IMPACT OF CLIMATE CHANGE ON AGRICULTURE, AQUACULTURE AND BIODIVERSITY

Bhardwaj, S.1*, Navrang, S.2, Gaidhani, S.3, Lal, B.4 and Roy, K.5

1* Main and Corresponding author: Department of Genetics & Plant Breeding. Indira Gandhi Krishi Vishwavidyalaya, Raipur 492012, Chhattisgarh.
2Department of Agronomy. Indira Gandhi Krishi Vishwavidyalaya, Raipur 492012, Chhattisgarh.
3Department of Genetics & Plant Breeding. Indira Gandhi Krishi Vishwavidyalaya, Raipur 492012, Chhattisgarh.
4Department of Soil Science and Agricultural Chemistry. Indira Gandhi Krishi Vishwavidyalaya, Raipur 492012, Chhattisgarh.
5Department of Fisheries. Indira Gandhi Krishi Vishwavidyalaya, Raipur 492012, Chhattisgarh.

Received 04 December 2013; accepted 14 December 2013

Abstract
An attempt has been made to review the impact of climatic variation on bio-resources and agriculture thereby suggesting measures to mitigate these impacts. The spatial distribution of surface warming suggests a mean annual rise in temperature in North India by 3°C by 2050. However, a marginal increase of 7-10 percent in annual rainfall is projected over the sub-continent by 2080. There may be the changes that some species of trees, flora and fauna may vanish and other emerge out coupled with the loss of several hyper-thermo-sensitive crops. Humans have influenced the CO₂ kinetics in the atmosphere at an accelerated rate. The IPCC reports state that human activities have tremendously influenced the global water cycle by impacting the global carbon cycle. Environmental stress on crops may increase, which may become more vulnerable to insects, pathogens and weeds. The effect of weed growth on yield suggests losses in the range 28-74% in rice and 15-80% in wheat. The global production may decrease in developing and increase in developed countries. Impact of the climate change has already been felt on fisheries and aquaculture in terms of modification of the distribution and productivity of marine and freshwater species, effect on biological processes and alteration in food webs, change in the reproductive behaviour of fishes, shift in the breeding season, shift of the habitat, etc.

Keywords: Climate change, global warming, biodiversity, impact, temperature, rainfall, agriculture, fisheries, aquaculture.

1. Introduction
Environment plays an important role in agriculture production; wholly the agriculture is depends upon the monsoon and mostly affected by uncertain climatic conditions. An Anthropogenic activities world over has exploited natural resources to meet their needs and have disturbed the eco-system on the earth. The Inter-Governmental Panel on Climate change (IPCC) projected an increase in global average temperature between 0.1-0.3°C per decade (Anon., 2007). These climate changes are expected to alter the natural ecosystem in many parts of the globe. Agricultural ecosystems are subject to severe climatic inter-annual variability; these systems may become more vulnerable under the expected scenarios of climate and can be deleterious for agriculture and biodiversity (Purohit, 2004a).

2. Climate change – Definition and Causes
Any change in climate over time due to natural variability or as a result of human activity is called climate change.

2.1. Causes for climate change
Gases that contribute to the green house effect includes:-

i. Water vapour: The most abundant Green house gas, but importantly it acts as a feedback to the climate. Water vapour increases as the Earth’s atmospheric warms, but so does the possibility of clouds and precipitation, making these some of the most important feedback mechanisms to the greenhouse effect (Kumar et al., 2013).

ii. Carbon dioxide (CO₂): A minor but very important component of the atmosphere, carbon dioxide is released through natural processes such as respiration
and volcano eruptions and through human activities such as deforestation, land use changes and burning fossil fuels. Human have increased atmospheric CO2 concentrations by a third since the Industrial Revolution began. This is the most important long-lived ‘forcing’ of climate change (Agrawal, 2004).

iii. Methane (CH4): A hydrocarbon gas produced both through natural sources and human activities, including the decomposition of wastes in landfills, agriculture and especially rice cultivation, as well as ruminant digestion and manure management associated with domestic livestock. On a molecule for molecule basis, methane is a far more active greenhouse gas than CO2, but also one which is much less abundant in the atmosphere.

iv. Nitrous oxide: A powerful greenhouse gas produce by soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production and biomass burning (Bagist Kumar, 2013a).

v. Chlorofluorocarbons (CFCs): Synthetic compounds of entirely of industrial origin used on a number of applications, but now largely regulated in production and release to the atmosphere by international agreement for their ability to contribute to destruction of the ozone layer. They are also greenhouse gases (Bagist Kumar et al., 2013b).

vi. Arsenic derived compounds: The arsenical compounds found in hydroponic system that as an accumulation in the shoots of English ryegrass, pea, maize, soybean, sunflower, rapeseed, tobacco and wheat plants which are known for a high P demand, exceeded significantly the Swiss tolerance value for fodder and food plants (0.4 and 0.2 mg as Kg−1) respectively(Gulz and Gupta,2000a).

2.2. Anthropogenic causes

Since the industrial revolution in 1750 up until 2009 an increase of approximately 38 percent in the atmospheric level of CO2 has been noticed. The rise in CO2 concentration from 280 ppm (Parts per million) in 1750 to 379 ppm in 2005 to approximately 395 ppm at present (Table 1), indicating the role of man in increasing the global atmospheric CO2 levels (IPCC, 2007). Humans have influenced the CO2 kinetics in the atmosphere at an accelerated rate. The IPCC reports state that human activities have tremendously influenced the global water cycle by impacting the global carbon cycle (NASA, 2010). The CO2 annual emission in 1970 was 21 gigatons by human activities, whereas in 2004 it increased to 38 gigatons, almost 80 percent increase in just three decades. CO2 also represented 77 percent of total anthropogenic greenhouse gases emissions in 2004.

Table 2: Predicted climate change (IPCC, 2007)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Year- 2025</th>
<th>2050</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 concentration</td>
<td>405-450 ppm</td>
<td>445-540 ppm</td>
<td>540-970 ppm</td>
</tr>
<tr>
<td>Global mean temperature change from the year 1990</td>
<td>0.4-1.1°C</td>
<td>0.8-2.6°C</td>
<td>1.4-5.8°C</td>
</tr>
<tr>
<td>Global mean sea level rise from the year 1990</td>
<td>3-14 cm.</td>
<td>5-32 cm.</td>
<td>9-88 cm.</td>
</tr>
</tbody>
</table>

The impacts are more likely on fragile ecosystem like and region where hot environment, low and erratic rainfall conditions prevail and crops are sensitive to soil water (Rao & Saxton, 1995). The PRECIS model for India showed an increase in an annual mean surface temperature by 3 to 5°C under A2 scenario and 2.5 to 4°C under B2 scenario with warming more pronounced in northern parts of India by the end of century. Warming is expected to be more in winter and post-monsoon season compared to South-West monsoon seasons (Kumar et al., 2006).

2.3. Global warming:

Global warming is defined as an observed gradual increase in the average temperature of the earth surface (IPCC, 2007). Historically, in 1750 (Prior to Industrial Revolution) atmospheric CO2 was 280 ppm. In 1898 for the first time an environmentalist named Svante Ahrrenius warned about the harmful effect of CO2 from coal and oil burning on the planet. Till 1955 the CO2 concentration rose to 315 ppm. Subsequently in 1998, warmest year of the 19th century was experienced (Venkataramanet al., 2012).

Studies on climate change and its future projections (Table 2) have confirmed the occurrence of increased global mean temperature and global mean sea level since 1990 (IPCC, 2007).

Table 3: Types of Green house gases

<table>
<thead>
<tr>
<th>Name of gas</th>
<th>Contribution (%)</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2</td>
<td>50</td>
<td>From burning coal &amp; oil, and the removal of vegetation</td>
</tr>
<tr>
<td>Chlorofluoro carbons(CFCs)</td>
<td>20</td>
<td>From air conditioners, refrigerators and aerosols</td>
</tr>
<tr>
<td>Methane(CH4)</td>
<td>16</td>
<td>From rice growing, animal waste, swamps and landfills</td>
</tr>
<tr>
<td>Ozone (O3)</td>
<td>8</td>
<td>From air pollution</td>
</tr>
<tr>
<td>Nitrous oxide(N2O)</td>
<td>6</td>
<td>From fertilizers, &amp; burning of coal and oil</td>
</tr>
</tbody>
</table>

3. Emission of Green House Gas (GHG)

Kyoto protocol on climate change in 1997 emerged as a global issue because of its deeper relationship with agricultural production activities (Rogenzweig and Parry, 1994); as they contribute to build up green house gases particularly methane, nitrous oxide, water vapor, carbon dioxide and halo carbons. IPCC has reported enormous increase in the concentrations of these gases over the last 200 years (Anon., 2001).

Green house Effect

Green house gases (Table 3) acts like the glass of a green house, the changes in climate of the earth and the subsequent effects are called green house effect. Green house effects may be beneficial, as the Earth gets warmer, there may be an increase in agricultural production. But the main issue is that the amount of green
house gases has increased dramatically. It grew 300% in the past 100 years (Gulz and Gupta, 2000b).

Table 4: Projected mean temperature and rainfall changes in the Indian sub-continent (Lal et al., 2001).

<table>
<thead>
<tr>
<th>Period</th>
<th>Season</th>
<th>Change in temperature (°C)</th>
<th>Change in rainfall (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lowest</td>
<td>highest</td>
<td>lowest</td>
</tr>
<tr>
<td>2020s</td>
<td>Annual</td>
<td>1</td>
<td>1.41</td>
</tr>
<tr>
<td></td>
<td>Rabi</td>
<td>1.08</td>
<td>1.54</td>
</tr>
<tr>
<td></td>
<td>Kharif</td>
<td>0.87</td>
<td>1.17</td>
</tr>
<tr>
<td>2050s</td>
<td>Annual</td>
<td>2.23</td>
<td>2.87</td>
</tr>
<tr>
<td></td>
<td>Rabi</td>
<td>2.54</td>
<td>3.18</td>
</tr>
<tr>
<td></td>
<td>Kharif</td>
<td>1.81</td>
<td>2.37</td>
</tr>
<tr>
<td>2080s</td>
<td>Annual</td>
<td>3.53</td>
<td>5.55</td>
</tr>
<tr>
<td></td>
<td>Kharif</td>
<td>2.91</td>
<td>4.62</td>
</tr>
</tbody>
</table>

Table 5: Response of C3 and C4 weeds to double atmospheric CO2 levels (Chandrasena, 2009b).

<table>
<thead>
<tr>
<th>Sn.</th>
<th>C3 Range of response biomass</th>
<th>C4 Range of response biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abutilon theophrasti 1.0 – 1.52</td>
<td>Amaranthus retroflexus 0.9 – 1.41</td>
</tr>
<tr>
<td>2</td>
<td>Bromus mollis 1.37</td>
<td>Andropogon virginianus 0.8 – 1.17</td>
</tr>
<tr>
<td>3</td>
<td>Bromus atrocortus 1.54</td>
<td>Cuperus rotundus 1.02</td>
</tr>
<tr>
<td>4</td>
<td>Cassia obtusifolia 1.4 – 1.8</td>
<td>Digitaria ciliaris 1.06 – 1.6</td>
</tr>
<tr>
<td>5</td>
<td>Chenopodium album 1.0 – 1.6</td>
<td>Echinochloa crusgalli 0.95 – 1.6</td>
</tr>
<tr>
<td>6</td>
<td>Daturastramonium 1.7 – 2.7</td>
<td>Eleusine indica 1.02 – 1.8</td>
</tr>
<tr>
<td>7</td>
<td>Phalaris aquatica 1.48</td>
<td>Sorghum halepense 0.56 – 1.1</td>
</tr>
</tbody>
</table>

4. Impact of global warming vis-à-vis green house effect

Global warming affects the rainfall and food production; some places have an increment in rainfall and some will decrease. There may be flooding or drought in various farmlands. Food is an important for lives; that means more people, especially in the developing countries suffers from hunger (Purohit, 2004b).

The spatial distribution of surface warming projects a mean annual rise in temperature in North India by 3°C by 2050. Annual mean area averaged surface warming over the Indian sub-continent is likely to range between 3.5 and 5.5 by 2080 (Table 4) (Lal et al., 2001).

These projections show more warming in winter season over the summer. In case of rainfall a marginal increase of 7-10 percent in annual rainfall is projected over the sub-continent by 2080. Nevertheless the study suggests a fall in rainfall by 5-25 percent in winter while it would be a 10-15 percent increase in summer(Lal et al., 2001).

5. Climate change and impact on Agriculture

The impact on global agricultural production is expected to be small due to climate change but regional vulnerability to food shortage may increase. Rogenzweig & Parry (1994) estimated the net effect of climate change on global production up to 5 percent but production may decreased in developing and increased in developed countries. As per IUCC doubling CO2 concentrations may increase the photosynthetic rates by as much as 30 to 100 percent in C3 plants as wheat, rice and soybean, whereas response in C4 plants such as maize, sorghum, sugarcane, millets etc. may remains as such (Anon., 1992).

The changes in precipitations and evapotranspiration trends, droughts, floods and tropical cyclones will have a negative impact on agriculture production. India, winter precipitations is projected to decline in the further, and hence, will result in increasing the demand of water for irrigating Rabi crops (Jain, S.K., 2012). Kharif crop production will also have to cope with heavy floods and droughts. (Shah et al., 2009).

Increased temperature will favour the growth of weeds and their shifting to the higher latitudes. As a result, environmental tress on crops may increase, which may become more vulnerable to insects, pathogens and weeds. The effect of weed growth on yield suggests losses in the range 28-74% in rice and 15-80% in wheat (Mahajanet al., 2012), and these drawbacks shall have an adverse impact on the nation’s economic growth and GDP. India is highly sensitive to climate change in term of its effect on water supply for irrigation need (Jain et al., 2011, Mall, et al., 2006).

5.1. Response of C3 and C4 weeds to double atmospheric CO2 levels

C3 and C4 weeds generally increase their biomass. In view of such results it couldbe predicted that elevated CO2 will lead to increased weed-crop competitions, negating some of the otherwise beneficial effect of CO2 fertilization of the C3 crops and their yields (Chandrasena, 2009a).

According to CRIDA annual report 2012-13, a Rice model DSSAT (CERES) was used in eastern India to assess the affected rice production due to climate change. A reduction in maturity days was evidenced in Ranchi. This may cause almost 10 percent reduction in rice production of the country in future (2020-2050). Due to the shifting pattern of climate, late sown crops may exhibit better performance due to the availability of favourable environmental conditions lately. In a study on the awareness and knowledge of farmers about climate change, conducted in Akola (Maharashtra) and Ananthapur (Andhra Pradesh), the farmers were educated about the increase in temperature during crop season, delay in monsoon, low precipitation and drought. As a result of which, they changed their sowing/ transplanting date, cropping pattern,
crop insurance and adopted the work of seasonal labour (CRIDA, 2013).

6. Climate change and its impact on biodiversity

Due to climate change scenario’s the biodiversity and the configuration of forest ecosystems may alter. IPCC suggested a significant forest dieback toward the end of this century and beyond especially in tropical and mountains areas (Anonymous, 2007). There are changes that some species of trees, flora and fauna may vanish and attain may emerge out. Climate change may lead to the loss of several hyper-thermo-sensitive crops like Basmati rice, apple, saffron, cabbage, cauliflower, carrots and peas from their native habits because of their specific hypothermal requirements for flowering, fruiting and development of aroma (Sarawagi, 2003).

7. Implications of climate change

The crops with C3 pathways may be benefitted while C4 crops may remains unaffected due to climate change. Growth and productivity of C3 crops increase directly by rising CO2 level but may be offset by increased atmospheric temperature; the photosynthetic rate of C3 crops increases mainly due to reduced photo respiration (Kumar et al., 2013). The crops like fodder, sugarcane, potato and root foliage crops are likely to be benefitted water availability may become a serious problem affecting flora and fauna due to greater losses of moisture through elevated evapotranspiration. The coastal areas may have submergence situations due to rise in the sea level and coastal biodiversity may also be affected (Sharma, 2005).

8. Climate change and aquaculture

Fish being a cold-blooded animal, all stages of aquaculture including reproductive behaviour, breeding, seed production and growth and behaviour of fish are going to be largely affected by the climate change phenomena. Therefore, aquaculture is going to be one of the worst hit sectors by the global warming. Impact of the climate change has already been felt on fisheries and aquaculture in terms of modification of the distribution and productivity of marine and freshwater species, effect on biological processes and alteration in food webs, change in the reproductive behaviour of fishes, shift in the breeding season, shift of the habitat, etc. (ICAR, 2011).

Fortunately, aquaculture offers option for permanent sequestration of the atmospheric CO2 through its incorporation into soil and biomass of plants, crustaceans, shellfish, fish and other organisms and thus, can act as a pro-carbon sink process and an important option for mitigating the global warming process (FAO, 2009). The Inter-Governmental panel for climate change (IPCC) report indicated that many of the developing countries tend to be vulnerable to extreme climate disturbances and thus may have an adverse impact of a gradual climate change on animal production system including fish farming (NCAP, 2008).

Global warming is likely to create favourable climate conditions for the growth of disease causative organisms and thus increased ambient water temperature is likely to cause a rise in the responses of disease occurrences spread by vectors. Similarly alterations in other sensitive water quality parameters such as ammonia, air and water temperature may have pronounced effect on feed utilization efficiency, growth and even on the sensory qualities of the cultured fish species. Concerted efforts in aquaculture research to reduce the vulnerability of aquaculture due to the impact of climate change (variables like solar radiation and air temperature) are therefore vital to make aquaculture more resilient (CIFA, 2011).

9. Strategies to mitigate the effect of climate change

i. The drought resistant cultivars should be evolved through research and development and by using climatic information strategically.

ii. On farm micro-irrigation technologies should be developed for efficient use of water. New agronomic practices and resources conservation technologies need to be fine tuned. Organic farming can slice down the green house gases (Kumar et al., 2005).

iii. Strengthening the reforestation projects and prevention of deforestation for monitoring and regulating of green house gases emission should be promoted for carbon sequestration (Calis, 2008). This can be achieved by preaching. “Each one, teach one and plant one” and rational use and conservation of forests and land resources.

iv. Promoting the “Reduce, re-use and recycle” slogan and switching over to the clear fuels and energy efficient technologies can make a differences to conserve healthy, natural environment.

v. Aquaculture can act as a pro-carbon sink process and an important option for mitigating the global warming process

Conclusion

Global climate change is not a new phenomenon. The effect of climate change posses many threats, one of the important consequences is bringing about changes in the quality of the bio-resources. The recent global warming causes by increased emissions of green house gases to the atmosphere by anthropogenic processes, has its effect on agriculture, aquaculture and biodiversity. The effect of climate change is significantly more on the semiariad, arid and coastal aquifers of the world. In a tropical country like India, the vulnerability is extremely high because of over exploitation of the agriculture and other sectors which are directly or indirectly linked with us.

References:

3. Anonymous, 2007. Climate change, the physical science basis. Inter-governmental panel on climate change. Cambridge University Press, CB24R, U.K.

Source of support: Nil; Conflict of interest: None declared