the IPCC (IPCC, 2007a) comes about both because of uncertainty in the physical models of climate forcing and response, and also from uncertainty about future emissions that are dependent on technological change, human population growth and other factors (O'Neill *et al.,* 2001). Much evidence within the IPCC

Working Group report on impacts adaptation and vulnerability (IPCC, 2007b), suggests that there are impacts related to these projected temperature increases. These include impacts on water stress, on extreme events and on pathogens and diseases that also become more likely and more significant with the projected rising temperatures. In other words, the projected temperature increases for the incoming century will be correlated with rising dangerous impacts of climate change on ecosystems, widespread aggregate impacts, and risk of catastrophic irreversible impacts (Mastandrea and Schneider, 2004; Schneider, 2004).

Agronomic research indicates that higher temperatures associated with climatic change will be harmful to the production of many crop and livestock groups. Where there is water stress, heat stress or a combination of the two, the world's cereal crops can be vulnerable to even minor changes in temperature. The agronomy of all crops will be affected by both temperature and precipitation change and by the increased atmospheric concentration of carbon dioxide. Many plant species respond to enriched CO_2 with enhanced photosynthetic rate and increased biomass. Rice, for example, is predicted to experience increased yield due to CO_2 fertilization at higher concentrations than present (around 380 ppmv). But it is estimated that the net yield increase turns negative as temperature increases by 3 or 4^{o}C. However, these crop model projections often hold precipitation constant and it is seasonal water availability, which most heavily influences crop yield changes, that may, for example, affect the largest grain-growing areas of the Asian sub-continent (see Lal *et al.,* 1998 and Matthews *et al.,* 1997). The feedback impacts of climate change on production of the major crops such as rice and wheat are therefore highly uncertain.

Effects of elevated CO_2 on crop growth and yield:

Studies at plot level over the last few decades have indicated that plant biomass and yield increase significantly at higher than present CO_2 levels. There are two responses involved; the photosynthetic response which leads to increased plant productivity, and the crop yield response. The crop yield response is lower than the photosynthetic response, however it could potentially lead to increases in yield of up to 20% (Ainsworth and Long 2005; Long *et al.,* 2004). The effects of elevated CO_2 on plant growth and yield however will depend on photosynthetic pathway, species, growth stage and management regime (Jablonski *et al.,* 2008; Kimball *et al.,* 2002; Norby *et al.,* 2003). It was recently suggested (Long *et al.,* 2005; 2006) that crop responses to elevated CO_2 were not as high as previously thought, however the latest research (Tubiello *et al.,* 2006) has confirmed the original findings with new results. Suggestions that current impact assessment simulation results are too optimistic in their assumptions about CO_2 response are now shown to be incorrect (Tubiello *et al.,* 2007).

While the effect of CO_2 may show positive effects on plant growth in experiments, the results of plot level experiments are likely to overestimate the reality of the CO_2 response because of complicating factors which occur in the real world and not in the experiments, such as pests and weeds, lack of and competition for other necessary resources, and extreme events. These interactions are not well understood at large scales nor well implemented in leading models (Easterling *et al.,* 2007).

Higher output and increasing inputs-use efficiency in cultivated crops is also realized and the same at much greater pace in C_3 plants (cotton). Study showed that increase in seed cotton yield up to 43% was realized at elevated CO_2 of 550 ppm throughout the crop-growing period. Severe sucking pest problem and dominance of weeds are expected in cotton. Thus, in total, elevated CO_2 favours cotton growth and yield but higher temperature influences these negatively. The effect of climate change on national cotton production system interpreted that increasing CO_2 concentration could help to increase cotton production in all the 3 zones (K Shankaranarayanan et al., 2010). Climate change impacts on crop growth and development that influence yield and fibre quality will most likely be the result of the net effects of increases in CO_2 concentration, reduced water availability and increased atmospheric evaporative demand as a result of lower rainfall and relative humidity and increases in temperature (Bange, 2007).

A number of agronomic practices evaluated under climate change on groundnut showed that the maximum increase in yield was simulated with supplemental irrigation, followed by delay in sowing and growing a longer maturity variety (Piara Singh et al., 2014).

The changing climatic conditions have a major impact on rainfed crops including pulses (Basu *et al.,* 2009). Pulses are reported to be particularly sensitive to heat stress at the bloom stage; only a few days exposure of high temperature (30-35ºC) can cause heavy yield losses through flower drop or pod damage (Siddique *et al.,* 1999). According to the study of Aggarwal, 2009 a 1^{o}C rise in mean temperature would reduce yields of wheat, soybean, mustard, groundnut, and potato by 3-7%.

Effects of elevated CO_2 on insect pests:

Climate change could profoundly affect the abundance, distribution or status of insect pests of crops. The impact of climate change on insect pest populations include changes in phenology, distribution, community composition and ecosystem dynamics that finally leads to extinction of species. There might be expanded pest host ranges, disruption of synchrony between pests and natural enemies, and increased frequency of pest outbreaks and upheavals. Due to the dynamic behaviour of insect populations they respond differently to the forces of climate change and accordingly change their pest status. The enhanced CO_2 level in the atmosphere will result in the more vegetative growth, larger crop canopy and denser foliage will create more relative humidity, thereby making micro-environment more favorable to pests. Increases in food quality, i.e. increase in the nitrogen content of plants due to high temperature, can results in sudden resurgence of population of pests. Moreover, under condition of stress, plant defensive systems are less effective and they become more susceptible to pest attack. As a result of this many minor pests have assumed the status of major pests, many pests have changed from secondary to primary and several new pest problems have appeared in certain regions. There has been an overall decline in the severity of *Helicoverpa armigera* (Hubner), the incidence of mealy bugs, particularly *Phenacoccus solenopsis* Tinsley and *Paracoccus marginatus* on cotton; sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner on sugarcane; tobacco caterpillar, *Spodoptera litura* (Fabricius) on several crops; *Spodoptera mauritia* Boisduval on rice; many species of mirid bug on cotton; *Maruca vitrata* (Geyer) on pigeonpea; silver leaf whitefly, *Bemisia argentifolii* on several crops; grey weevil, *Myllocerus* spp. and sugarcane leafhopper, *Pyrilla perpusilla* Walker on sorghum and pearl millet; wasp, *Tanaostigmodes cajaninae* on pigeonpea; diamondback moth, *Plutella xylostella* (Linnaeus) on cruciferous vegetables; Rhinoceros beetle, *Oryctes rhinoceros* (Linnaeus) on coconut and oil palms; Tea mosquito bug, *Helopeltis antonii* Signoret on cashew; and Sapota seed borer, *Trymalitis marginatus* Meyric is on the rise (Bharath Kumar Neelaboina et al, 2018).

The effect of temperature on insect pests varies and depends on the development strategy of an insect species. Alterations of CO_2 and temperature will affect the insect pests by decreasing their relative growth rate (RGR) and prolonged developmental time in Lepidoptera (leaf chewers) whereas increased abundance and fecundity in homoptera (sap suckers). Changes in foliar chemistry under elevated condition are likely to alter interaction between herbivorous insect and their natural enemies (Bharath Kumar Neelaboina et al., 2018). Changes in foliar chemistry under elevated condition are likely to alter interaction between herbivorous insect and their natural enemies. Though plant biomass increased but their nutritional quality gets deteriorated such as lower nitrogen (N) content, higher C:N ratio, starch, total soluble sugars and polyphenols that affect insect growth, consumption and digestibility. The effect of increased CO_2 and temperature on mulberry plants directly affects the lifecycle of silkworm. Like other lepidopterans silkworm may also feed more quantity of mulberry leaves to balance the deteriorated nutrition in mulberry leaves which may result in increased life cycle. Therefore, it will be interesting to observe the effect of increased feeding by beneficial insects such as mulberry silkworm which feed only on mulberry leaves.

Interactions of elevated CO_2 with other factors:

Although an increase in CO_2 in isolation from other factors is shown to increase crop growth and productivity, these effects will often be countered in reality by other changes in the system. Higher temperatures during certain growth stages may be detrimental to yield and quality (Baker, 2004; Thomas *et al.,* 2003). Increased growth caused by elevated

CO_2 may lead to greater water demand (Xiao *et al.,* 2005), which in many parts of the world may be combined with increasing pressure on water resources, which may also be declining, and hence become a limiting factor. Climate impacts on crops may depend heavily on the precipitation scenario considered. Similarly, the availability of soil nutrients such as nitrogen and phosphorus may also prove to be limiting factors in the CO_2 response. Studies have shown that high soil N contents increase the relative response to elevated CO_2 concentrations (Nowak *et al.,* 2004).

Increased frequency of extreme events:

The increased frequency and intensity of extreme events, such as floods, droughts, heat waves, and windstorms is likely to lead to greater production losses than any increase in mean temperature (Porter and Semenov 2005). Both short duration events such as heatwaves and floods, as well as longer-term events with sustained above normal temperatures have the potential to cause considerable damage to crops and yields depending on their occurrence in the growing season. Large-scale circulation changes such as the El-Niño Southern Oscillation (ENSO) have important impacts on production and therefore GDP. In Australia the effect of the drought in 2002-03 caused a reduction in GDP of 1.6% (O'Meagher 2005). The 2003 heatwave in Europe, which broke several temperature records, resulted in a fall in corn yield in Italy of 36% (Cias *et al.,* 2005), and is likely to be indicative of future summers (Schaer et al*.,* 2004). Understanding the links between increased frequency of extreme events and ecosystem disturbances is very important, however few models consider effects of climate variability as well as mean variables.

Impacts on weeds, pests, diseases and animal health:

Although the qualitative picture of interactions between CO_2 and pests, diseases and weeds are understood, quantitative information is currently still lacking. Interactions between CO_2 and temperature are recognised as a key determinant in plant damage from pests in the future, and interactions between CO_2 and precipitation are also likely to be important (Zvera and Kozlov, 2006; Stacey and Fellows, 2002). However, most studies continue to investigate pest damage in response to either CO_2 (Chakraborty and Datta 2003; Chen *et al.,* 2005) or temperature, but not in combination.

Increased climate extremes may promote plant disease and pest outbreaks. Studies have shown that the spread of animal diseases from low to mid-latitudes is occurring already. Bluetongue, a disease affecting sheep and cattle, and is already spreading from the tropics to the mid-latitudes including France, the United Kingdom and Nordic countries, while cattle tick *(Boophilus microplus)* may affect the Australian beef industry.

Vulnerability of carbon pools:

Climate change has the potential to affect the global terrestrial carbon sink and to further perturb atmospheric CO_2 concentrations (Cias *et al.,* 2005; Betts *et al.,* 2004). Land-use planning and management practices, including set-aside policies, reforestation, and N fertilization, irrigation and tillage practices all have the potential to affect future changes in carbon stocks and fluxes. Carbon stored in soil organic matter has been shown to be affected by atmospheric CO_2 levels (Gill *et al.,* 2002), temperature (Ciais *et al.,* 2005), and air pollution (Loya *et al.,* 2003; Booker *et al.,* 2005), although considerable uncertainty remains. These relationships highlight the importance of co- ordinating adaptation and mitigation strategies and considering the effects of climate policy on land-use change and long-term sustainability of production systems.

Results from integrated assessment and crop models over the 20 years indicate consistently that impacts in the agricultural sector are likely to be small in the first half of 21st century although they are likely to become increasingly negative in the second half as mean temperatures increase (IPCC, 2007; 2001). However, uncertainties which could potentially alter these findings consist of a range of factors, from the strength and saturation point of the elevated CO_2 response of crops grown in real fields rather than experimental plots, to the timing and implementation of adaptation strategies and the interaction between mitigation and adaptation strategies (Tubiello *et al.,* 2007).

Food crop farming:

The possibility for surprise events that are not considered in impact assessments cannot be ruled out. The most recent IPCC report lists three main factors which have not been considered in modelling to date:

- Increases in the frequency of climate extremes may lower crop yields beyond the impacts of mean climate change. Long-term yields may be affected by the increased occurrence of extreme weather events, which may directly damage crops at crucial developmental stages, or may make the timing of field applications more difficult, reducing the efficiency of farm inputs (Porter and Semenov, 2005, Antle *et al.,* 2004).
- Impacts of climate change on irrigation water requirements may be large. Recent studies have found that there may be a global increase of net crop irrigation requirements of 5-8% by 2070, with considerable regional variation (Döll, 2002). Increases in water stress are projected for the Middle East and south-east Asia (Fischer *et al.,* 2007; Arnell, 2004). These increases in irrigation water requirements may undermine any potential positive effect of CO_2 fertilization.
- Stabilisation of CO_2 concentrations reduces damage to crop production in the long term. Overall impacts on global crop production are projected to be significantly less under lower levels of CO_2 stabilisation (Arnell, 2004; Tubiello and Fischer, 2007) (*i.e.* at 550ppm compared to 750ppm or a BAU scenario). In the first half of this century, some regions may be worse off with mitigation than without, because of lower CO_2 levels and resulting lack of CO_2 stimulation effects on crops (Tubiello and Fischer, 2007).

Agriculture as a source of emissions

Emerging scientific evidence on temperature thresholds has injected greater urgency into discussions about how to avoid the consequence of dangerous climate change (IPCC, 2007). This agenda has been supported by *The Stern Review of the Economics of Climate Change* (Stern, 2006), which provides a compelling if contested economic basis for advancing greater spending on mitigation strategies. In most OECD countries there is now a proactive programme to determine where emissions reductions should take place.

Agriculture is a major source of global greenhouse emissions, accounting for an estimated emission of 5.1 to 6.1 Gt CO_2-eq/yr in 2005. This represents 10-12% of total global anthropogenic emissions of greenhouse gases (GHGs) (Smith *et al.,* 2007), although scientific uncertainly also suggests this could be as high as 18-31%. Methane (CH_4), mainly from enteric fermentation, rice cultivation and manure handling, contributes 3.3 Gt CO_2-eq/yr,[1] nitrous oxide (N_2O), from a range of soil and land management practices, contributes 2.8 Gt CO_2-eq/yr. Of global anthropogenic emissions agriculture is estimated to account for about 60% of N_2O and about 50% of CH_4. Despite large annual exchanges of CO_2 between the atmosphere and agricultural lands, the net flux is estimated to be approximately balanced, with CO_2 emissions around 0.04 Gt CO_2/yr only (emissions from electricity and fuel-use are covered in the buildings and transport sector, respectively).

Agriculture and land-use also have large potential to act as sinks of carbon. Forests hold an enormous amount of carbon; however, significant volumes are also stored in soils and peatland. Changes in land-use and tillage practices can result in this carbon being released to the atmosphere.

In addition, climate change itself may lead to the degradation of these resources and their subsequent release of carbon (Pielke *et al.,* 2002) so it is vital to understand the role of land-use (including agriculture, horticulture and forestry) as both an emissions source and sink, and how this could change over time and with increasing levels of climate change.

Globally, agricultural CH_4 and N_2O emissions have increased by nearly 17% from 1990 to 2005, an average annual emission increase of about 60 Mt CO_2-eq/yr. During that period, the five regions composed of Non- Annex I countries showed a 32% increase, and were, by 2005, responsible for about three quarters of total agricultural emissions. The other five regions, mostly Annex I countries, collectively showed a decrease of 12% in the emissions of these gases. OECD (2008) provides a breakdown for member states since 1990.

Global CO_2 concentration has been increased by approximately 30% since the industrial revolution resulted in increase of ~0.66 °C in mean annual global surface temperature.

Without abatement measures, emissions are likely to climb steadily by 1.1% per year, from 6.2 Gt of CO_2 equivalent, to 8.2 Gt CO_2e in 2030 – equal to a 31% increase in emissions over the period, according to McKinsey & Company (2009). The increase is driven mainly by population growth and greater world demand for meat, linked to increased *per capita* GDP. These projections are, however, speculative, depending on demand- side changes (Fiala, 2008). Increasing concern about the magnitude of these emissions has been expressed in relation to the need to distribute mitigation between developing and developed countries (FAO, 2007). In some countries, estimated emissions have already fallen, largely due to falling livestock numbers and, in some regions, further spontaneous cuts are anticipated to deliver similar savings over the next decade or so. However, more aggressive emissions targets need to be developed with some consideration of the economic potential for mitigation within agriculture relative to other sectors. Current estimates suggest that this potential is approximately 1.5-1.6 Gt CO_2e/year (by 2030), which is less than the total technical potential, of around 5.5-6 Gt CO_2e/year (UNFCCC, 2008).

Ultimately there is a need to address agricultural emissions without compromising other objectives for the sector such as food security, environmental sustainability and poverty alleviation.

Impact of climate change on Indian Agriculture and Government Initiatives

Agriculture is extremely vulnerable to climate change. Indian agriculture faces the dual challenge of feeding a billion people in a changing climatic and economic scenario. Even it is the main source of livelihood for almost 60% of the country's total population. The impacts of climate change on agriculture will be severely felt in India. It has been projected that under the scenario of a 2.5°C to 4.9°C temperature rise, rice yields will drop by 32%-40% and wheat yields by 41%-52%. This would cause GDP to fall by 1.8%-3.4%. Agricultural productivity is sensitive in two broad classes of climate-induced effects (a) direct effects from changes in temperature, precipitation, or carbon dioxide concentrations and (b) indirect effects through changes in soil moisture and the distribution and frequency of infestation by pests and diseases (Khajuria and Ravindranath, 2012).

Rainfall in India has a direct relationship with the monsoons which originate from the Indian and Arabian Seas. A warmer climate will accelerate the hydrologic cycle, altering rainfall, magnitude and timing of run-off. Warm air holds more moisture and it will result in an increase in evaporation of surface moisture. Climate change has a direct impact on crop evapotranspiration (ET). In arid regions of Rajasthan state an increase of 14.8 per cent in total ET demand has been projected with increase in temperature. The study further indicates that even a marginal increase in ET demand due to global warming would have a larger impact on the fragile water resources of arid zone ecosystem of Rajasthan. Therefore, change in climate will affect the soil moisture, groundwater recharge, and frequency of flood or drought, and finally groundwater level in different areas. Effect of climate change will affect water cycle. In addition, rise in sea level will increase the risk of permanent or seasonal saline intrusion into ground water and rivers which will have an impact on quality of water and its potential use of domestic, agricultural and industrial uses. Climate change will have number of effects on agriculture.

Higher temperatures and changing precipitation patterns will severely affect the production patterns of different crops. Agricultural productivity will also be affected due to increased carbon dioxide in the atmosphere. All these changes will increase the vulnerability of the landless and the poor. Several recent analyses have concluded that the higher temperatures expected in coming years will disproportionately affect agriculture in the planet's lower latitudes where most of the world's poor live. In such a scenario, agriculture will need better management of natural resources like land, water and genetic resources to make it more resilient. India has made a National Action Plan on Climate Change which was unveiled in 2008. There are eight national missions that would form the core of the national plan. These include national missions for solar energy, enhanced energy efficiency, sustainable habitat, conserving water, sustaining the Himalayan ecosystem, a "Green India", sustainable agriculture and strategic knowledge platform for climate change. However, there are some innovative responses by water utilities to address these climate change risks and it has resulted in pushing the frontiers in a number of areas. It includes desalination, re-use and storm water harvesting and aquifer recharge. It would be worthwhile to give high priority to "more crops per drop" approach, rainwater harvesting, aquifer recharge, revival of water bodies and conservation technologies. In the last decade, the Central Government has tried to address the issue through several initiatives such as subsidies for micro-irrigation (which optimizes water usage for agriculture), national watershed development project for rain fed areas and artificial recharge to ground water through dug wells in hard rock areas and rural water supply enhancement programmed through the catchment area approach.

In 2007, Union Ministry of Water Resources of the country initiated a Farmer Participatory Action Research Programmed in over 2000 villages all over the country to assess the impact of water saving technologies on agriculture production. It has been found that yield and income can be increased by 50 to 100 per cent in most of the crops by using water saving technologies. Additional yield of 1 ton per hectare can be realized through supplemental irrigation. Our agriculture is more prone to monsoon rains as we are growing high water requiring crops like rice and sugarcane. We should increase area under low water requiring but high value crops like pulses and oilseeds to counter the erratic monsoons.

Karnataka is expected to be one of the most vulnerable states to climate change. The coastal areas too are believed to be susceptible. Rainfall and temperature in the state are highly variable. The crops are generally rainfed in nature, and therefore have been at the risk of the vagaries of weather. In this gigantic situation, it is necessary that a multi-disciplinary team works under a single focused umbrella to cope up with adversities of climate change. Hence, in this direction, there was a need to take up research on response of host-plant interactions under climate change conditions which would further help to formulate feasible management strategies. These strategies could further be transferred to the wellbeing of the farming community.

It is against this background, the present project of **"CLIMATE CHANGE AND ITS EFFECT ON IMPORTANT AGRICULTURAL CROPS OF HYDERABAD KARNATAKA REGION"** has been taken up by University of Agricultural Sciences, Raichur at Centre of Agro-climatic studies, College of Agriculture, Raichur. The project was implemented from 2012-13 to 2014-15. The details of the project are as under:

1.	**Title of Project**	**:**	**"CLIMATE CHANGE AND ITS EFFECT ON IMPORTANT AGRICULTURAL CROPS OF HYDERABAD KARNATAKA REGION"**
2.	**Nodal officer and Principal Investigator**	**:**	**Dr. A. G. Sreenivas,** Professor of Entomology and Project Leader on Climate Change, College of Agriculture, University of Agricultural Sciences, Raichur
3.	**Implementing Institution (S) and other collaborating Institution (s)**	**:**	Centre of Agro-climatic studies, College of Agriculture, Raichur
4.	**Date of commencement of Project**	**:**	2012-13
5.	**Approved date of completion**	**:**	2014-15
6.	**Actual date of completion**	**:**	2014-15
7.	**Project cost**	**:**	Rs. 50 lakhs

The objectives of the study are:

1. Collection, compilation, archival and characterization of historical weather parameters of Hyderabad Karnataka Region.
2. To downsize the regional climate change scenarios to local level at a higher resolution of about 50 km on spatial scale as well as daily resolution on temporal scale.

3. To identify and evaluate vulnerable components of various agricultural systems including pests and diseases, and to develop resource management strategies to mitigate climate change impacts.
4. To disseminate the available technologies to the farmers and planners on real time basis through effective communication networking on the adverse effects of climate towards improving the socio-economic status.
5. To identify and develop crop genotypes adaptable to climate change scenarios by utilizing available genetic resources/land races and crop growth simulation models.
6. To develop weather and climate based agro-advisories through GIS medium.

HYPOTHESIS

The context of evaluation arises from the following facts:

1. On an average, the annual rainfall over Karnataka state has decreased by 6% over the period of 1951- 2004. The decrease is higher than average in the coastal and northern parts of the state. Temperatures have increased by all over the state with higher increases (≥ 0.6°C in the last 100 years) in the northern regions.
2. All of the state is projected to experience a warming of 1.8 to 2.2 ^{0}C by the 2030s (relative to the 1970s). The annual rainfall for the north-eastern and south-western parts of the state are projected to decrease. This projection is consistent with decreases that are already being observed over the last 30 years. The north-eastern districts of the state are projected to experience more frequent incidences of drought.
3. In the new millennium, Northern Karnataka has faced successive drought years and has also been at the receiving end of many extreme climatic situations, particularly high maximum temperatures in 2004 (more than 40 oC for 10 days during March 2004), lower minimum temperatures in 2007 (5.6 to 8.2oC from November 22-25, 2007), hail storms in 2005 (March 5, 2005), very heavy rainfall on 12th October 2009 (280 mm in Raichur and more in other areas) and unseasonal rains and cloudy conditions during April 2012 (more than 40 mm). These sudden variation in the climatic factors has severely affected the crop growth and yields.
4. Higher temperatures and changing precipitation patterns will severely affect the production patterns of different crops. Agricultural productivity will also be affected due to increased carbon dioxide in the atmosphere. All these changes will increase the vulnerability of the landless and the poor.
5. Agricultural productivity is sensitive in two broad classes of climate-induced effects (a) direct effects from changes in temperature, precipitation, or carbon dioxide concentrations and (b) indirect effects through changes in soil moisture and the distribution and frequency of infestation by pests and diseases.

6. There is a need to address agricultural emissions without compromising other objectives for the global agricultural sector such as food security, environmental sustainability and poverty alleviation.
7. Agriculture will need better management of natural resources like land, water and genetic resources to make it more resilient. There is need to downsize the regional climate change scenarios to local level at a higher resolution of about 50 km on spatial scale as well as daily resolution on temporal scale.
8. There is need to evaluate vulnerable components of various cropping systems, develop resource management strategies to mitigate the effect of vulnerable components and disseminate these to the farmers and planners on real time basis through effective communication networking.

OBJECTIVES AND ISSUES FOR EVALUATION

The scope of evaluation is to study the impact of scheme, **"CLIMATE CHANGE AND ITS EFFECT ON IMPORTANT AGRICULTURAL CROPS OF HYDERABAD KARNATAKA REGION"** sanctioned under Rashtriya Krishi Vikas Yojane and been taken up by University of Agricultural Sciences, Raichur at Centre of Agro-climatic studies, College of Agriculture, Raichur. The project was implemented from 2012-13 to 2014-15 under the Principal Investigator, Dr. A. G. Sreenivas, Professor of Entomology and Project Leader on Climate Change, College of Agriculture, University of Agricultural Sciences, Raichur. The total cost of the project was Rs. 50 lakhs.

1. Stake Holders

a) University of Agricultural Sciences, Raichur – Sponsorer
b) Rashtriya Krishi Vikas Yojane – as Monitoring Authority
c) Institution of Agriculture Technologists – as Consultant
d) Farmers / beneficiaries as target group of evaluation

2. Purpose of Evaluation

Evaluation Framework

The focus of Evaluation is:

1. to understand the past trends and variability in rainfall, minimum and maximum temperature in Hyderabad Karnataka since the knowledge on the past could provide guidance for the future and also to downsize the regional climate change scenarios to local level at a higher resolution of about 50 km on spatial scale as well as daily resolution on temporal scale..
2. To assess whether vulnerable components of crop growth for adaptation to climate change have been identified and analyse present vulnerability in the face of current climate variability.

3. To examine whether farmers are educated on the resource management strategies to mitigate the effect of vulnerable components on real time basis through effective communication networking.

LOG FRAME

The intention of the project is

a. to evaluate vulnerable components of various cropping/ farming systems besides characterization of weather parameters,
b. develop resource management strategies to mitigate the effect of vulnerable components through development of vulnerable crop index and
c. disseminate these to the farmers and planners on real time basis through effective communication networking.

Evaluation Subject

1. Is there any predictable variability in temperature and rainfall in Hyderabad Karnataka area which can be used in capacity building of the farmers on resource management studies to mitigate vulnerability?
2. Whether vulnerable components of crop growth in the face of climate variability can be identified and evaluated for adaptation to tide over the variability?
3. Whether resource management strategies can be developed and farmers can be educated to mitigate the effect of vulnerable components on real time basis through effective communication networking?

EVALUATION DESIGN

Evaluation design has a rationale of requirement of field level data (primary) that is required to study evaluation objective with respect to beneficiary farmers on one part and the projects taken up for study per se on the other part. The evaluation requires analysis of administration obligations under the two heads and hence a secondary data analysis becomes important and accordingly formats were designed to procure secondary data. The third obligation under evaluation is opinion of stake holders with respect to improvement of the schemes, which require group discussions and exchange of views both in the form of a format, as well as group discussions with the stake holders. The entire evaluation process required a central administration of all activities.

A core team of experts at the Institution level considered three methods to bring a meaningful evaluation of the subject, keeping in mind the scope, evaluation questions and sub-questions duly keeping its focus on the purpose of evaluation. The three methods are:

a. Accessing and analysis of secondary data from the implementing department.
b. Interaction with Principal Investigator and his team.

c. Actual visit to the project site to study and obtain necessary information to elicit answers to the evaluation questions.

DATA COLLECTION AND ANALYSIS

PROGRESS REVIEW

The project was implemented during 2012-13 at Centre of Agro-Climatic Studies, College of Agriculture, Raichur and also at IAAS units at Raichur and Bidar.

Evaluation of vulnerable components of various cropping systems

Four Open Top Chambers with a SCADA (Supervisory Control and Data Acquisition System) were procured and installed during 2012-13. In the subsequent year, three more Open Top Chambers were installed. The project was taken up in crops that included Bt cotton, Pigeonpea, Mulberry, Groundnut and Maize which were grown in the open top chambers (OTC's) under different set of climate change treatments viz., elevated CO_2 @ 550 ± 25 ppm with 2°C rise in temperature, ambient CO_2 of 390 ppm ± 25 ppm with 2°C rise in temperature, elevated CO_2 @ 550 ± 25 ppm with normal temperature, reference open top chamber and reference plot as a control outside in natural condition. Promising genotypes of the respective crops viz., Jadoo and RAHH 909 in cotton, WRP-1 and Gulyal Red in Pigeonpea and DMR-54, DMR-64, DMR-27 and DMR-88 (quality protein genotypes) in maize were tested in preliminary trials to know the crop specific performance under changed climatic conditions. All the physiological growth parameters were recorded at regular intervals. Likewise, the effect of elevated CO_2 and temperature on beneficial insect (silkworm) mediated by crop was undertaken.

Similarly, three Plant Growth Chambers were constructed at Centre of Agro-Climatic Studies, College of Agriculture, Raichur to take up insect-plant interaction studies to know the effect of climate change on them and formulate feasible management strategies. The PGCs were constructed with designed door construction with inner glass door with silicone and outer door with magnetic sealing for dual airtight packing. All the environmental conditions, viz., temperature, CO_2, relative humidity and light were regulated to simulate natural conditions and PGCs were used to study the effect of climate change on insects and diseases mediated by crops under controlled conditions.

The timeline of action of these strategies was 5 years (2012-2017).

The studies revealed the following:

1. Pigeon pea and Maize being a C4 crops showed good response to elevated CO_2 (550 ppm) alone and in combination with temperature (2°C raise than normal) in terms more growth, yield and yield parameters. More yield up to 35 % increase was noticed in some genotypes of Maize while, some genotypes showed decrease in yield. In pigeonpea genotypes, 30-20 % yield increase was noticed in enriched CO_2 conditions. The studies on crops have shown that, C3 crops like pigeon pea and Bt cotton and maize being a C4 crop showed good response to climate change in terms of more growth, yield and yield parameters. However, C3 crops were more benefitted by enriched CO_2. Biochemically, nitrogen related compounds viz., leaf nitrogen, proteins, amino acids, pigments have decreased while, and the carbon related compounds viz., leaf carbon, C: N ratio, carbohydrates, fatty acids have increased. Hence these crops may yield more in the changed climatic situations which might be beneficiary to the farmers.
2. Transgenic and carbon responsive (C3) crop Bt cotton was also subjected to varied climate change treatments by selecting one variety (RAHH 909) and one private popular hybrid (Jadoo). Results revealed that growth, yield and yield parameters were more due to greater responsiveness of Bt cotton to CO_2 which resulted in increased photosynthetic rate leading to increased biomass. Up to 40 % yields were increased in cotton genotypes under elevated CO_2 conditions.
3. The studies on insects has given evidence that, climate change in the form of increased CO_2 and temperature have substantial impact on host-herbivore interactions leading to food web. In future climate change situations, there are risks of increase in population of some pests and with the evidence of our studies, management strategies could be planned by the farmers, scientists could plan to breed resistant genotypes and policy makers could prepare policies keeping these results in mind.

Cotton

The impact of climate change in terms of elevated CO_2 and temperature on two promising cotton genotypes Jaadoo and RAHH-1009 was studied. Elevated CO_2 increased specific leaf weight of cotton which could be attributed to increased carbohydrate accumulation and/or change in leaf thickness. The greater CO_2 responsiveness of photosynthetic rate of plant is expected to result in biomass and yield improvements. The large effect of CO_2 on photosynthesis at high temperature is not observed in all C3 plants as evident from present study where there was no significant difference between CO_2 and temperature treatments.

Studies on climate change provides scientific evidence that, due to climate change, induced stress can alter the endotoxin expression in transgenic crops like Bt cotton (up to 25% and 10 % reduction in endotoxin produced by cry 1Ac and Cry 2Ab2 respectively). This might be one of the reasons for pink bollworm outburst in Bt cotton in recent years in the country.

Groundnut

Significantly lower leaf nitrogen, higher carbon, higher relative proportion of carbon to nitrogen, higher phenols and tannins observed in the groundnut foliage grown under elevated CO_2 levels. Finding have indicated that the changes in the phytochemistry of groundnut under e CO_2 (550 ppm) had led to deterioration of nutritional quality as a result of which, relative consumption rate (RCR) and approximate digestibility was significantly more under e CO_2 + eTemperature (550ppm + 2oC) treatment and lowest in reference plot.

Maize

Most of the morphological, physiological, biochemical and biophysical parameters indicated better performance under elevated CO_2 regime as compared to elevated temperature regime at all growth stages. The results indicated that on doubling the CO_2 level of the existing (350 ppm) at existing temperature, a yield of grain in maize was increased. Unlike effect of CO_2, crop yields were decreased with increase in temperature and the effect is species-specific.

Pigeon pea

There was significant difference among the climate change treatments as well as genotypes for traits such as number of branches, chlorophyll content and NBI while, flavonoids did not vary significantly among all the treatments. A significant positive effect of elevated CO_2 and temperature was found for yield and biomass parameters. Among the two genotypes, WRP-1 performed well under all treatments showing the stability of this genotypes to varied climatic conditions.

Mulberry

The climate change in terms of eCO_2 and temperature has favoured the growth and development of mulberry, as it was evidenced by the accelerated growth rates in terms of plant height, number of leaves, leaf area and leaf area index. The changes in phytochemistry altered the biology of silkworm which was evidenced by decrease in larval weight, increased larval duration, decrease in size, increased pupal duration, decreased cocoon shell, cocoon filament weight, filament length, ERR, productivity, denier in eCO_2 conditions compared to a CO_2 treatment. The data showed great variations in egg laying of silkworm under different treatments. The maximum average number of eggs were laid in reference plot (582.833) and minimum egg laying was recorded in eCO_2 (550 ppm) treatment.

Development of resource management strategies to mitigate the effect of vulnerable components

The strategies were mainly identification and isolation of crop genotypes adaptable to climate change scenarios by utilizing available genetic resources based on physiological responses, biotechnological approaches and later crop growth simulation models.

Investigations on the status of insect pests and diseases in Direct Seeded Rice (DSR) was carried out during 2013-14 in different Agricultural Research Stations and Farmers' fields of jurisdiction of University of Agricultural Sciences, Raichur. Status of insect pests and natural enemies were documented in Direct Seeded Rice and transplanted paddy ecosystem under protected and unprotected conditions. The incidence of yellow stem borer and leaf folder damage was found to be more in Direct Seeded Rice as compared to transplanted paddy in both kharif and rabi seasons. However, sucking insect pests (GLH, BPH, WBPH) incidence was more in transplanted paddy compared to Direct Seeded Rice. The cost of cultivation under DSR was considerably lower (Rs. 29,078/ ha) than transplanted paddy (Rs. 39,063/ ha) cultivation due to reduction in cost towards seeds, nursery raising, transplanting and minimum usage of plant protection chemicals and fertilizers in DSR situation. Cost incurred towards plant protection was higher (Rs. 5,245/ ha) in transplanted paddy compared to DSR (Rs. 4,095/ ha) under protected conditions. The net returns of DSR (Rs. 49,036/ ha) was higher as compared to transplanted paddy (Rs. 44,091/ ha) and input output ratio of DSR was high (2.69) as compared to transplanted paddy (2.13).

Direct Seeded Rice project, apart from for popularising the technology as an alternative to puddled transplanted rice, the method convinced the farmers about the benefits of cost saving (Rs. 6000/acre), water saving (37%) and reduction in methane emission (35%).

The strategy of taking up DSR technique on large scale was taken to farmers' fields by educating the farmers on the benefits of DSR technique vis a vis the transplanted paddy. Farmers have in a large way adopted the technique.

Spread of DSR Technology									
Years	2009-	2010-	2012-	2013-	2014-	2015-	2016-	2017-	2018-
DSR area (acres)	10	1000	10000	50,000	70,000	50,000	70,000	75,000	50000
Water saving: 37 % approximately & Methane gas emission: 35%									
Cost of Cultivation; Transplanting - Rs. 25,000/ac and DSR – 18,000 to 19000/ac									
Insect Pests & Diseases: BPH & sheath blight is low in DSR. In addition, predatory									
Net savings (per acre): Rs.6000 -12000									

Dissemination of resource management strategies on real time basis through effective communication networking.

The strategies mainly involved enrolling the farmers in the weather based Agro-services and disseminating the knowledge of daily weather data. Six Automated Weather Stations were installed in Hyderabad Karnataka districts, viz., ARS, Kalaburagi (Kalaburgi), ARS, Malnoor (Raichur), ARS, Hagari (Ballari), ARS, Bidar (Bidar), ARS, Kawadimatti (Vijayapura) and ARS, Raddewadagi (Kalaburgi). The Automated Weather Station (AWS) is an automated version of the traditional weather station that helps in saving human labour and enables weather measurements from remote areas. An AWS will typically consist of a weather-proof enclosure containing the data logger, rechargeable battery, telemetry and the meteorological sensors with attached solar panel or wind turbine. It automatically records temperature, relative humidity, light intensity, rainfall and wind speed and direction which are logged on to the system.

Farmers from all the six districts were enrolled in the weather based Agro-services data base. Daily weather data of the respective districts, viz., rainfall, temperature (Maximum and minimum) and wind speed was communicated to individual farmers of each district by SMS to their mobile phones. This helped them to prepare for the agricultural operations. Similarly, weather forecast of future /advance was also sent to those field level workers and farmers whoever was accessible to email. Progressive farmers were identified for verification of weather forecast and advisories at two IAAS units (located at Raichur and Bidar).

Weather based Agro-services SMS were sent to farmers of the H-K region on an ongoing basis and as of date 21884 farmers of Raichur district, 16352 farmers of Kalaburagi, 9879 farmers of Ballari and 9060 farmers of Koppal, totaling to 57175 farmers, have been benefitted with this service. These services have helped to increase the knowledge of the farmers about the farming practices and also get real-time weather information to take up appropriate practices to increase yield and thus increase the monetary benefits.

FINDINGS AND DISCUSSION

PAST TRENDS IN CLIMATE VARIABILITY

The focus of Evaluation was to understand the past trends and variability in rainfall, minimum and maximum temperature in Hyderabad Karnataka since the knowledge on the past could provide guidance for the future. However, no serious efforts appear to have been made to understand the past trends and variability in rainfall and temperature. A summary of the past trends as indicated in the report mentions that in the new millennium, Northern Karnataka has faced successive drought years and has also been at the receiving end of many extreme climatic situations, particularly high maximum temperatures in 2004 (more than 40 ^{o}C for 10 days during March 2004), lower minimum temperatures in 2007 (5.6 to 8.2^{o}C from November 22-25, 2007), hail storms in 2005 (March 5, 2005), very heavy rainfall on 12th October 2009 (280 mm in Raichur and more in other areas) and unseasonal rains and cloudy conditions during April 2012 (more than 40 mm). The details are very sketchy and need more data base.

In the Interim Report on Karnataka State Climate Change Action Plan submitted by Bangalore Climate Change Initiative- Karnataka (BCCI-K) headed by Prof. B. K. Chandrashekar to Government of Karnataka, a detailed analysis of climate change variability in Karnataka State over the last 50 years has been made. According to the report, on an average, the annual rainfall over the state has decreased by 6% over the period of 1951- 2004. The decrease is higher than average in the coastal and northern parts of the state.

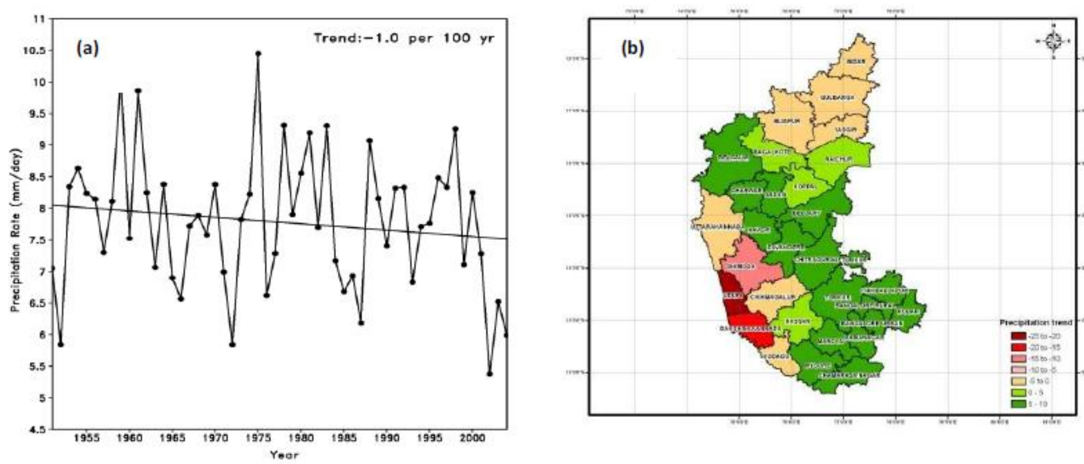

Fig: Time series of precipitation rate during monsoon season (June-September) over the box 11.5-18.5° N, 74–78.5° E in the IMD gridded rainfall analysis.

The analysis of the meteorological measurements of temperature for Karnataka shows a steady warming trend in both the minimum and maximum temperatures. Figure below shows an increase all over the region. Districts of North Interior Karnataka (Bidar, Vijayapura, Kalaburgi, Yadgir and Raichur) experience an increase in minimum temperature of ≥ 0.6°C in the last 100 years. The maximum temperature trend indicates an increase of ≥ 0.6°C in the last 100 years over Kalaburgi, Vijayapura, Bidar, Raichur and Yadgir.

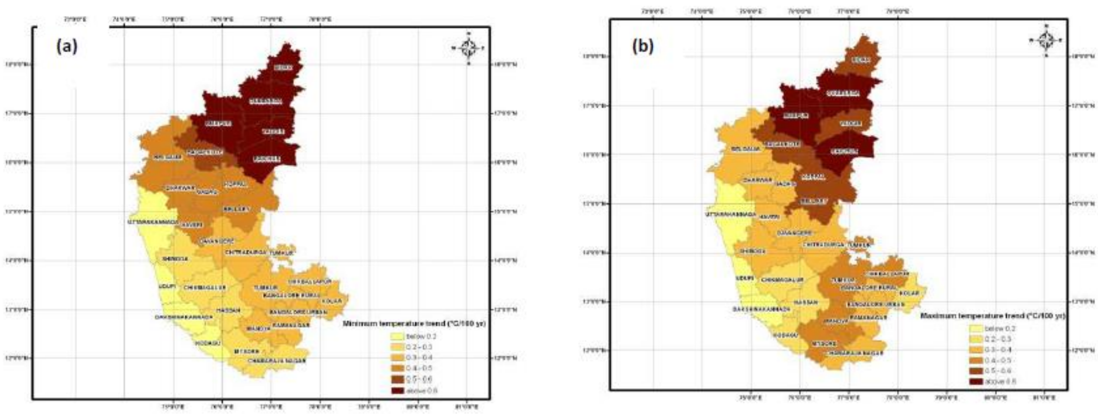

Fig: Spatial pattern of Minimum and Maximum Temperature trends for June, July, August and September (°C per 100 yr) over Karnataka for the period 1901-2002.

Climate change projections have been made using simulation data from the global climate model, HadCM3 from the Hadley Centre, UK (Collins et al., 2001).

The projected increase for annual average temperatures for the northern districts is higher than the southern districts. These regions are expected to experience a warming above 20 °C by 2030s. Most of the state is projected to experience a warming of 1.8 to 2.2 ^{0}C. The northern part of the state also is projected to have higher increases in minimum and maximum temperatures.

The north-eastern and south-western parts of the state are projected to experience decrease in the quantum of rainfall, annually. This roughly correlates with observed trends over the last 30 years. Over the JJAS (June July August September) season too, north-eastern and south-western parts of the state are projected to experience reduced amounts of rainfall

A period of absence of rainfall (daily rainfall < 2.5 mm) for 40 or more contiguous days is defined as “an incidence of severe drought”. This agrees with the FAO definition of droughts. Further, we identify two major growing seasons in Karnataka: *Kharif* (July 2nd week to October 2nd week) and *Rabi* (September 1st week to February 4th week). The number of incidences of severe droughts are estimated for 2021-2050 for each grid point and compared to the baseline. The percentage increase is calculated; this increase gives an indication of possible increases in drought instances for that grid-point. Grids that are not drought-prone (number of severe drought instances less than 10 in the 30-year baseline) are excluded. The results of the analysis are shown in the following figure.

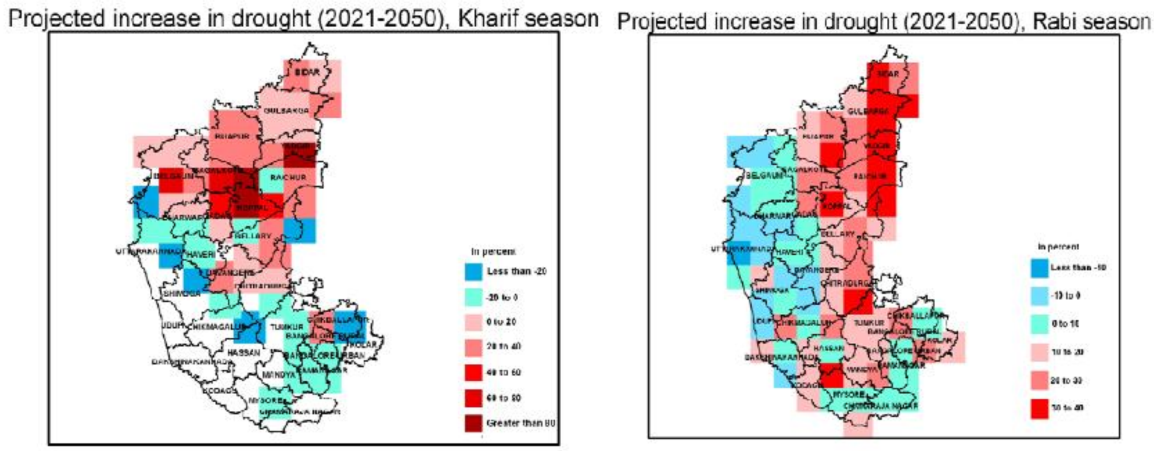

Fig: Projected increase in drought during kharif and rabi season in Karnataka (2021-2050)

In the Kharif season, most northern districts are projected to have an increase in drought incidences by 10-80%. Districts of Koppal and Yadgir are projected to have almost a doubling of drought frequency in the Kharif season. In the Rabi season, drought frequency is projected to increase in most of the eastern districts of the state. The western parts of the state are projected to have more rainfall and hence a smaller number of droughts in the Rabi season.

The present study should have kept these observations in view and downsized the regional climate change scenarios to local level at a higher resolution of about 50 km on spatial scale as well as daily resolution on temporal scale. This does not appear to have been attempted. This could have given a better understanding of the climate variability and helped in development of suitable resource management strategies to mitigate the effects of such variability. This could also have been used to assess the impact of future projected climate variability and its impact of crop production so that suitable action plan could have been put in place to mitigate its impact. Further, it would have been better if there was convergence of similar departments like IMD and KSMD.

PROJECTED IMPACT OF CLIMATE VARIABILITY ON CROPS

The impact of projected climate change (2071-2100) and its likely impact on groundnut yield of Saurashtra region of Gujarat simulated using DSSAT (v 4.5) model revealed that the pod yield of groundnut is likely to decrease during the projected period by 20 to 34% in different districts (Rajkot, Bhavanagar, Kesod and Bhuj). Further delay in the sowing (15 days after onset of monsoon) reduces the pod yield by 2 to 7%. The biomass of groundnut may decrease by 20 to 36% and the LAI will decrease even more (42-47%). The duration of anthesis date of groundnut may get reduced by 23 to 36% while maturity date reduced by 7- 16% in different districts of Saurasthra under projected period (2071-2100) as compared to the baseline period. Reduction in groundnut phenological duration, growth and development under projected climate might be attributed only because of air and soil temperatures above optimum can cause significant yield loss in peanut (Patel et al, 2013).

Simulation of the crop yield rice, groundnuts, and sugarcane under a plausible change in climate for the coastal areas of South India through the end of this century using the Decision Support System for Agrotechnology Transfer (DSSAT) 4.5 model reveal that under the RCP 4.5 scenario there will be decreases in the major C3 and C4 crop yields in the study area. This would affect not only the local food security, but the livelihood security as well. This necessitates timely planning to achieve sustainable crop productivity and livelihood security. On the other hand, this situation warrants appropriate adaptations and policy intervention at the sub-district level for achieving sustainable crop productivity in the future (Ramachandran et al, 2017).

Impact assessment of maize yield to temperature rise showed reduction in yield in both Delhi and Patna with atmospheric temperature rise during the kharif season with percentage reduction was similar in both locations. In rabi crop, future temperature increases initially showed a positive response up to 2^oC. Climate change is projected to reduce kharif maize yield in India, however, projected increase in rainfall may be beneficial in some locations during rabi season (Satyavan Singh et al 2010).

In all the above projections yield reduction on account of future projection of climate variability has been attributed. This necessitates timely planning to achieve sustainable crop productivity and livelihood security.

CLIMATE CHANGE IMPACT STUDY RESULTS

The studies on crops have shown that, C3 crops like pigeon pea and Bt cotton and C4 crop like maize showed good response to climate change in terms of more growth, yield and yield parameters. However, C3 crops were more benefitted by enriched CO_2. Biochemically, nitrogen related compounds viz., leaf nitrogen, proteins, amino acids, pigments have decreased while, and the carbon related compounds viz., leaf carbon, C: N ratio, carbohydrates, fatty acids have increased. Hence these crops may yield more in the changed climatic situations which might be beneficiary to the farmers. However, the studies on insects has given evidence that, climate change in the form of increased CO_2 and temperature have substantial impact on host-herbivore interactions leading to risks of increase in population of some pests and need for management strategies to tackle the problem by breeding resistant genotypes and ensuring that these aberrations do not lead to reduction in crop yields.

Studies on climate change provides scientific evidence that, due to climate change, induced stress can alter the endotoxin expression in transgenic crops like Bt cotton (up to

25% and 10 % reduction in endotoxin produced by cry 1Ac and Cry 2Ab2 respectively). This might be one of the reasons for pink bollworm outburst in Bt cotton in recent years in the country. Indeed, this work needs more concentrated efforts to understand the long term effect on economics of crop production in coming days.

IDENTIFICATION OF VULNERABLE COMPONENTS

The studies revealed no large effect of CO_2 on photosynthesis at high temperature in all C3 plants. This shows that there may not be any appreciable increase in yield on account of higher CO_2 concentration and higher temperature. It was also observed that due to climate change, induced stress can alter the endotoxin expression in transgenic crops like Bt cotton (up to 25% and 10 % reduction in endotoxin produced by cry 1Ac and Cry 2Ab2 respectively). This might be one of the reasons for pink bollworm outburst in Bt cotton in recent years in the country. However, this observation needs to be validated by a systematic study.

Significantly lower leaf nitrogen, higher carbon, higher relative proportion of carbon to nitrogen, higher phenols and tannins were observed in the groundnut foliage grown under elevated CO_2 levels. Finding have indicated that the changes in the phytochemistry of groundnut under eCO_2 (550 ppm) had led to deterioration of nutritional quality of grains/ produce..

In mulberry, the changes in phytochemistry altered the biology of silkworm which was evidenced by decrease in larval weight, increased larval duration, decrease in size, increased pupal duration, decreased cocoon shell, cocoon filament weight, filament length, ERR, productivity, denier in eCO_2 conditions. This shows that in addition to reduction in yield, there will be increase in rearing period and quality of cocoons is also affected.

While all the studies in different crops have revealed impact of yield and quality parameters of different crops, the studies have not identified vulnerable components of climate change and suitable management strategies to mitigate their impact.

DISSEMINATION OF RESOURCE MANAGEMENT STRATEGIES

The strategies mainly involved enrolling the farmers in the weather based Agro-services and disseminating the knowledge of daily weather data. Six Automated Weather Stations were installed at all district headquarters of the Hyderabad Karnataka districts. Farmers from all the six districts were enrolled in the weather based Agro-services data base. Daily weather data of the respective districts was communicated to individual farmers of each district by SMS to their mobile phones. These services are reported to have helped to increase the knowledge of the farmers about the farming practices and also get real-time weather information to take up appropriate practices to increase yield and thus increase the monetary benefits.

It is observed that the studies have not been able to identify vulnerable components so that suitable resource management strategies to mitigate the effect of vulnerable components could be developed. In the absence of the strategies to mitigate the effects of climate change, sharing the weather information on real time basis will not help the farmers to take up suitable remedial action to mitigate the impact of climate variability on crop growth. Strategies similar to contingent crop planning could have been developed to ensure that the climate variability does not impact the crop production. Simple strategies such as protective irrigation of crops under prolonged drought periods, sprinkler irrigation to reduce the ambient temperature could have been identified and communicated to farmers. While creation of a huge database of farmers in the Hyderabad Karnataka Area is a welcome and right step in educating the farmers, this database could have been used more effectively in educating the farmers in the area.

REFLECTIONS AND CONCLUSIONS

1. The topic selected for the study is highly relevant to the present-day problems being encountered by farmers in improving their income and sustainability.
2. The outcome of the project is highly scientific and valuable. However, there is need for convergence of more line departments in decision support system as climate change impacts various crop production activities.
3. Good number of technical papers have been published in answering some of the scientific reasons for findings specially in Indian dynamics. The scientists need to be complemented.
4. The study could have made a detailed analysis of past trends in climate variability and made detailed projections on crop production based on future climate variability and vulnerability projections.
5. The study could not downsize the regional climate change scenarios to local level at a higher resolution of about 50 km on spatial scale as well as daily resolution on temporal scale. This could have given a better understanding of the climate variability and helped in development of suitable resource management strategies to mitigate the effects of such variability and also to assess the impact of future projected climate variability and its impact of crop production so that suitable action plan could have been put in place to mitigate its impact.
6. While all the studies in different crops have revealed impact of yield and quality parameters of different crops, the studies have not identified vulnerable components of climate change and suitable management strategies to mitigate their impact.
7. More emphasis should be on C_4 plants response to elevated CO_2 concentration and temperature.
8. There is need for streamlining research in the area of water management and rainfed agriculture more so on climatic variability which is having impact on climate as well as humans.
9. While creation of a huge database of farmers in the Hyderabad Karnataka Area is a welcome and right step in educating the farmers, this database could have been used more effectively in educating the farmers in the area. In the absence of the strategies to mitigate the effects of climate change, sharing the weather information on real time basis will not help the farmers to take up suitable remedial action to mitigate the impact of climate variability on crop growth.
10. Economic impact on crop loss and quality are missing.
11. There is no attempt to study impact on agricultural systems in the regions as envisaged in the objectives.
12. The process of dissemination of technology is some what weak and needs to be strengthened.

DEVELOPMENTS / IMPROVEMENTS AFTER THE STUDY

The infrastructure created by the study included establishment of Centre for Agro-climatic Studies, installation of Open Top Chambers, Plant Growth Chambers and Automated Weather Stations ate six places and purchase of equipment like BOD incubators, CO2 analyser, Portable Photosynthesis System Infra-Red Gas Analyser (IRGA), Hand held NDVI Optical Sensor unit, Flavonoid Chlorophyll Meter, Leaf Area Meter, Aquaterr Digital Soil Moisture Meter, etc. This has helped the University to assign research works related to Climate Change to 12 students enrolled for Masters' and Doctoral degrees. Further two externally funded ad-hoc projects relating climate change have been taken up.

Human resource development in terms of two national training programme on climate change were organized. One day workshop "Statistical Methods for Insect Pests and Disease Forecasting" under DST- ICRISAT Center of Excellence on Climate Change Research for Plant Protection: Pest and Disease Management for Climate Change Adaptation was held. However, the impact assessment on capacity building of human resources development needs to be strengthened.

ACTION POINTS

1. The topic selected for the study is highly relevant to the present-day problems being encountered by farmers in improving their income. The study could have made a detailed analysis of past trends in climate variability and made detailed projections on crop production based on future climate variability projections. There is need to downsize the regional climate change scenarios to local level to have a better understanding of the climate variability and help in development of suitable resource management strategies to mitigate the effects of such variability. Besides, preparation of vulnerability area index is needed.
2. The outcome of the project is highly scientific and valuable. However, there is need for convergence of more departments in decision support system as climate change impacts various crop production activities.
3. Good number of technical papers have been published in answering some of the scientific reasonings of findings specially in Indian dynamics. The scientists need to be complemented.
4. There is need to identify and evaluate critical vulnerable components of various agricultural systems including pests and diseases, and to develop resource management strategies to mitigate climate change impacts.
5. The observations that induced stress on account of climate change can alter the endotoxin expression in transgenic crops like Bt cotton (up to 25% and 10 % reduction in endotoxin produced by cry 1Ac and Cry 2Ab2 respectively) which might be one of the reasons for pink bollworm outburst in Bt cotton in recent years in the country needs to be validated by a systematic study.
6. While creation of a huge database of farmers in the Hyderabad Karnataka Area is a welcome and right step in educating the farmers, this database could have been used more effectively in educating the farmers in the area by sharing the strategies to mitigate the effects of climate change.
7. Mating Disruption Techniques to control Pink Bollworm infestation in cotton and Direct Seeded Rice technology to save water and reduce methane generation should be validated and encouraged in all intensive cropping areas of the State, more so in northern parts of Karnataka .
8. There is need for streamlining of research in the area of water management and rainfed agriculture more so on climatic aridity which is having impact on climate as well as humans.
9. Crop diversification in rainfed area and their responses to climate change is needed. Besides, dynamics of soil health status needs to be studied under increased temperature and rainfall distribution through multi-disciplinary approach.

RESEARCHABLE ISSUES

7. Need for research on climate policy on land use changes and long term impact on sustainability of production systems in terms of nutritional quality and economics.
8. Contingent crop planning through diversified farming systems/ cropping systems for climatic aberrations through multi-disciplinary approach.
9. Standardization of agronomic practices for climatic aberrations.
10. Strengthening of breeding strategy for short duration pulses to meet the climatic variations with special reference to biotic and abiotic factors.
11. Documentation of incidence of insect pests and diseases with reference to climatic variations and soil nutritional status.
12. Creation of carbon sink in campus by students.

VISIT OF THE EVALUATION TEAM TO OPEN TOP CHAMBERS

REFERENCES

Aggarwal, P.K. 2009. Vulnerability of Indian Agriculture to Climate Change: Current State of Knowledge. Unpublished manuscript, Indian Agricultural Research Institute, New Delhi, Available online at http:// moef.nic.in/downloads/others/Vulnerability_PK%20 Aggarwal.pdf

Ainsworth, E.A. and S.P. Long (2005), "What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analysis of the responses of photosynthesis, canopy properties and plant production to rising CO_2", *New Phytol*., 165.

Antle, J.M., S.M. Capalbo, E.T. Elliott and K.H. Paustian (2004), "Adaptation, spatial heterogeneity, and the vulnerability of agricultural systems to climate change and CO_2 fertilisation: an integrated assessment approach", *Climate Change*, 64.

Arnell, N.W. (2003), "Effects of IPCC SRES emissions scenarios on river runoff: a global perspective", *Hydrology and Earth System Science,* 7.

Arnell, N.W. (2004), "Climate change and global water resources: SRES emissions and socio-economic scenarios", *Global Environmental Change,* 14.

Arnell, N.W. and E.K. Delaney (2006), "Adapting to climate change: public water supply in England and Wales", *Climatic Change*.Baker, J.T (2004), "Yield responses of southern US rice cultivars to CO_2 and temperature", *Agr. For. Meterol*., 122.

Bange, M. (2007). Effects of climate change on cotton growth and development. *The Australian Cotton Grower,* 40-45.

Basu, P.S., Ali, M. and Chaturvedi, S.K. 2009. Terminal heat stress adversely affects chickpea productivity in northern India- Strategies to improve thermo tolerance in the crop under climate change. ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture, pp. 189-193.

Betts, R.A. (2000), "Offset of the potential carbon sink from boreal forestation by decreases in surface albedo", *Nature,* 408.

Bharath Kumar Neelaboina, Gulzar Ahmadkhan, Shiva Kumar, Mudasir Gani, Mir Nisar Ahmad and MK Ghosh, Impact of climate change on Agriculture and Sericulture, *Journal of Entomology and Zoology Studies* 2018; 6(5): 426-429

Booker, F.L., S.A. Prior, H.A. Torbert, E.L. Fiscus, W.A. Pursley and S. Hu (2005), "Decomposition of soybean grown under elevated concentrations of CO_2 and O_3", *Global Change Biology*, 11.

Chakraborty, S. and S. Datta. (2003), "How will plant pathogens adapt to host plant resistance at elevated CO_2 under a changing climate?", *New Phytol,* 159.

Chen, F.J., G.E. Feng and M.N. Parajulee (2005), "Impact of elevated CO_2 on tritrophic interaction of *Gossypium hirsutum, Aphis, gossypii*, and Leis *axyridis", Environmental Entymology*, 34.

Ciais, P. *et al.* (2005), "Europe-wide reduction in primary productivity caused by the heat and drought in 2003", *Nature,* 437.

Collins, M., Tett, S.F.B., and Cooper, C. (2001). The internal climate variability of HadCM3, a version of the Hadley Centre coupled model without flux adjustments. *Climate Dynamics* 17: 61–81

Döll, P. (2002), "Impact of climate change and variability on irrigation requirements: a global perspective", *Climatic Change,* 54.

Easterling, W.E. *et al.* (2007), "Food, fibre and forest products" in

Food and Agriculture Organization of the United Nations [FAO, Rome] (2007), *Livestock's long shadow: environmental issues and options, CRC* version CLIMATE 210by297.doc.

FAO (2009), "Enabling agriculture to contribute to climate change mitigation. A submission by the Food and Agriculture Organization to the UNFCCC", http://unfccc.int/resource/docs/2008/smsn/igo/036.pdf.

Fischlin, A. *et al.* (2007), "Ecosystems, their properties, goods, and services" in M.L. Parry *et al.* (eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge University Press.

Gill, R.A. *et al.* (2002) "Nonlinear grassland responses to past and future atmospheric CO_2", *Nature*, 417.

IPCC (2006), IPCC Guidelines for National Greenhouse Gas Inventories: 2006, prepared by the National Greenhouse Gas Inventories Programme, IPCC, Japan.

IPCC (2007a), "Summary for Policymakers", in S. Solomon et al. (eds), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom; and New York, United States.

IPCC, (2007b), M.L. Parry et al. (eds), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom.

Jablonski, L.M., X. Wang and P.S. Curtis (2008), "Plant reproduction under elevated CO_2 conditions: a meta-analysis of reports on 79 crop and wild species", *New Phytology*, 156.

Khajuria A, Ravindranath NH (2012) Climate Change in Context of Indian Agricultural Sector. *J Earth Sci Climate Change* 3:110. doi:10.4172/2157-7617.1000110

Kimball, B.A., K. Kobayashi and M. Bindi (2002), "Responses of agricultural crops to free-air CO_2 enrichment", *Adv. Agron*, 77.

Lal, M., K.K. Singh, L.S. Rathore, G. Srinivasan and S.A. Saseendrean (1998), "Vulnerability of rice and wheat yields in north-west India to future changes in climate", *Agriculture and Forest Meteorology*, 89.

Long, S.P., E.A. Ainsworth, A.D.B. Leakey and P.B. Morgan (2005), "Global food insecurity. Treatment of major food crops with elevated carbon dioxide or ozone under large-scale fully open-air conditions suggests recent models may have overestimated future yields", Philosophical Transactions of The Royal Society: Biological Sciences, 360

Loya, W.M., K.S. Pregitzer, N.J. Karberg, J.S. King and J.P. Giardina (2003), "Reduction of soil carbon formation by tropospheric ozone under increased carbon dioxide levels", *Nature*, 425.

McKinsey & Company (2009), "Pathways to a low-carbon Economy – Global Greenhouse Gases (GHG) Abatement Cost Curve", http://globalghgcostcurve.bymckinsey.com/ Version 2 of the Global Greenhouse Gas Abatement Cost Curve, January.

Mastrandrea, M.D. and S.H. Schneider (2004), "Probabilistic integrated assessment of dangerous climate change", *Science,* 304.

O'Meagher, B. (2005), "Policy for agricultural drought in Australia: an economics perspective" in L.C. Botterill and D. Wilhite (eds), *From Disaster Response to Risk Management: Australia's National Drought Policy,* Dordrecht: Springer.

OECD (1989), *Economic Instruments for Environmental Protection*, OECD, Paris.

OECD (2008), *Environmental Performance of Agriculture in OECD Countries since 1990,* OECD, Paris.

O'Neill, B.C., F.L. MacKellar and W. Lutz (2001), *Population and Climate Change,* Cambridge University Press, Cambridge.

Matthews, R.B., M.J. Kropff and D. Bachelet (1997), "Simulating the impact of climatic change on rice production in Asia and evaluating options for adaptation", *Agricultural Systems,* 54.

Norby, R.J. *et al.* (2003), "Leaf dynamics of a deciduous forest canopy; no response to elevated CO_2", *Oecologia,* 136.

Nowak, R.S., D.S. Ellsworth and S.D. Smith (2004), "Tansley Review: functional responses of plants to elevated atmospheric CO_2 – Do photosynthetic and productivity data from FACE experiments support early predictions?", *New Phytol*., 162.

H.R. Patel, M.M. Lungaria, B.I. Karande, Vyas Pandey, S. B. Yadav, A.V. Shah, V.U.M. Rao and S. Nareshkumar (2013), Impact of projected climate change on groundnut in Gujarat, *Journal of Agro Meteorology* 15 (Special Issue I), 1-4, (March-2013)

Piara Singh, NP Singh, KJ Boote, S Nedumaran, K Srinivas and MC Bantilan (2014), Management options to increase groundnut productivity under climate change at selected sites in India, *Journal of Agrometeorology 16 (1): 52-59 (June 2014)*

Pielke, R.A., Sr, *et al.* (2002), "The influence of land-use change and landscape dynamics on the climate system: relevance to climate-change policy beyond the radiative effect of greenhouse gases", *Philosophical Transactions of The Royal Society, A,* 360.

Ramachandran A, Dhanya Praveen, Jaganathan, RajaLakshmi, Palanivelu K (2017), Spatiotemporal analysis of projected impacts of climate change on the major C3 and C4 crop yield under representative concentration pathway 4.5: Insight from the coasts of Tamil Nadu, South India, *PLoS ONE* 12(7): e0180706.

Porter, J.R. and M.A. Semenov (2005), "Crop responses to climatic variation", *Philosophical Transactions of The Royal Society, B, 360*.

K Sankaranarayanan, CS Praharaj, P Nalayinin, K K Bandopadhyay and N Gopalakrishnan, (2010), Climate change and its impact on cotton (Gossypium sp.), *Indian Journal of Agricultural Sciences* **80** (7): 561–75, July 2010

Satyavan Singh, Byjesh Kattarkandi, Sikha Deka and Rajendra Choudhary (2010), Impact of climatic variability and climate change on maize productivity in north India, *Current Advances in Agricultural Sciences* 2(1): 5-9 (June 2010)

Schiermeier, Q. (2006), *The costs of global warming,* 439.

Siddique K.H.M., Loss S.P., Regan K.L. and Jettner R.L. 1999. Adaptation and seed yield of cool season grain legumes in Mediterranean continents of South Western Australia. *Australian Journal of Agricultural Research*, **50**: 75-387.

Smith, P. *et al.* (eds) (2007), *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge University Press, Cambridge, United Kingdom; and New York, United States, www.mnp.nl/ipcc/pages_media/FAR4docs/.

Stacey, D.A. and M.D.E. Fellows (2002), "Influence of elevated CO_2 on interspecific interactions at higher trophic levels", *Global Change Biology*, 8.

Stern, N. (2006), *The Stern Review of the Economics of Climate Change*, HM Treasury, London, United Kingdom.

Thomas, D., H. Osbahr, C. Twyman, W.N. Adger and B. Hewitson (2005), *Adaptations to climate change amongst natural resource-dependent societies in the developing world: across the*

Southern African climate gradient, Technical Report 35, The Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, United Kingdom.

Tubiello, F. and G. Fischer (2007), "Reducing climate change impacts on agriculture: Global and regional effects of mitigation, 2000-2080", *Technol. Forecasting Soc. Change*, 74.

Tubiello, F., A. Rahman, W. Mann, J. Schmidhuber, M. Koleva and A. Muller (2009), "Carbon financial mechanisms for agriculture and rural development: challenges and opportunities along the Bali Roadmap. An Essay", *Climatic Change,* DOI 10.1007/s10584-009- 9611-5.

Tubiello, F.N., J.-F. Soussana and S.M. Howden (2007), *Crop and pasture response to climate change. Proceedings of the National Academy of Sciences,* Vol. 104, No. 50.

United Nations Framework Convention on Climate Change [UNFCCC] (1992), United Nations Framework Convention on Climate Change, UNEP/WMO, Geneva, Switzerland.

UNFCCC (2007), "Investment and financial flows to address climate change. Background paper on analysis of existing and planned investment and financial flows relevant to the development of effective and appropriate international response to climate change", UNFCC, Geneva, Switzerland.

UNFCCC (2008), *Challenges and opportunities for mitigation in the agricultural sector,* Technical paper, FCCC/TP/2008/8.

Xiao, G., W. Liu, Q. Xu, Z. Sun and J. Wang (2005), "Effects of temperature increase and elevated CO_2 concentration, with supplemental irrigation, on the yield of rain-fed spring wheat in a semi-arid region of China", *Agr. Water Management*, 74.

Zvereva, E.L. and M.V. Kozlov (2006), "Consequences of simultaneous elevation of carbon dioxide and temperature for plant – herbivore interactions: a meta-analysis", *Global Change Biology*, 12

TERMS OF REFERENCE

FOR EVALUATION OF THE PROJECT ENTITLED 'CLIMATE CHANGE AND ITS EFFECT ON IMPORTANT AGRICULTURAL CROPS OF HYDERABAD KARNATAKA REGION' IMPLEMENTED DURING THE PERIOD 2012-13 BY UNIVERSITY OF AGRICULTURAL SCIENCES, RAICHUR AT CENTER OF AGRO-CLIMATIC STUDIES, COLLEGE OF AGRICULTURE, RAICHUR

1. Title of the study:
'Climate Change and its Effect on Important Agricultural Crops of Hyderabad Karnataka Region'
2. Department/ Agency implementing the Scheme:
Center of Agro-Climatic Studies, UAS, Raichur
3. Project approval No. (Sector): KA/RKVY-AGRE/2012/325
KA/RKVY-AGRE/2013/446
KA/RKVY-AGRE/2014/576
4. Year of Start: 2012-13
Year of Conclusion: 2014-15
5. Total budget of the project: 2012-13 : 50 lakh
2013-18 : 125 lakhs
2014-15 80 lakhs
6.Background and the Context:

According to the Fourth Assessment Report of the Inter-governmental Panel on Climate Change (IPCC, 2007), the impact of climate change on Indian agriculture is expected to be more severe than expected till now, because Indian per capita CO_2 emissions are approximately 1.0 ton per annum compared to the world average of 4.0 tons per annum. Rainfed agriculture, in particular, is likely to face more uncertainties, and hence become riskier, as per the projected changes in rainfall patterns and increase in drought events.

Karnataka is expected to be one of the most vulnerable states to climate change. In the past two decades, we have become aware of the increase in temperature of the earth's lower atmosphere due to pollution from the very fast-developing industry, including vehicular pollution. The climate change can create a plethora of problems that include crop losses, crop yield reduction, soil losses, microbial variability, insect-disease variability, biodiversity, and finally affect the socio-economic status of the people in general and farmers in particular. The University of Agricultural Sciences, Raichur, covers about 22% of the geographical, about 31% of total cultivated and about 20% of the irrigated area in the State, spreading across six districts of North Eastern Karnataka. A number of agricultural (pigeon pea, cotton, chilli, paddy, sunflower, sugarcane, groundnut, bajra, *rabi* sorghum, chickpea, safflower, wheat and other minor millets), horticultural (pomegranate, mango, banan, citrus, ber, papaya and vegetables crops) and few plantation crops represent the rich heritage of the area.

In the new millennium Northern Karnataka has faced successive drought years, and has also been at the receiving end of many extreme weather situations, with particular reference to high maximum temperature in 2004 (More than 40 °C for ten days during March), lower minimum temperature in 2007 (5.6 to 8.2 C from 22-25 November), hail storms in 2005 (March 9, 2005), very heavy rainfall on 12 October 2009 (280 mm in Raichur, and even more in others) and un-seasonal rainfall and cloudy conditions during April 2012 (more than 40 mm). The experiences suggest that North Karnataka is very vulnerable to extreme weather situations in the future – due to climate change. In view of the above and also to address the climate change related issues from Government of Karnataka an project proposal entitled ''Climate Change and its Effect on Important Agricultural Crops of Hyderabad Karnataka Region' was sanctioned during 2012-13 under RKVY grants.

7. The Objectives

The objectives of the project are as follows

1. Collection, compilation, archival and characterization of historical weather parameters of Hyderabad Karnataka Region
2. To downscale the regional climate change scenarios to local level at a higher resolution of about 50 km on spatial scale as well as daily resolution on temporal scale
3. To identify and evaluate vulnerable components of various agricultural systems including pests and diseases, and to develop resource management strategies to mitigate climate change impacts
4. To disseminate the available technologies to the farmers and planners on real time basis through effective communication networking on the adverse effects of climate towards improving the socio-economic status
5. To identify and develop crop genotypes adaptable to climate change scenarios by utilizing available genetic resources/land races and crop growth simulation models
6. To develop weather and climate based agro-advisories through GIS medium

8.Present Status of the Project

The above project was implemented during 2012-13 at center of Agro-Climatic studies, UAS, Raichur. With the start up grants the four Open Top Chambers were commissioned with a SCADA (Supervisory Control and Data Acquisition System). Further, in the subsequent year 3 more OTC's along with 6 automatic weather stations were installed both head quarter and research stations.

Effect of climate change in terms of elevated CO_2 and temperature on the growth and yield of major crops *viz*., *Bt* cotton, Redgram, Bengal gram, Groundnut, Sunflower and Maize has been studied and the results have been presented in the above sections.

As a part of mitigation of climate change Direct seeded rice technology was popularized in TBP and UKP command areas. Wherein, with the joint venture under public – private – partnership mode between UAS, Raichur - PI Foundation, Gurugrama and farmers the large scale demonstrations was taken directly in the farmers' fields continuously from 2013-14 to 2017-18 so due to persistent efforts this technology became so popular among the farmers that area under DSR increased from 1000 acres in 2012-13 to 1.0 lakh acres with cost saving of minimum Rs. 6000/acre, irrigation of 37 % in addition to reduction in methane gas emission of 35 %.

9.Outcome:

- Open Top Chambers procured was installed and commissioned. All 6 Automatic weather stations purchased were installed in the different Agricultural Research Stations of UAS, Raichur establishment.
- Identification of progressive farmers for verification of weather forecast and advisories at two IAAS units (located at Raichur and Bidar).
- Farmers from six districts of Hyderabad Karnataka *viz*., Raichur, Ballari, Koppal, Yadagir, Kalaburgi and Bidar enrolled in the weather based Agro-services data base. Daily weather data of the respective districts was communicated to individual farmers of each district by SMS to their mobiles phones. This has helped them to prepare for the agricultural operations. Similarly, weather forecast of future /advance was also sent to those field level workers and farmers whoever is accessible to email.
- Weather based Agro-services in the form of SMS to farmers of the H-K region is ongoing and as of date 21884 farmers of Raichur district, 16352 farmers of Kalaburagi, 9879 farmers of Bellary and 9060 farmers of Koppal totalling to 57175 farmers are getting benefitted with this service.

Effect of climate change on Major crops of Hyderabad Karnataka Region

1. Cotton

The eCO_2 and temperature favoured growth and development of *Bt* cotton which was evidenced by accelerated growth in terms of more plant height, leaves, leaf area and sympodia. This resulted in increased yield in eCO_2 and temperature treatments wherein, maximum seed cotton yield (321.67 g/plant) was obtained which was 21.25 per cent more compared to reference plot (standard check). Biochemical analysis of *Bt* cotton showed lot of changes in it, wherein, the chlorophyll content, carbon and carbon-based compounds *viz.,* tannins, phenols and sugars significantly increased in eCO_2 as compared to aCO_2 treatments. On the contrary, nitrogen (N) and N-based compounds *viz.,* proteins and amino acids decreased in eCO_2 conditions which in turn altered C: N ratio and decreased *Bt* toxin production (25.64 % of Cry1Ac in leaves, 23.52 % in squares and 14.13 % in boll; 7.70 % of Cry2Ab2 toxin in leaves, 6.87 % in squares and 5.33 % in boll). When aphid was reared on such biochemically altered *Bt* cotton plants resulted in decreased nymphal period (3.67 ± 0.21 days), adult longevity (9.43 ± 0.41 days) and total life cycle (12.28 ± 0.23 days). Whereas, fecundity was increased (32.46 ± 0.95) leading to increased mean aphid population (14.30 to 12.58 %) with reduced fitness and decreased seed cotton yield (76.75 to 76.66 %) in eCO_2 treatments, in the sense that, bi-trophic interaction has negative bearing on host. In tri-trophic interactions, the negative effect posed by aphid on crop was nullified by predator as it devoured the aphids greatly at the cost of its fitness which was slightly affected.

2. Mulbery

The climate change in terms of eCO_2 and temperature has favoured the growth and development of mulberry, as it was evidenced by the accelerated growth rates in terms of plant height, number of leaves, leaf area and leaf area index (LAI). The leaf yield and plant bio-mass per plant were significantly higher 701.17 g and 1026.28 g in eCO_2 (550 ppm) treatment over standard check. The phytochemistry of mulberry plant was expedited and showed that, the chlorophyll content (25.45 to 28.52), carbon (21.25 to 25.67) and carbon based compounds *viz.,* tannins (0.98 to 1.91), phenols (3.09 to 4.19) and sugars (11.89 to 13.08) have significantly increased in the eCO_2 conditions (CO_2 alone and in combinations with temperature) as compared to aCO_2 treatments. On the contrary, nitrogen (2.94 to 3.93) and N based compounds *viz*., proteins (4.82 to 6.24) and carbohydrates (4.84 to 5.26) have decreased in the eCO_2 conditions which has resulted in change in carbon to nitrogen (C:N) ratio (5.45 to 8.89). And even some other flavonoid contents (1.05 to 1.53) present in mulberry *viz*., rutin (0.53 to 1.06), morin (0.85 to 1.28), also showed positive response towards eCO_2 alone whereas, decreased in value towards eTemperature but quercetin was not detected.The changes in phytochemistry altered the biology of silkworm which was evidenced by decrease in larval weight, increased larval duration, decreased in size, increased pupal duration, decreased cocoon shell, cocoon filament weight, filament length, ERR, productivity, denier in eCO_2 conditions compared to aCO_2 treatments. The data showed great variations in egg laying of silkworm under different treatments. The maximum average number of eggs were laid in reference plot (582.833) and minimum egg laying was recorded in eCO_2 (550 ppm) treatment (483.917).

3. Groundnut:

Significantly lower leaf nitrogen, higher carbon, higher relative proportion of carbon to nitrogen, higher phenols and tannins observed in the groundnut foliage grown under elevated CO_2 levels. The present findings indicated that the changes in phytochemistry of groundnut under eCO_2 had lead to deterioration of nutritional quality as a result of which, relative consumption rate (RCR) and approximate digestibility was significantly more under eCO_2 + eTemperature (550 ppm + 2 °C) treatment (285.59 mg g-1 d-1 and 77.13 %) and lowest in reference plot (270.35 mg g-1 d-1 and 73.83 %). As the consequences of this, the larva produced more faecal matter and higher larval weight gain compared to ambient. Slower relative growth rate (RGR) and lesser efficiency parameters such as efficiency of conversion of ingested food and digested food (ECI and ECD) was noticed under elevated CO_2 condition compared to ambient. Longer larval duration, pupal duration was observed under eCO2 + eTemperature (550 ppm + 2 °C) (22.8 days, 8.38 days) compared to reference plot (20.575 days, 6.20 days). Lower moth emergence in eCO_2 + eTemperature (550 ppm + 2 °C) treatment (62.31 %) and highest moth emergence recorded in reference plot (86.97 %). Reduced fecundity of 484.94eggs/female was observed under eCO_2 + eTemperature (550 ppm + 2 °C) compared to reference plot (520.67 eggs/female).

4. Maize:

Most of the morphological, physiological, biochemical and biophysical parameters indicated better performance under elevated CO_2 regime as compared to elevated temperature regime at all growth stages.Various morphological parameters studied indicated that, the genotypes HTMR-1, 900M-GOLD and HTMR-2 performed better under elevated CO_2 and temperature regime. The maximum reduction with respect to these parameters was observed in ARJUN and NK 6240 genotypes. The exposure of the crop elevated CO_2 and temperature regime resulted in the significant decrease in the photosynthetic rates. The minimum reduction was observed in HTMR-1, HTMR-2 and NK 6240 and the maximum in ARJUN and 900M-GOLD. Among the genotypes NK 6240, HTMR-1 and 900 M-GOLD genotype recorded maximum transpiration rate and stomatal conductance whereas, the genotypes HTMR-2 and ARJUN had the least transpiration rate and stomatal conductance. A significant increase in chlorophyll content, reducing and non-reducing sugars was seen in elevated CO_2 treatment but soluble protein was decreased. Whereas, under elevated temperature regimes chlorophyll content, reducing and non-reducing sugars are decreased due to altered C: N ratio. The results indicated that on doubling the CO_2 level of the existing (350 ppm) at existing temperature, a yield of grain in maize was increased. Unlike effect of CO_2, crop yields were decreased with increase in temperature and the effect is species-specific.

5. Pigeonpea

Present studies showed that, elevated CO_2 increased plant and seed weights of pigeon pea as typically observed in most of the legume species. Pigeon pea has been able to use the increased carbon under elevated condition which helped in increased symbiotic N fixation and thus was able to add to more seed weight without incurring a reduction in seed. Increased CO_2 decrease the oxygenase activity of Rubisco (enzyme which influence photosynthesis) and there by reduces the loss of carbon through photorespiration. The greater (CO_2) responsiveness of photosynthetic rate of plant is expected to result in biomass and yield improvements. The large effect of CO_2 on photosynthesis at high temperature is not observed in all C_3 plants as evident from present study there was no significant difference between treatments CO_2 and temperature. Greater seed yields under CO_2 enrichment were attributed to increases in flower numbers due to increased branching, but not due to increases in individual seed weight or number of seeds per pod. Legumes are often able to use increased carbon gain under elevated CO_2 for increased N_2 fixation and thus may be able to increase seed number and/or mass without a loss in seed nitrogen.

Climate Change Training Programme

Knowledge development for extension personnel's about impact of climate change through participatory approach

The model training course *was conducted for 8 days from 08th January 2018 to 15th January 2018 at Department of Entomology, University of Agricultural Sciences, Raichur with the support of University* of Agricultural Sciences, Raichur and Directorate of Extension, Ministry of Agriculture and Cooperation and Farmers Welfare, GOI, New Delhi. The training course had enrolled 19 participants from various state agricultural departments and NGOs from various states of the country wherein, participants from New Delhi (02), Uttar Pradesh (01), Tamil Nadu (02), Telangana (03) and Karnataka (11) underwent this course. Among the participants, 3 were extension officers, 7 agriculture officers, 2 assistant professors, 3 subject matter specialists, 1 technical assistant, 2 senior research fellows and 1 NGO manager. The training course also included visit to international institutes for climate change research like CRIDA and ICRISAT, Hyderabad.

The second climate change off campus collaborative training programme was jointly organised by UAS, Raichur and National Institute of Agricultural Extension Management (MANAGE), Hyderabad, from 01- 10 August, 2019 at Center of Agro climatic studies, UAS, Raichur. This training programme included 25 participants from various sectors *viz.,* Assistant professor, Scientists and Extension personnel's from UAS, Raichur and Agriculture officer and Assistant Agriculture officer from state department of Agriculture Karnataka, Telangana and Andhraprdesh. The training was inaugurated by Dr. M.B. Rajegowda (Former Professor of Agro-meterology and Former Registrar, UAS, Bangalore) and Dr. K. N. Kattimani, Hon'ble Vice Chancellor, UAS, Raichur and precided by Dr. B.K. Desai, Directorate of Research, UAS, Raichur. During the ten days training programme, the trainees were exposed to different climate change issues *viz*., causes, effects and mitigation in respect of live demonstration blocks at Agricultural Research Station, Sirguppa, Farmer's fields and College of Agriculture, Raichur.

Climate Change Mitigation strategy: Direct Seeded Rice (DSR)

Investigations on the status of insect pests and diseases in direct seeded rice was carried out during 2013-14 in the different Agricultural Research Stations and Farmers fields of UAS, Raichur jurisdiction. Status of insect pests and natural enemies were documented in direct seeded rice and transplanted paddy ecosystem under protected and unprotected situations. The incidence of yellow stem borer and leaf folder damage was found to be more in direct seeded rice compared to transplanted rice situation during both *kharif* and *rabi* season. Whereas, sucking pests (GLH, BPH, WBPH) incidence was more in transplanted rice compared to direct seeded rice ecosystem. Per hectare cost of cultivation under direct seeded rice was considerably lower (Rs. 29,078 ha^{-1}) than transplanted rice (Rs.39, 063 ha^{-1}) cultivation due to reduction in the cost towards seeds, nursery raising, transplanting and minimum usage of plant protection chemicals and fertilizers in direct seeded rice situation. Cost incurred towards plant protection was higher (Rs. 5245 ha^{-1}) in the transplanted rice compared to direct seeded rice (Rs.4095 ha^{-1}) under protected situation. The net returns of direct seeded rice (49,036 ha^{-1}) was high as compared to transplanted rice (44,091 ha^{-1}) and input output ratio of direct seeded rice was high (2.69) as than the transplanted rice (2.13) under protected condition.

13. List of Assets

Sl. No.	Name of the Asset	Date of Purchase	Qty. (No's)	Total Cost (Lakh)	Purpose of Purchase
1	Established the Centre for Agro-climatic study centre with separated building	2014-15	1	40.0	A separate building of 2000 sq. ft has been established which a state of art and hope 5th in the country having a separate facility to study the climate change research on Agricuture.
2.	Open Top Chambers (OTC)	2012-13 & 2013-14	7	56.00	To study the effect of elevated CO_2 and temperature on the insect pests and diseases of crops
3.	BOD incubators	2019-20	2	2.82	To grow and maintain microbiological cultures
4.	CO_2 analyser	2019-20	1	10.50	For closed system measurement of soil respiration and net canopy CO_2 flux
5	CO2 and Temperature regulatory room	2014-15	1	2.75	Separate room to accommodate the supervisory control and data acquisition system which automatically regulates the CO2 and temperature for simulating on to the crops
6	Portable photosynthesis system Infra-Red Gas Analyser (IRGA)	2013-14	1	40.00	Measures fluorescence and gas exchange simultaneously over the same leaf area with full control of environmental variables. Measure small photosynthesis rates and CO_2 exchange.
7	Environmental / Growth chambers	2014-15	3	30.00	Plant growth and development parameters as well as insect growth and life cycle etc.
8	Automatic weather stations	2013-14	1	3.20	Weather data collection.

9	NDVI meter hand held optical sensor unit	2013-14	1	4.94	Measures Plant reflectance and normalized difference vegetation index.
10	Flavonoid-Chlorophyll meter	2013-14	1	4.44	Total flavonoids, chlorophyll, anthocyanin and nitrogen balance index can be calculated.
11	Leaf area meter Model CI-202	2014-15	1	4.20	Leaf area can be measured
12	Deep freezer (-50 °C to -80 °C)	2014-15	1	3.58	Storage of research samples (germplasms, enzymes, molecular assay kits)
13	Chlorophyll meter (CCM-200)	2013-14	1	1.40	Chlorophyll can be measured
14	Auto Clave Vertical 50 ltrs	2014-15	1	0.88	Sterilising media and glasswares.
15	Aquaterr Digital soil moisture meter (Model-200)	2014-15	1	0.69	Measures soil moisture and pH
16	Hot air oven	2014-15	1	0.69	Sterilise glassware, for drying soil and plant samples etc.
17	Infrared thermometer	2013-14	1	1.50	Measurement of temperature
18	Stand Micron (Microscope with camera option)	2014-15	2	0.20	Identifying specimens, taking photos and morphometric measurements.

11. Where the project is undertaken : Center of Agro-Climatic Studies, University of Agricultural Sciences, Raichur

Places to visit to evaluate the project : Center of Agro-Climatic Studies, University of Agricultural Sciences, Raichur

12.Contact person for this Project: Dr. A. G. Sreenivas

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EVALUATION TEAM MEMBERS

Sl. No.	Name	Designation
1	Dr. M. A. Shankar	Principal Investigator
2	Dr. B. C. Suryanarayana	Associate Investigator
3	Sri. Siddaraju	Associate Investigator

Dr. M. A. Shankar is a doctorate in Agriculture with specialization in Agronomy. He is former Director of Research, University of Agricultural Sciences, Bengaluru and presently the Executive Member of Institution of Agricultural Technologists, Bengaluru and Co-Chairman of Agribusiness Consultancy Subcommittee. He has implemented 51 research projects for the University funded by International organizations, Central and State governments, Private firms. He has guided 6 Ph. D. students and 15 M. Sc., (Agri) students. As Dean of College of Agriculture, Hassan, he has, with his administrative skills, streamlined accounting, financial, academic and administrative issues. He has been involved in review and evaluation of Technical Reports of 32 All India Co-ordinated Research Projects (AICRP) spread all over India. He has also evaluated 11 operational research projects for the technical feasibility and implementation. He has published 173 peer reviewed research papers. He has also penned 54 booklets and books for the University. He has vast experience in evaluation studies of projects.

Dr.Suryanarayana, B.C. is a doctorate in Agriculture with specialization in Agronomy and is a Certified Associate of Indian Institute of Banking (CAIIB), Fellow of Indian Institute of Valuers. He worked in State Bank of India from the year 1981 to 2014 as a Technical Officer and retired as Asst. General Manager (Rural Development). He is a practicing consultant in the field of Agriculture, Horticulture, poultry, dairy, fisheries and plant tissue culture and covered cultivation. He has about 35 years of experience in the field and has prepared several project reports for financial institution, written books in vanilla cultivation, anthurium, medicinal and aromatic crops, minor irrigation, poultry and dairy farming. He has appraised more than 6,000 proposals in agriculture and related fields for funding by the Bank and has also been involved in many studies relating to development of Agriculture and allied activities. He has served as a General Manager in a bio-fertilizer, bio-pesticides and organic manures manufacturing company and is also a Technical Director in a company involved in manufacture of agricultural implements and equipment.

Sri. Siddaraju is a Graduate in Agriculture with more than 35 experience in the field of Agriculture. He has served in the Karnataka State Department of Agriculture (KSDA) as Asst. Agricultural Officer in Farmers' Training and Education Centre, Soil Testing laboratory and as Subject Matter Specialist. He was Deputy Director of Agriculture (Commercial Crops) for 6 years, District Watershed Development Officer for 2 years. He has also been Joint Director of Agriculture (Inputs) for 5 years. He was involved in preparation of Annual Programme Planning booklets pertaining to Agricultural Inputs in Department of Agriculture. After retirement, he is serving as Chairman, Agriculture Consultancy Subcommittee, Institution of Agricultural Technologists, Bengaluru and has been actively involved in evaluation studies of projects.