SACHCHIDANAND TRIPATHI, RAJKUMARI SANAYAIMA DEVI, SANDEEP KUMAR AND VIRAT JOLLI (Eds.)

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PREAMBLE OF THE CONFERENCE

Impact of climate change has become a harsh reality for India and the world. Climate change related disasters have brought wide spread misery and huge economic losses to India adversely affecting human health, agriculture and food security, natural resources and energy security; and biodiversity. Various national and international institutions like IPCC have shown a stark picture in Indian context. The scenario is anticipated to worsen as humans continue to pump greenhouse gases into the atmosphere without being aware of the contribution they are making for their own downfall. Over the past decades, climate change has become one of the most heavily researched subjects in science. However, in recent years the impact of climate change has become prominently visible with an erratic monsoon creating drought in some areas and extreme deluge in others like Uttarakhand and Jammu and Kashmir. Annual mean temperature in India for the past 110 years shows an increasing trend. There is also a definite increase in the sea-level and sea surface temperature. Simply put, the values in India are comparable to global values and yet, public participation in addressing this issue is only minor. India and the world faces two challenges dealing with climate change, first to reduce carbon dioxide (CO_2) emission by moving to alternative technologies as early as possible and second to build community resilience to deal with recurring impact of climate change which now have become inevitable.

Under the above scenario Department of Botany, Deen Dayal Upadhyaya College (University of Delhi) has organised a National Conference during March 02-03, 2015 to provide a common platform for the students, academicians and scientific community (scientists / researchers) from different disciplines to share their observations and experiences so as to generate sufficient interest for further research in the area of climate change adaptation and mitigation.

THEMES OF THE CONFERENCE :

⇒ CLIMATE CHANGE SCENARIO IN INDIA
⇒ NATURAL RESOURCE AND FOOD SECURITY UNDER CLIMATE CHANGE
⇒ CLIMATE CHANGE AND ENERGY SECURITY
⇒ ROLE OF SCIENCE AND TECHNOLOGY UNDER CLIMATE CHANGE (SCIENCE AND TECHNOLOGY AND BIOTECHNOLOGY)
⇒ ECONOMICS AND CLIMATE CHANGE
⇒ ADAPTATION AND MITIGATION UNDER CLIMATE CHANGE

DEPARTMENT OF BOTANY
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02-03, March 2015
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Editors
Sachchidanand Tripathi
Rajkumari Sanayaima Devi
Sandeep Kumar
Virat Jolli

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EDITORIAL

The Department of Botany, Deen Dayal Upadhyaya College is delighted to publish a conference proceeding on Climate Change. The proceeding contains many interesting research articles from discipline like humanities, sciences and commerce. It will surely widen reader knowledge base and improve his or her understanding about climate change in Indian perspective. We have put all our efforts to compile and edit the proceeding book and would like to thank all the contributing authors for sharing their valuable research work through this medium. In this editorial section we have also given key suggestions, and recommendations that culminate out from conference which we believe should be taken into consideration by Government of India.

Impact of Climate Change has become a harsh reality for India and the World. Climate change related disasters have brought wide spread misery and huge economic losses to India adversely affecting human health, agriculture and food security, natural resources and energy security, and Biodiversity. Various national and international institutions like IPCC have shown a stark picture in Indian context. The scenario is anticipated to worsen as humans continue to pump greenhouse gases into the atmosphere without being aware of the contribution they are making for their own downfall. Over the past decades, climate change has become one of the most heavily researched subjects in science. However, in recent years the impact of climate change has become prominently visible with an erratic monsoon creating drought in some areas and extreme deluge in others like Uttarakhand and Jammu and Kashmir. Annual mean temperature in India for the past 110 years shows an increasing trend. There is also a definite increase in the sea-level and sea surface temperature. Simply put, the values in India are comparable to global values and yet, public participation in addressing this issue is only minor. India and the World faces two challenges dealing with climate change, first to reduce Carbon dioxide (CO_2) emission by moving to alternative technologies as early as possible and second to build community resilience to deal with recurring impact of Climate change which now have become inevitable.

Under above scenario Department of Botany, Deen Dayal Upadhyaya College (University of Delhi) has organized a National Conference at Conference Centre, University of Delhi, on 02-03 March 2015 to provide a common platform for the students, academicians and scientific community (scientists / researchers) from different disciplines to share their observations and experiences so as to generate sufficient interest for further research in the area of climate change and its adaptation and mitigation.

The conference was inaugurated by **Prof. Akhilesh Kumar Tyagi**, Director, National Institute of Plant and Genome Research, New Delhi. In the inaugural address he gave a detailed account of biotechnological researches in relation to various environmental stresses prevailing in India and emphasized on the need for increasing government funding towards climate change research. **Prof A.K. Pandey**, Chairman Governing Body Deen Dayal Upadhyaya College, **Dr. S.K. Garg**, Principal DDU College and Prof**. A. S. Raghubanshi**, Director, IESD, BHU, Varanasi have presented their views on the themes of the conference.

The keynote address was delivered by **Dr. Suruchi Bhadwal**, Associate Director, Earth Science and Climate Change Division, The Energy Resource Institute (TERI), New Delhi. During her address she gave an overall view of Impacts of climate change in Indian context. She said there were enough evidences of warming (0.51^0 C/100yrs) of Indian mean annual temperature. Increase in number of floods, flash floods and heat wave in many parts of India was a result of climate change. Future projections of climate over India also predict warming trends.

During the conference a total of 192 papers were presented which comprised of 25 invited papers, 34 oral presentations and 133 poster presentations.

The conference was truly of a National character as delegates from various Indian Universities, Research Institutions, Non-Governmental Organizations and Private Universities like *BHU, Varanasi; University of Delhi; Allahabad University; J.N.U, Delhi; Punjabi University, Patiala; Guru Nanak Dev University, Amritsar; Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan); Guru Gobind Singh Indraprastha University, Delhi; University of Energy and petroleum University, Dehradun (U.K.); Sher-e-Kashmir University of Agriculture Science and Technology (Jammu and Kashmir); Aligarh Muslim University (U.P); Guru Ghasidas University (Chattisgarh); Bhim Rao Ambedkar University, Lucknow; FRI, Dehradun; ISRO, Hyderabad; IIT Roorkee, Pondicherry University (Pudducherry);CSIR-NEERI, Delhi; Amity and SRM University; Climate Change Reality etc.* presented their research work at the conference.

During two days of the conference, papers were presented under six technical sessions and two poster sessions with following sub themes: **Climate change scenario in India, Natural resource and food security under climate change, Climate change and energy security, Role of science and technology under climate change, Economics and climate change, Adaptation and mitigation under climate change**

To encourage the participation of young scientists, two extra sessions have been dedicated to young scientists. In these sessions 20 oral presentations were held.

One of the main aims of the conference was to encourage the participation of Undergraduate and Post-graduate students in a scientific conference of National repute. This was to inculcate the scientific temperament amongst them. Apart from this, overwhelming participation of various University Colleges and University students in Poster Session is the positive outcome of this conference.

Prof. N. Parthasarthy (Pondicherry University) highlighted the current threats to natural resources under climate change. Dr. C.S. Jha (NRS, ISRO) discussed the measures of natural resource management under changing climate and illustrated ISRO's initiative on monitoring Indian carbon cycle. Prof. Paramjit Khurana (Univeristy of Delhi) stressed the role of biotechnological measures to ensure food security under changing climate. It was stressed that climate change, loss or change in natural resources, attaining food security, ensuring energy security, and impact on economy are complex interlinked issues, understanding of these processes and awareness are lacking, and the dimensions of the problems go beyond the geographical, social and political scales within they are usually dealt with. The participants agreed that there is a constant pressure on natural resources which is also affecting food security under changing climate. Therefore, in order to put adaptation and mitigation principles successfully into action and to overcome hindrances, the conference made the following recommendations:

- Formulation of plans at national, regional and local level should be based on a firm understanding of ecosystem function and the provision of ecosystem services,

- Effective and constructive intra and inter-state coordination is needed to implement and compliance with environmental laws and climate change policy of India,
- Governments, funding agencies etc. should provide more alternatives of funding for climate change related projects,
- Further research should be promoted to fill knowledge gaps,
- Large and heterogeneous areas possessing fragile ecosystems such as mountains, hills, semi arid, deserts, wetland areas should be given a high priority for protection,
- Create awareness among stakeholders when there is uncertainty about impacts from climate change as well as land use changes; and balance the different interests to promote sustainable management of natural resources,
- Coordination with people and stakeholders through, effective environmental education, communication and engagement is of utmost importance,
- Give environmental protection authorities more responsibility and legal authority, and ensure Intra-and inter- state collaboration and coherent, cross-sectoral National policy, and
- Consistent monitoring programmes are important to assess the progress of initiatives undertaken to tackle climate change.

Prof. A.S. Raghubanshi, emphasized upon the current challenges to urban areas under climate change. There was a consensus among participants that urban ecosystem in India is facing tremendous pressure in terms of rising air temperatures (e.g. heat waves), variations in the water cycle leading to both water stress and extreme rainfall events and flooding, deteriorating air quality, biological invasions, intensive use of areas for infrastructure and buildings that makes adaptation and mitigation planning more difficult. It was agreed that for a better adaptation towards climate change the green infrastructure should be enhanced through an ecosystem based approach. To achieve this goal it was recommended that:

- All stakeholders should be involved to frame the urban climate change adaptation and mitigation strategies,
- Participation platforms and new partnerships should be build,
- Advisory bodies should be established at state and national level for greening public and private investments,
- Involvement of volunteers lending their support towards adaptation and mitigation should be promoted

Prof. N.C. Gupta highlighted the current scenario of energy sector in India and emphasized on certain measures to ameliorate the impact of climate change on meeting the energy security. The participants agreed that climate change is a substantial energy security threat. On one hand it can directly influence the energy security by damaging power plants and transmission lines, disrupting the delivery of imported energy fuels, and destroying crops for biofuels through direct flooding and natural disasters, on the other it has severe impacts on food security, health, and environmental refugees that can complicate formulation of sound energy policy.

The major chunk of the leading GHG i.e. CO_2 comes from energy supply (coal based power plants) and transport (fossil fuels). It was emphasized during the discussion that measures to reduce India's carbon footprint are essential in mitigating the impact of climate change.

The conference provided following recommendations to reduce India's Carbon Footprint:

- Establishing new grids or establish smart distribution systems to connect the installations of renewable energy plants
- To improve cost efficiency for renewable energies, distribution grids with high transmission capacities should be established.
- Along with technological transformation, change in the behavior of energy consumption should be promoted
- Incorporate all stakeholders, by actively including NGOs and private sector to achieve a transition in energy behavior toward sustainable development
- Adoption of clean coal technology and formulation of policy and legal framework for Carbon Capture Storage (CCS) Technology development.
- Efficient carbon capture measures such as building a pipeline network should be adopted.
- It is of immense importance to do research on the capacities of storage before starting to apply new techniques.
- Proper implementation of energy efficiency policy measures in buildings of various sectors and transport systems.
- Framing a climate policy that can help to reduce the import dependency on energy minerals, thereby ameliorating the threats of unstable prices and political circumstances.
- Arrangements of legislation on the different administrative levels are necessary with introduction of an impact assessment system which incorporates a set of emission reduction targets and energy conservation projects
- Introduction of a comprehensive environment tax and proper implementation of already existing environmental policies.

Overall, a consensus was there among the participants that the measures could be taken at different levels. Building better awareness, providing sufficient funding and working on long-term sustainable solutions are the basis for effective mitigatory and adaptive measures. Additionally, successfully putting in place, adaptation actions requires identifying the right scale of implementation, involvement of local communities and long-term integrated climate change management planning, derived and implemented through stakeholder engagement (for example, conferences, symposia, workshops, meetings, participation). There was an agreement for practical action at the local scale, particularly providing more help and specific guidance for practitioners working in nature conservation, building partnerships between nature's conservation and other sectors and interest groups including a best practice approach.

Acknowledgements: We thank Department of Science and Technology-Science and Engineering Research Board (Government of India), Biodiversity & Environmental Sustainability for their funding and support. We thank University of Delhi for providing Conference Centre and University Guest House Facility.

Sachchidanand Tripathi
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Mapping Green Spaces of Delhi: Understanding the Drivers of Change and Towards Mitigation and Adaptation of Climate Change

Somajita Paul [1, 2,*] and Harini Nagendra[3]
[1]*Ashoka Trust for Research in Ecology and the Environment (ATREE), Royal Enclave, Jakkur Post, Srirampura, Bangalore 560064, India*
[2]*Manipal Academy of Higher Education, Manipal 576104, India*
[3]*School of Development, Azim Premji University, PES Institute of Technology Campus, Pixel Park, B Block, Electronics City, Hosur Road, Bangalore 560100, India*
***Corresponding author:** somajita.paul@gmail.com

Abstract-Impact of climate change can be felt in urban centres across the world, affecting its physical and ecological systems and eventually the health and wellbeing of the human societies. There are also efforts to reduce vulnerabilities of the climate change and build resilience to the impacts of climate change. Vegetation is an effective means to reduce heat storage uptake, thus greening of urban areas is one such strategy to reduce the effect of climate change and mitigation. It involves the protection of natural carbon "sinks" like the urban forests or green spaces and creation of the new ones. Delhi, the worlds' second most populous city, has experienced rapid, planned and unplanned expansion, at the cost of its green cover in recent decades. There is also rise in the mean annual temperature in past decades. In this study, we use satellite images from 1986, 1999 and 2010 to map changes in urban and green cover, and assess the fragmentation of green spaces. We find that urban patterns of development have shaped the distribution and fragmentation of green spaces, with the city centre containing more green spaces with less fragmentation compared to intermediate areas and the peri-urban periphery. Results can provide important devise policies intended for mitigation and adaptation to climate change at local level in other cities.

Keywords: Land Use Land Cover Change; Vegetation Change; Fragmentation; Urban Institutions; Mitigation; Climate Change.

1. INTRODUCTION

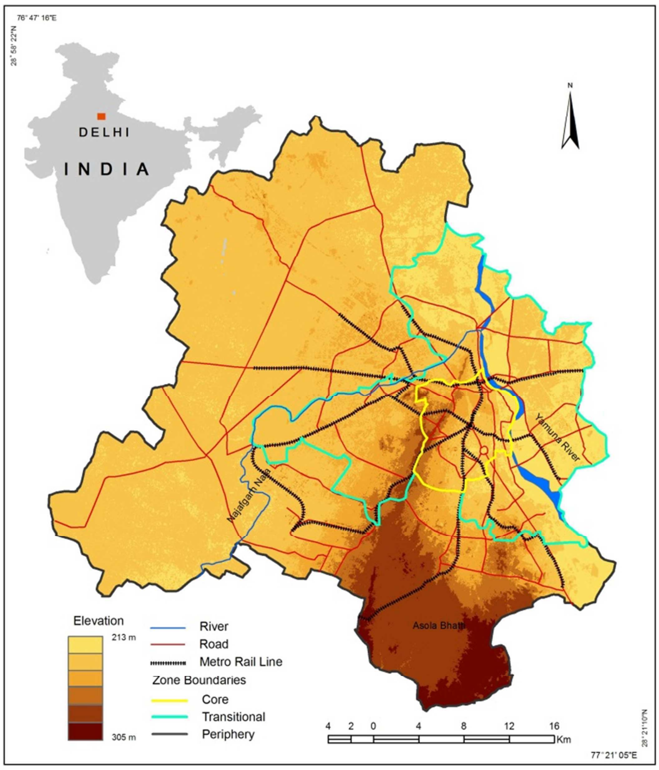
Impact of climate change can be felt in the urban centres across the world. About 66% of the world's population will be urban population by the year 2050 (World urbanization Prospect 2014). Thus, more and more people will be exposed to climatic uncertainties and forced to cope with them. The climatic uncertainties are related to increased storm events, warming, enhanced urban heat island effect and variable precipitation regime. The increase in temperature affects the urban microclimate with negative implications for energy and water consumption. The changing climate impacts the life and wellbeing of the people as well as the urban community and ecosystems in a broad variety of ways in different scales. It is also going to impact the low lying and coastal cities due to sea level rise. The climate change effects human health through increased discomfort, morbidity and mortality (Patz et al. 2005). The rapidly expanding cities will face water scarcity (Vörösmarty et al.2000) and adversely affecting food security (Schmidhuber and Tubiello 2007).Climate change also effects the local ecosystem and is associated with the variation in phenology, increased competition from the exotic species and pole ward range shift in individual species(Permesan2006;Wilby and Perry 2006).The forests may face rapid alterations in the timing, intensity, frequency, and extent of disturbances(Dale at al.2001).The energy demand for cooling and heating devices is also associated with the climate changes (Hamlet et al.2010). The warming of the climate will benefit few cool countries and hit the warm countries hard (Mendelsohn et al. 2000).

Efforts are made to reduce the vulnerabilities of the climate change and build resilience to the impacts of *climate change*. There is international funding to support the adaptive capacity of the vulnerable urban stake holders (Ayers 2009).A wide variety of policy responses are emerging at local and regional levels to considering adaptation and mitigation simultaneously, and strengthening synergies between them. Policy makers have set targets for Green house emission and implemented it as in US at sub national levels (Lutsey and Sperling 2008). Different measures have also been taken to reduce greenhouse gas emissions and to improve air quality as in Dhaka. The countries like Bangladesh which are vulnerable to floods have taken flood protection measures, like construction of embankments, raised roads flood walls, etc. (Alam and Golam Rabbani 2007).The Latin American countries have set a range of programmes for prevention and mitigation, like early warning system for hurricanes and prepare communities for risk management, cooperation, information exchange and advice(Hardoy and Pandiella 2009).Japanese government have implemented Heat Wave Warning Systems (HWWS) at municipality levels, for prevention of heat-related deaths and disease (Martinez et al. 2011). United Kingdom government have taken top-down targeted approach in flood defence and water supply sectors (Tomkins et al. 2010). Vegetation is an effective means to reduce heat storage uptake, through evaporative cooling in the tropical areas and low albedo in Boreal forest. The green cover is able attenuate global warming through carbon sequestration.

Urban trees, be it a single specimen or planted forest strands, forms distinct micro to local scale climates contributing to the larger urban climate mosaic (Oke et al. 1989).Urban trees and high-albedo surfaces can ameliorate the heat-island effect. Mitigation of urban heat islands can potentially reduce energy use in air conditioning and improvement in urban air quality (Shashua and Hoffman2000; Akbari et al., 2001). Study in US show that the urban trees have huge potential in removing air pollutants, reduce atmospheric carbon dioxide (sequester carbon) and saves annual heating and cooling costs (McPherson et al.1997; Nowak and Crane 2002).Gill et al. (2007) in their study in Greater Manchester showed that the promotion of green space network / green infrastructure in a city is an effective strategy in of climate change adaptation. Urban green space also provides various ecosystem services including air purification, water infiltration, and reduction in water pollution, noise reduction (Kong et al. 2007). The urban vegetation plays an important recreational, spiritual, therapeutic and cultural role in the lives of city dwellers (Bolund and Hunhammar 1999). The greening of urban areas is one such strategy to reduce the effect of climate change, through enhancement of carbon sequestration and mitigate fluxes of GHGs (Sohl et al. 2012).It involves the protection of natural carbon "sinks" like the urban forests or green spaces and creation of the new ones.

Yet despite their importance, urban green spaces are at increasing risk, shrinking in area and experiencing fragmentation and loss in connectivity due to increasing demands for urban expansion and the increased intensity of the urban footprint in and around cities (Seto et al. 2012). Their distribution is spatially irregular and driven by various biophysical, ecological, social and economic forces (Pickett et al. 2001).Accurate knowledge of the factors driving changes in the extent, location and distribution of green spaces is important to help city planners design better policies for conservation of urban green spaces for the betterment of the civil society and the ecosystem.

Delhi, India's capital, is the largest Indian city in terms of population. The NCTD contains 25 million people, which is anticipated to increase to 36 million by 2030 (United Nations 2014).Rapid urbanization has come at the cost of the city's greenery, leading to large scale clearing of wetlands, tree cover and grasslands, and impacting impact biodiversity. There is a steady rise in mean annual temperature in past decades. Study has shown that high population density is one of the main contributing factors for the high surface temperature, urban heat island intensity and also micro-climate of Delhi (Mohan et al. 2011; Mallick et al. 2013). But water bodies, agricultural crop land and dense vegetation tend to have low surface temperature at day time over Delhi (Kant et al.2009) while the areas of high-density residential and industrial land uses have higher temperature (Roy et al. 2011). The Delhi government aims at promoting and facilitating the environment friendly projects for reduction in the emissions of Greenhouse Gases, and addressing climate change related issues. The government under took Climate change agenda for 2009 -2012on various identified sectors. Like water conservation through water harvestation, energy conservation, clean power generation,



creation of city forest. Apart from the government, the residents' welfare associations, Environmental NGO's are also actively involved in the conservation and regeneration of the urban forest.

In this study, we use satellite images from 1986, 1999 and 2010 to map changes in urban and green cover, and assess the fragmentation of green spaces as a consequence of rapid urbanization. This research helps in advancing our understanding of how urbanization shapes changes in green spaces, and can contribute to climate change mitigation and adaptation interventions at the local level.

2. STUDY AREA

National Capital Territory of Delhi (NCTD) is located between 28°24'17"N and 28 ° 53'00" N and 76 ° 50'24"E and 77 ° 20'37" E. It covers an area of 1,490 km^2 and elevation ranges from 213 to 305 m above sea level. The topography of the NCTD is heterogeneous, ranging from the largely agricultural plains in the north, to the arid foothills of the Aravalli range in the south and the Yamuna River transverses the city from north to south. The climate is humid subtropical, with hot and long summer, and brief winters with heavy fog. The annual temperature varies from about 3º in the winter, to about 45º C in summer. The rainfall is dominated by the monsoon, with most rain occurring from the middle of June to the end of September, providing 400 to 600 mm of precipitation annually. The native vegetation of NCTD comprises of thorn forest. According to Champion and Seth (1968) the ridge forest of Delhi falls into category of 'tropical thorn forest'.

Administratively NCT Delhi is divided into 9 districts, 27 administrative sub-divisions or Tehsils. The NCTD consists of three local bodies – (i) New Delhi Municipal Council (NDMC), (ii) Delhi Cantonment Board (DCB) and (iii) Municipal Corporation of Delhi (MCD). The population density of NCTD in 2001 was 9340 people/km^2, the highest in the country (FSI 2009) and is growing at the rate of 20.96 and with a population of 167.53 lakh (Census, 2011).

NCTD also witnessed rapid urbanization with 647.04 km^2 of the land of NCTD being built-up (Sharma and Joshi, 2013). About three-quarters of the households live in unplanned settlements (Ahmed et al. 2013). Since late 1950's growth of number motor vehicles is more than the urban population growth (Badami and Haider 2007).
There is extensive tree cover in the managed green spaces, like the parks, educational institutional areas, government and military areas, archeological sites (Krishen, 2006; Khera et al. 2009). Delhi also has a wildlife sanctuary, the Asola-Bhatti sanctuary which covers an area of 1991 ha.

Delhi has a juxtaposition of the old and the new areas. The old area of the city is the walled Shahjahanabad with densely packed buildings. The Mughal emperor Shah Jahan founded Shahjahanabad in 1638. This area comes within present day MCD. The capital of British India has been transferred to Delhi from Calcutta in 1911. The British architect Edward Lutyen designed the garden city of New Delhi, popularly known as Lutyen's Delhi, with a geometrical plan and wide roads (Dupoint, 2004). The British also built the Delhi cantonment in the 1914, with wide roads and bungalows and administrative building to house the British army. Post-independence the planners played direct role in the urban development of the city. The present day NDMC and DCB corresponds to the Lutyens' Delhi and the Cantonment area.

We followed the definitions used by Jain et al. (2011) (Figure 1). The city Core represents the older part of Delhi (Karol Bagh, PaharGanj, Sadar Bazar, Daryaganj, Kotwali, Parliament Street, Connaught Place and ChanakyaPuri). A Transitional zone (called 'Ring 1' by [Jain et al. 2011], represents intermediate areas of the city (Seelampur, Shahdara, Seemapuri, Gandhi Nagar, VivekVihar and PreetVihar, Patel Nagar, Rajouri Garden, Civil Lines, Model Town and Defence Colony Tehsils). The city Periphery (defined as 'Ring 2' by [Jain et al. 2011]) is the peri-urban outer ring of development in NCTD (Saraswati Vihar, Kalkaji, Punjabi Bagh, Narela, HauzKhas, VasantVihar, and Najafgarh Tehsils).

3. METHODS

Three satellite images were used for this analysis. A 60m resolution of Landsat Image of January 1986 has been downloaded from the USGS Global Visualization Viewer (http://glovis.usgs.gov). The satellite imagery of January 1986 has a 10 % cloud cover owing to western disturbances. The image of January 1986 was chosen because of non availability of any other image of the region from the 1980's. A 30 m resolution of Landsat ETM+ image of October 1999 was downloaded from the Global Land Cover Facility at the University of Maryland. A 23m November 2010 IRS LISS 3 image was also acquired from the National Remote Sensing Agency of India. The 2010 image was spatially registered to nine 1:50,000 Survey of India topographic sheets, after which the 1999 image was registered to the 2010 image and 1986 image.

Care was taken to ensure that spatial over-lays were well matched, with root mean square registration errors less than half a pixel, followed by careful visual examination of the overlaid images across a number of well distributed locations using swiping. Supervised classification of both images was then conducted (Jensen 2000), categorizing land cover into three classes for each time period – vegetation (tree cover), built area (urban cover, including buildings, roads and other asphalted or concreted areas) and other areas (agriculture, open fields, barren rocks, grassy patches, and other non-tree, water and non-urban land cover categories). The training information for supervised classification was collected from visual interpretation of Google Earth imagery and topographical sheets. Extensive manual editing corrected for errors in classification (Nagendra et al. 2012), and this improved the accuracy of the classification. Due to western disturbances, the North West part of the National Capital Territory has about 10% cloud cover in the 1986 image. The topographical sheet and Google Earth shows this region to be a cultivated area. This cloud covered areas have been recoded as cultivated areas in the classified image. Delhi experienced flood like condition in the year 2010. Water logged areas posed a challenge for the classification of some open areas/ agricultural fields in this image, appearing as water body in the classification. Other than this, the images had some problem areas like the open areas with grass cover which has been classified as cultivated land and the silt along the bank of Yamuna has been misclassified as built-up areas. It has been observed that there is no urban settlement within some distance from Yamuna River. Thus, if any such area was found,

these have been recoded / reclassified as cultivation; and the misclassified water bodies have been corrected.
All image operations were conducted using ERDAS Imagine software. Independent accuracy assessment of the classified images was conducted using an identical, independent set of ground verification points that were not used as inputs in the supervised classification. In order to remove noise in the classification and to ensure greater image to image correspondence, a 3 × 3 filter was applied to the change image. This was done to retain the majority category, and dissolve all smaller pixels into this category. Such filters are generally used in land cover change analysis of highly fragmented urban areas (Huang et al. 2007; Thapa and Murayama 2009; Nagendra et al. 2012).

The human induced landuse changes can lead to fragmentation of natural vegetal cover, thus endangering the biodiversity and degradation of the habitat. Hence, there is a requirement for the understanding of the type and magnitude of human disturbance leading to fragmentation. Thus Landscape Fragmentation tool (LFT) was used for the quantification of dynamics of vegetation fragmentation. Centre for Land use Education and Research (CLEAR), university of Connecticut developed this tool. On the basis of edge width LFT classifies the vegetation cover into 4 main categories- - *patch, edge, perforated, and core* (Vogt et al. 2007). Patch pixels are within a small vegetation fragment that does not contain any core forest pixels. Perforated pixels occur on the edges along small vegetation gaps. Core pixels are vegetation pixels that are more than 100 meters from the nearest urban pixel.

4. RESULTS AND DISCUSSION

We achieved a high degree of classification accuracy. The classified map of 1986(Figure 2) had an overall accuracy of 90.43%and kappa of 0.89; the map of 1999(Figure 3) had an accuracy of 87.88% and kappa of0.85; and the classified map of 2010 had an accuracy of 90.91% and kappa of 0.88 (Figure 4).

Since 1986, there has been a steady decrease in vegetation cover in all the three zones of the NCTD. The city Core and Transitional zone has the maximum proportion of vegetation cover compared to the Periphery. This can be attributed to the fact that a major part of the Delhi Central Ridge forest falls within the Core, which also contains a large number of avenue trees in areas of Lutyens' Delhi. Most of the vegetation in the Transitional zone is located within Delhi Cantonment and also contains a number of military and educational campuses which are densely vegetated.

The Transitional Zone also contains a section of the Northern Ridge and Central Ridge forests. There is decreasing trend in the vegetation cover in the Core. In 1986, it was 64.86 %(44.50 km^2) and decreased to 58.95% (40.47 km ^{2}) in 1999 and further to 43.98% (30.19km^2) in 2010 (Table 1). This is indicative of the impact of urban growth and infrastructure expansion on urban tree cover, which has been most noticeable in the green city Core.

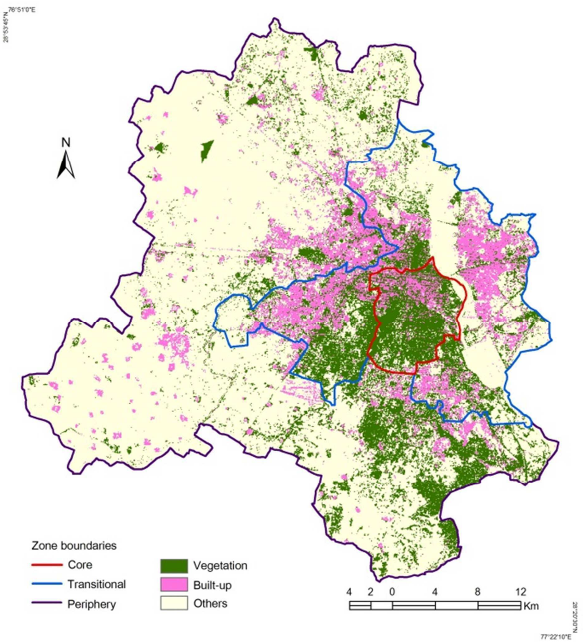


Figure 2. Landuse/ cover in three zones of the NCTD in 1986.

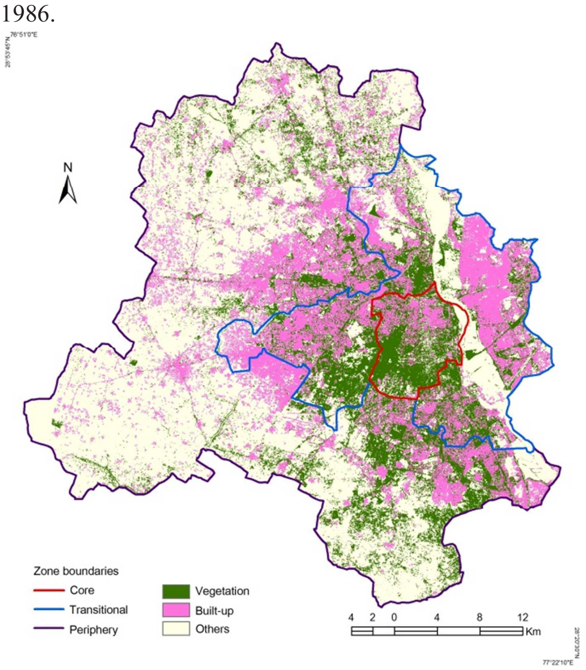


Figure 3. Land use/ cover in three zones of the NCTD in 1999.

The reversal of this trend can be observed in the periphery zone. The vegetation cover increased from 13.16 % (140.55km^2) in 1986 to 14.70% (156.95 km^2) and 16.52% (176.44 km^2) in 1999 and 2010 respectively in the periphery. This is due to afforestation programs on public lands, largely in the Periphery. There is trend of increase in built-up area over time, in all three zones of the NCTD.This trend corresponds with an opposite trend of decrease in the vegetated area over time, across all zones. The Transitional zone had larger proportion of built-up area compared with the Core and Periphery. The proportion of built-up area increased from 24.65% (87 km^2) in 1986 to 50.97% (179.91 km^2) in 2010. There is consistent decrease in the area under other (agriculture, open fields, barren rocks, grassy patches, and other non-tree, water and non-urban land cover categories) category in the landscape. It occupied a much larger proportion of area in the Transitional zone and Periphery compared to Core in all the years. These trends to indicate that the decrease in vegetation and other landuse /cover category is largely as a consequence of large scale increase in built-up (urban) area and infrastructural expansion.

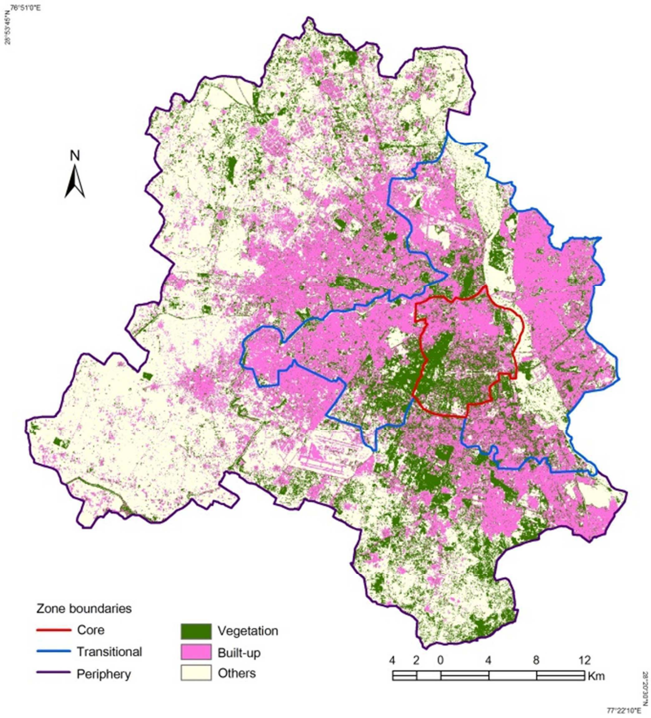


Figure 4. Landuse/cover in three zones of the NCTD in 2010.

Table1: Area and percentage of area within different land use/ land cover in three zones of the NCTD in 1986, 1999 and 2010

Year	Area in km²	Core	Transitional	Periphery	NCTD
1986	Vegetation	44.40 (64.68%)	89.36 (25.32%)	140.55 (13.16%)	274.31 (18.42%)
	Built-up	13.87 (20.21%)	87.00 (24.65%)	78.40 (7.34%)	179.27 (12.04%)
	Others	10.37 (15.10%)	176.61 (50.03%)	848.89 (79.50%)	1035.87 (69.55%)
1999	Vegetation	40.47 (58.95%)	98.41 (27.88%)	156.94 (14.70%)	295.81 (19.86%)
	Built-up	16.35 (23.82%)	131.86 (37.36%)	201.11 (18.83%)	349.32 (23.45%)
	Others	11.82 (17.22%)	122.70 (34.76%)	709.80 (66.47%)	844.32 (56.69%)
2010	Vegetation	30.19 (43.98%)	79.16 (22.43%)	176.44 (16.52%)	285.79 (19.19%
	Built-up	27.83 (40.55%)	179.91 (50.97%)	275.86 (25.83%)	483.60 (32.47%)
	Others	10.62 (15.47%)	93.90 (26.60%)	615.55 (57.64%)	720.06 (48.34%)

Over the years fragmentation of green is taking place in the landscape (Table 2).The patch and edge areas have increased to 83.03km^2 and 106.51 km^2 in 1999 and again came down to 67.54 km^2 and 93.97 km^2 in 2010.Perforations were high in 1986 (52.99 km^2) & 1999 (51.98 km^2) but it decreased in 2010(25.03km^2).The area of the core forest is declining, due to the fragmentation of large patches because of construction and infrastructural expansion, despite afforestation initiatives (Bajwa 2010). The resultant fragmentation of green networks decreases their capacity to provide important ecosystem services (Jim and Chen 2003) such as urban microclimatic regulation and rainfall percolation.

Year	Fragmentation category (area in km^2)	Core	Transitional	Periphery	NCTD
1986	Patch	2.74 (6.03%)	24.71 (28.13%)	45.47 (33.59%)	72.91 (27.14%)
	Edge	11.84 (26.05%)	32.22 (36.68%)	50.25 (37.12%)	94.30 (35.11%)
	Perforation	16.56 (36.45%)	17.50 (19.92%)	18.93 (13.98%)	52.99 (19.73%)
	Core vegetation	14.30 (31.47%)	13.41 (15.27%)	20.71 (15.30%)	48.42 (18.03%)
1999	Patch	2.62 (6.40%)	21.85 (22.87%)	58.57 (41.39%)	83.03 (29.88%)
	Edge	13.49 (32.97%)	38.57 (40.37%)	54.45 (38.48%)	106.51 (38.32%)
	Perforation	13.29 (32.50%)	21.28 (22.27%)	17.41 (12.30%)	51.98 (18.70%)
	Core vegetation	11.50 (28.13%)	13.84 (14.48%)	11.08 (7.83%)	36.42 (13.10%)
2010	Patch	3.06 (10.40%)	17.61 (27.98%)	46.86 (35.39%)	67.54 (30.04%)
	Edge	10.89 (36.96%)	26.04 (41.36%)	57.04 (43.08%)	93.97 (41.80%)
	Perforation	7.03 (23.86%)	8.04 (12.78%)	9.96 (7.52%)	25.03 (11.13%)
	Core vegetation	8.48 (28.77%)	11.26 (17.89%)	18.53 (14.00%)	38.27 (17.02%)

Table 2: Area and percentage of area within different vegetation fragmentation categories in three zones of the NCTD in 1986, 1999 and 2010.

5. CONCLUSIONS

Delhi has been experiencing trend of increasing temperature post 1990, mostly brought about by the industrialization, increasing population and massive urbanization. The consistent rise in temperature leads to formation of urban heat island over Delhi (Mohan et al. 2011). This study, focusing on the dynamics of vegetation, can contribute to sustainable urban land use planning for climate change adaptation and mitigation in Indian cities.

The effects of climate change will last many years making adaptation a necessity (Faber 2007). Mitigation policies can substantially reduce the risks associated with human-induced global warming (Oppenheimer et al. 2014).The Delhi city authorities have been dealing with climate change through integrating mitigation and adaptation strategies for building resilience to climate change. Attention has been paid on energy, water conservation, and reduction of pollution and over all greenhouse gas emission and enhancing the sinks of greenhouse gases.

In this study, we find that there is high proportion of green cover in the oldest parts of the city, the Core. This can be attributed to the colonial history of Delhi as a densely planted area, with large parks, a wooded cantonment and large areas of the Delhi Ridge forest. Other research from Indian cities such as Ranchi (Kumar et al. 2011) and Kolkata (Bhatta 2009) also finds greater sprawl in the city periphery, as we find in our study. The analysis shows that the City Core has more vegetation than the Periphery due to its history of greening, but now the vegetation in this region is being rapidly cleared, while there is some plantation in the Periphery due to compulsory afforestation measures to compensate for tree felling in the city. In order to provide a buffer against increased heat effects due to climate change, and to contribute to climate change mitigation and pollution reduction through carbon sequestration and greening, such efforts need to be increased by planners and civil society groups.

With the will and involvement of the city authorities, environmental NGO's and Public institutions, the conservation and the enhancement of the urban vegetation can contribute significantly to climate change mitigation through carbon sequestration. This must be considered in policy, planning, and management. This research helps in advancing our understanding of the potential of urban green spaces for buffering climate change related impacts in India's capital. Similar studies need to be conducted in a wider range of Indian cities, to help devise policies intended for mitigation and adaptation to climate change at the local level.

REFERENCES

1. Ahmad, Sohail, Osman Balaban, Christopher NH Doll, and Magali Dreyfus. 2013. "Delhi revisited." *Cities* 31: 641-653.
2. Akbari, Hashem, Mel Pomerantz, and Haider Taha. 2001. "Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas." *Solar Energy*70, no. 3: 295-310.
3. Alam, Mozaharul, and MD Golam Rabbani. 2007. "Vulnerabilities and responses to climate change for Dhaka." *Environment and Urbanization* 19, no. 1: 81-97
4. Ayers, Jessica. "International funding to support urban adaptation to climate change. 2009." *Environment and Urbanization* 21, no. 1 : 225-240.
5. Badami, Madhav G., and Murtaza Haider. 2007."An analysis of public bus transit performance in Indian cities." *Transportation Research Part A: Policy and Practice* 41, no. 10 : 961-981.
6. Bajwa, Meher. 2010. "Urban biodiversity: an essay on natural capital and social innovation using Delhi as an example." *Journal of Resources, Energy and Development* 7, no. 2 : 95-115.
7. Bhatta, B. 2009. "Analysis of urban growth pattern using remote sensing and GIS: a case study of Kolkata, India." *International Journal of Remote Sensing* 30, no. 18 : 4733-4746.
8. Bolund, Per, and Sven Hunhammar. 1999. "Ecosystem services in urban areas."*Ecological Economics* 29, no. 2: 293-301.
9. Census of India, 2011.http://censusindia.gov.in
10. Champion, Sir H G, and Shiam Kishore Seth.1968. "A revised survey of the forest types of India." *A revised survey of the forest types of India.*
11. Dale, Virginia H., Linda A. Joyce, Steve McNulty, Ronald P. Neilson, Matthew P. Ayres, Michael D. Flannigan, Paul J. Hanson et al. 2001. "Climate Change and Forest Disturbances: Climate change can affect forests by altering the frequency, intensity, duration, and timing of fire, drought, introduced species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides." *BioScience* 51, no. 9 : 723-734.
12. Dupont, Veronique. 2004. "Socio-spatial differentiation and residential segregation in Delhi: a question of scale?." *Geoforum* 35, no. 2: 157-175.
13. Farber, Daniel A. 2007. "Adapting to climate change: who should pay." *J. Land Use &Envtl. L.* 23: 1.
14. Gill, S. E., J. F. Handley, A. R. Ennos, and Stephan Pauleit. 2007. "Adapting cities for climate change: the role of the green infrastructure." *Built Environment (1978)*: 115-133.
15. Hamlet, Alan F., Se-Yeun Lee, Kristian EB Mickelson, and Marketa M. Elsner. 2010. "Effects of projected climate change on energy supply and demand in the Pacific Northwest and Washington State." *Climatic Change* 102, no. 1-2: 103-128.
16. Hardoy, Jorgelina, and Gustavo Pandiella. 2009. "Urban poverty and vulnerability to climate change in Latin America." *Environment and Urbanization* 21, no. 1: 203-224.
17. Huang, Jingnan, X. X. Lu, and Jefferey M. Sellers. 2007. "A global comparative analysis of urban form: Applying spatial metrics and remote sensing."*Landscape and Urban Planning* 82, no. 4: 184-197.
18. Jain, Manisha, HannesTaubenböck, and SridharanNamperumal. 2011. "Seamless urbanisation and knotted city growth: Delhi Metropolitan Region." *Real CORP*: 18-20.
19. Jensen, J. R. 2000. Remote sensing of the environment: An earth resource perspective. New Jersey, USA: Prentice Hall.
20. Jim, Chi Yung, and Sophia S. Chen. 2003. "Comprehensive greenspace planning based on landscape ecology principles in compact Nanjing city, China."*Landscape and urban planning* 65, no. 3 : 95-116.
21. Kant, Yogesh, B. D. Bharath, Javed Mallick, Clement Atzberger, and Norman Kerle. 2009. "Satellite-based analysis of the role of land use/land cover and vegetation density on surface temperature regime of Delhi, India." *Journal of the Indian Society of Remote Sensing* 37, no. 2: 201-214.
22. Kong, Fanhua, Haiwei Yin, and NobukazuNakagoshi. 2007."Using GIS and landscape metrics in the hedonic price modeling of the amenity value of urban green space: A case study in Jinan City, China." *Landscape and Urban Planning* 79, no. 3: 240-252.
23. Khera, N., V. Mehta, and B. C. Sabata. 2009. "Interrelationship of birds and habitat features in urban greenspaces in Delhi, India." *Urban Forestry &Urban Greening*8, no. 3: 187-196.
24. Krishen, Pradip. 2006. *Trees of Delhi: a field guide*. Penguin Books India.
25. Kumar, Amit, Arvind Chandra Pandey, NajmulHoda, and A. T. Jeyaseelan. 2011. "Evaluation of urban sprawl pattern in the tribal-dominated cities of Jharkhand state, India." *International Journal of Remote Sensing* 32, no. 22 : 7651-7675.
26. Lutsey, Nicholas, and Daniel Sperling. 2008."America's bottom-up climate change mitigation policy." *Energy Policy* 36, no. 2: 673-685.
27. Mallick, Javed, and Atiqur Rahman. 2012."Impact of population density on the surface temperature and micro-climate of Delhi." *CurrSci* 102: 1708-13.
29. Mallick, Javed, AtiqurRahman, and Chander Kumar Singh. 2013."Modeling urban heat islands in heterogeneous land surface and its correlation with impervious surface area by using night-time ASTER satellite data in highly urbanizing city, Delhi-India." *Advances in Space Research* 52, no. 4: 639-655.
30. Martinez, Gerardo Sanchez, Chisato Imai, and KanakoMasumo. 2011. "Local heat stroke prevention plans in Japan: characteristics and elements for public health adaptation to climate change." *International Journal of Environmental Research and Public Health* 8, no. 12: 4563-4581.
31. McPherson, E. Gregory, David Nowak, Gordon Heisler, Sue Grimmond, Catherine Souch, Rich Grant, and Rowan Rowntree. 1997. "Quantifying urban forest structure, function, and value: the Chicago Urban Forest Climate Project."*Urban Ecosystems* 1, no. 1 : 49-61.

32. Mendelsohn, Robert, Wendy Morrison, Michael E. Schlesinger, and Natalia G. Andronova. 2000. "Country-specific market impacts of climate change." *Climatic Change* 45, no. 3-4 : 553-569.
33. Mohan, Manju, AnuragKandya, and Arunachalam Battiprolu. 2011."Urban heat island effect over national capital region of India: a study using the temperature trends." *Journal of Environmental Protection* 2, no. 04 : 465.
34. Nagendra, Harini, Suparsh Nagendran, Somajita Paul, and Sajid Pareeth. 2012. "Graying, greening and fragmentation in the rapidly expanding Indian city of Bangalore." *Landscape and Urban Planning* 105, no. 4: 400-406.
35. Nowak, David J., and Daniel E. Crane."Carbon storage and sequestration by urban trees in the USA. 2002." *Environmental Pollution* 116, no. 3 : 381-389.
36. Oke, Tim R., J. M. Crowther, K. G. McNaughton, J. L. Monteith, and B. Gardiner. 1989."The micrometeorology of the urban forest [and discussion]."*Philosophical Transactions of the Royal Society of London. B, Biological Sciences* 324, no. 1223 : 335-349.
37. Oppenheimer, M., M. Campos, R. Warren, J. Birkmann, G. Luber, B. O'Neill, and K. Takahashi. 2014."Emergent risks and key vulnerabilities." *Climate Change*: 1039-1099.
38. Parmesan, Camille. 2006."Ecological and evolutionary responses to recent climate change." *Annual Review of Ecology, Evolution, and Systematics* : 637-669.
39. Patz, Jonathan A., Diarmid Campbell-Lendrum, Tracey Holloway, and Jonathan A. Foley. 2005."Impact of regional climate change on human health." *Nature* 438, no. 7066 310-317.
40. Pickett, Steward TA, M. L. Cadenasso, J. M. Grove, C. H. Nilon, R. V. Pouyat, W. C. Zipperer, and R. Costanza. 2001."Urban ecological systems: linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas."*Annual Review of Ecology and Systematic* : 127-157.
41. Roy, Shouraseni Sen, R. B. Singh, and Manoj Kumar. 2011."An analysis of local spatial temperature patterns in the Delhi Metropolitan Area." *Physical Geography* 32, no. 2 : 114-138.
42. Schmidhuber, Josef, and Francesco N. Tubiello. 2007."Global food security under climate change." *Proceedings of the National Academy of Sciences* 104, no. 50: 19703-19708.
43. Seto, Karen C., BurakGüneralp, and Lucy R. Hutyra. 2012. "Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools."*Proceedings of the National Academy of Sciences* 109, no. 40: 16083-16088.
44. Sharma, Richa, and P. K. Joshi. 2013. "Monitoring urban landscape dynamics over Delhi (India) using remote sensing (1998–2011) inputs." *Journal of the Indian Society of Remote Sensing* 41, no. 3: 641-650.
45. Shashua-Bar, L., and M. E. Hoffman. 2000. "Vegetation as a climatic component in the design of an urban street: An empirical model for predicting the cooling effect of urban green areas with trees." *Energy and Buildings* 31, no. 3 : 221-235.
46. Sohl, Terry L., Benjamin M. Sleeter, Zhiliang Zhu, Kristi L. Sayler, Stacie Bennett, Michelle Bouchard, Ryan Reker et al. 2012. "A land-use and land-cover modeling strategy tosupport a national assessment of carbon stocks and fluxes." *Applied Geography* 34: 111-124.
47. Thapa, Rajesh Bahadur, and Yuji Murayama. 2009. "Urban mapping, accuracy, & image classification: A comparison of multiple approaches in Tsukuba City, Japan." *Applied Geography* 29, no. 1: 135-144.
48. Tompkins, Emma L., W. Neil Adger, Emily Boyd, Sophie Nicholson-Cole, Keith Weatherhead, and Nigel Arnell. 2010."Observed adaptation to climate change: UK evidence of transition to a well-adapting society." *Global Environmental Change*20, no. 4 : 627-635.
49. United Nations. 2014. World Urbanization Prospects: The 2014 Revision; United Nations: New York, NY, USA.
50. Vogt, Peter, Kurt H. Riitters, Christine Estreguil, JacekKozak, Timothy G. Wade, and James D. Wickham. 2007. "Mapping spatial patterns with morphological image processing." *Landscape Ecology* 22, no. 2: 171-177.
51. Vörösmarty, Charles J., Pamela Green, Joseph Salisbury, and Richard B. Lammers. 2000. "Global water resources: vulnerability from climate change and population growth." *Science* 289, no. 5477 : 284-288.
52. Wilby, Robert L., and George LW Perry. 2006. "Climate change, biodiversity and the urban environment: a critical review based on London, UK." *Progress in Physical Geography* 30, no. 1: 73-98.

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Integrating Biochar as Conservation Agriculture Tool under Climate Change Mitigation Scenario

Rishikesh Singh[1*], Pratap Srivastava[2], Pardeep Singh[3], Shweta Upadhyay[1], A.S. Raghubanshi[1] and J. Nagendra Babu[4]

[1]Institute of Environment & Sustainable Development (IESD), Banaras Hindu University (BHU), Varanasi-221005, India

[2] Ecosystems Analysis Laboratory, Department of Botany, Banaras Hindu University (BHU), Varanasi-221005, India

[3]Department of Chemistry, Indian Institute of Technology (IIT), Banaras Hindu University (BHU), Varanasi-221005, India

[4] Centre for Environmental Science and Technology, Central University of Punjab (CUPB), Bathinda-151001, India

***Corresponding author:** rishikesh.iesd@gmail.com

Abstract— Surplus crop residue generated from different cereal crops and their open burning leading to several environmental anomalies are of serious concern, though worldwide but more in developing nations. Residue retention under conservation agriculture strategy is one of the suggested alternatives; however, it is not yet succeeded well in tropical regions due to higher rate of decomposition. Fast release of photo-synthetically locked atmospheric CO_2 to the atmosphere is a major constraint for this strategy. Therefore, instead of earlier complete residue retention or 'slash and burn' approaches, recently 'slash and char' strategy is being promoted for agricultural residue management as well as climate change mitigation in developed countries. However, complete slash and char approach may lead to loss of various ecosystem services provided by crop residue such as soil erosion control and soil physical management. Recently, research is progressing towards biochar-residue integrated approach under conservation agriculture systems. In the present work, we revisited the crop residue and its fate under various management strategies and emphasized on the judicious use of crop residue and its biochar in integrated manner for agricultural sustainability. Further, a critical insight has been given on the mechanistic behavior of crop residue-biochar integration as soil conservatory as well as climate mitigatory approaches. Overall, this article will provide a retrospective and prospective approach of biochar-residue integration under tropical ecosystems.

Keywords: Lignocellulosic Biomass, Pyrolysis, Biochar, Climate Change, Carbon Credit.

1. INTRODUCTION

Green house gaseous (GHGs) emissions are considered as the major contributors to the present human-induced climate change. The present emission has attained a 49.5 GT yr^{-1} in terms of carbon dioxide equivalents (CO_{2eq}) level in the year 2010 (IPCC, 2014). The major contributors are anthropogenic forces such as population, economic structure and income distribution, consumption patterns, social behavior at individual level, energy resource utilization and land-use changes in terms of fossil fuel consumption, deforestation, agriculture activities, etc. As per the fifth assessment report of IPCC (2014), proportional sharing in GHGs emission of various sectors is mainly comprised of energy production (34%), and agriculture, forestry and land-use (AFOLU) (24%) mainly contributed by biomass burning and resource-intensive agronomic activities, in addition to their wider measurement uncertainties (Houghton et al., 2012; Tubiello et al., 2013). Further, the exhaustive agricultural practices for meeting the dietary demand of ever-growing population have been well quoted as a potential cause of diminishing various components of agro-ecosystems worldwide (Godfray et al., 2010; Lal, 2011). Therefore, the mitigation of climate change is the key concern of the present global meetings. Further, agriculture sector contributing 1/4th of the global GHGs emission is the major point of attraction for the climate change mitigation (IPCC, 2014).

In order to mitigate the unprecedented impact of climate change several measures have been proposed in the recent meetings of the UNEP in 21st century. Various soil adoptive management strategies have been suggested and some are applied for improving soil environment by regaining SOM level and decreasing GHG emissions *via* improved soil microbial activities (Delgado et al., 2011; Abhilash et al., 2013). Some of these strategies are conservation agriculture practices (Kassam et al., 2009; Tullberg, 2010), organic farming (Robertson and Nash, 2013; Singh, 2013; Thierfelder et al., 2013), genetically improved crop varieties (Murphy et al., 2007), various soil amendments (Delgado et al., 2011) (e.g., sewage sludge, fly-ash, biochar, biofertilizers, etc.), improved use of agrochemicals, and use of slow-release fertilizers (Delgado et al., 2011), etc. These strategies have been partially adapted in various parts of the world and are reported to provide specific ecosystem services, though research is still in progress to make them more suitable in terms of expected changing climate scenario.

Terrestrial carbon sequestration (TCS) is one of the important measures for climate change mitigation to be focused. As terrestrial resources contains more than 2.5 times higher (about 2344 Gt) carbon than the atmospheric C pools (Fowles, 2006; Stockmann et al., 2013); and is more prone to the human-driven land use changes (Stockmann et al., 2013), therefore long time TCS could be a potential strategy to mitigate present global climate change with enhanced level of atmospheric CO_2. Various geo- and eco-engineering approaches such as plant sequestration, no-tillage, geological carbon sequestration, and biochar sequestration, etc. (Lehmann, 2007a, b) have been proposed to enhance terrestrial C pool (Galaz, 2012). Though, all these approaches have various *pros* and *cons* due to their inherent socio-economic and environmental behaviors. Of them, biochar sequestration to soil has been found as an effective and low-risk strategy to mitigate climate change (Keiluweit et al., 2010; Nguyen et al., 2010) due to its inherent higher recalcitrance against microbial activities and subsequent improvement of soil environment (Lehmann, 2007a; Singh et al., 2015). Further, this approach of climate change mitigation has lesser limitation as compared to the other mitigation approaches such as geological C storage, afforestation, grassland conversion and management, and conservation agriculture having maximally decadal to centennial sequestration potential after that believed to act as a source of CO_2 itself or through leakage (Lehmann, 2007a). Therefore, after reviewing various aspects of biochar as a tool for climate change mitigation and combating land degradation, UN Framework Convention on Climate Change (UNFCCC) had included biochar in its proposals for "Enhanced Action on Mitigation" (Barrow, 2012).

Presently, lignocellulosic biomass has been considered as the most important assets for green technologies (Blanco-Cancui and Lal, 2007; Singh et al., 2015). Leading researches denotes its use as biofuel source, for soil C stock management by adopting conservation agriculture and for livestock feeding material. Further, for managing these surplus lignocellulosic biomasses, conversion to biochar has been promoted by most of the leading researches worldwide. Therefore, management of agricultural organic residues (including animal manures) as an important resource is necessitated recently (Misselbrook et al., 2012). However, an integrative approach should be applied for continuous monitoring along with differing background climatic and geographic details of these interrelated systems (Singh et al., 2015). Therefore, the present article will deal with crop residue composition, its fate in field, and its utilization in conservation agriculture as well as biofuel technologies in brief. Further, crop residue derived biochar and its integration with residue retention approach of conservation agriculture in a closed loop cycle for the mitigation of climate change and sustainability of agriculture will be discussed in detail in the later sections.

2. Crop Residue and Its Fate in Farmers' Field

Recently, residue generation and its management is a hot topic of research (Lal, 2008; Lal and Pimentel, 2009; Tilmann et al., 2009; Delgado et al., 2011; Singh et al., 2015). As estimated by Lal (2008), each year about 4000 MT crop residue is produced worldwide from 27 food crops, majorly (~50%) contributed by rice-wheat cereal crops (Kim and Dale, 2004; FAO, 2006; Buranov and Mazza, 2008). Asian countries shares about ~43% (228 MT) and ~90% (623 MT) of wheat and rice crop residue, respectively, generated worldwide (Kim and Dale, 2004; FAO, 2006; Buranov and Mazza, 2008). About 7-25% of wheat and most of the rice residues have been reported to burn within crop fields (Sidhu et al., 1998). Generally, lignocellulosic biomasses consist of cellulose (38–50%), hemicellulose (23–32%), lignin (15–25%) interlinked with various multiple bonds and patterns; and a small amount of extractives (McKendry, 2002; Mussatto et al., 2008). Therefore, their open burning leads to release of various air pollutants such as non-methane hydrocarbon compounds (NMHCs), particulate matter ($PM_{2.5}$ and PM_{10}) primarily originating from ash, polycyclic aromatic hydrocarbons (PAHs), and soot (organic carbon and black carbon) in the atmosphere (Jain et al., 2006) due to breakage of these structural bonds. This further adds various pollutants and GHGs to the environment with quick release of photo-synthetically trapped CO_2 (Pandey and Sahu, 2014). Residue burning and its post consequences give further impetus to the policy makers to take stress on its management (Pandey and Sahu, 2014).

Recently, crop residue is considered as a precious resource because of its multifaceted uses (Blanco-Cancui and Lal, 2007; Singh et al., 2015). Its potential use include its utilization for livestock feed, incorporation in conservation agriculture system and as a feedstock for biofuel generation especially in biochemical and thermochemical processes (Lehmann, 2007a; Lal, 2008; Bonin and Lal, 2012; Singh et al., 2015) and anaerobic composting before incorporation to soil (Xia et al., 2014). Therefore, various studies recommend government to provide incentives to the farmers for eco-friendly residue management strategies for ecological trade-offs in terms of soil fertility (Xia et al., 2014). However, most of the management studies suggested conservation agriculture (Laik et al., 2014) and thermochemical processes (Singh et al., 2015) for regulating open crop residue burning, and thus crop residue management and atmospheric pollution control. In the coming sections, we will critically discuss the role of crop residue under conservation agriculture and thermochemical conversion systems.

3. CROP RESIDUE: A FEEDSTOCK FOR CONSERVATION AGRICULTURE

Management of SOM reserves synchronized with nutrient cycling has been suggested as one of the important strategy for attaining long term food security and agricultural sustainability under changing climate scenario (Jones et al., 2012). Conservation agriculture system (including a package of reduced tillage, residue retention and crop rotation practices) has been foreseen as one of the indigenous soil improvement strategy (Robertson and Nash, 2013; Thierfelder et al., 2013). The important changes or ecosystem services under this system include improved soil biodiversity, increased SOM content in its vicinity, moderate GHG emissions, C sequestration, erosion control, increased water use efficiency *via* improved soil physical, chemical and biological properties especially for top soil, thus overall climate regulation (Singh et al., 2008; Karlen et al., 2009; Palm et al., 2014) (Figure 1). Further, integration of conservation agriculture along with various best management practices adopted regionally has been suggested as potentially safe strategy for system productivity and sustainability (Laik et al., 2014).

However, further research is required for establishing such integration at larger scale (Laik et al., 2014), because these benefits of conservation agriculture are generally uncertain with significant variations in the climate, soils and crop rotations as compared to conventional systems (Palm et al., 2014). For example, the lack of residue, partial adoption of conservation agricultural practices and strong competition for alternative uses of crop residue in biofuel sectors are regarded as the major constraints for sole belief on conservation agriculture (Laik et al., 2014; Palm et al., 2014). Further, residue retention and its degradation may lead to release of nutrients, GHGs emission and pest infestations (Lehmann, 2007a; Blanco-Cancui and Lal, 2007; Karlen et al., 2009; Palm et al., 2014). For example, several studies suggested multiple effects of crop residue incorporation on GHGs emission and topsoil density in long term (Palm et al., 2014; Shen et al., 2014; Xia et al., 2014). Xia et al. (2014) suggested that long term straw incorporation may result into higher emissions than sequestration as they observed three to four fold increases in global warming potential of CH_4 induced by straw-added SOC. Further, aggregate stability under conservation agriculture is higher than conventional systems as revealed by mean weight diameter (MWD), suggesting C sequestration potential for conservation agriculture systems (Paul et al., 2013). However, physical protection of C content is not clearly visible under various conservation agriculture practices, possibly due to scarcity of residue availability. Further, they suggested that proper integration of no-tillage with residue retention would lead to improvement of soil C contents in upper soil layers (Paul et al., 2013). Gatere et al. (2014) observed higher maize yield under rainfall <1000 mm yr^{-1} condition as compared to higher rainfall conditions in valley area under conservation farming systems. Similarly, higher yield is reported under this system due to sufficient soil moisture during dry seasons; however, the rate of residue retention is uncertain (Palm et al., 2014). These shortcomings in conservation agriculture system pave the way for certain modulation in it by harmonizing the balance between soil health and crop yield along with reduced GHGs emissions and C sequestration.

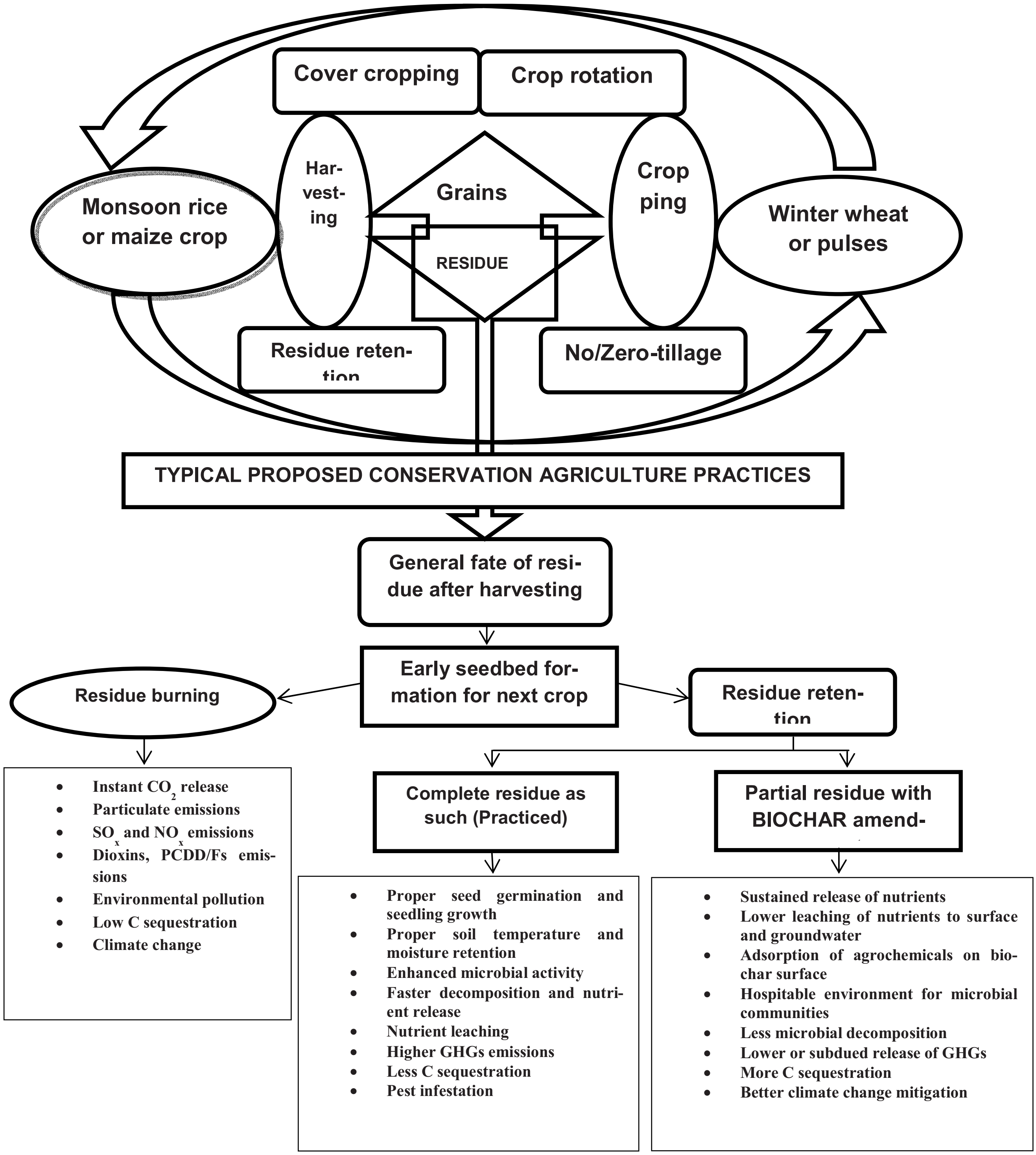
3.1 Need of alternative approaches for residue management for Climate change mitigation

There are a few questions related with conservation agriculture on soil quality improvement in long term under varying climatic conditions in different parts of the world, though it has been successfully applied in South America (Gatere et al., 2014). Lack of harmony between agronomists and ecologists may also lead to widening of understanding gaps of the soil total health and sustainability. Therefore, for improving the agricultural sustainability and crop residue derived ecosystem service, a critical understanding of agronomy and ecology has been emphasized (Palm et al., 2014). Further, sole adoption of best management practices will not be able to support soil quality, however, for overall management of GHGs emission an active net withdrawal of carbon dioxide (CO_2) from the atmosphere for long term is required (Lackner, 2003). In addition, world is presently undergoing through acute energy crisis due to diminishing fossil fuels and related pollutions. The urgent need of green energy fuels from such materials have been researched and being recommended now-a-days. Such processes include partial utilization of crop residue as feedstock for biofuel production through biochemical and thermochemical pathways (Lehmann, 2007a,b; Tilmann et al., 2009; Bonin and Lal, 2012). Recently, research communities have more focused on thermochemical processes like pyrolysis and gasification due to their C neutrality as compared to the other processes (Lehmann, 2007a). Thus, in the coming section, we will discuss the role of biochar derived from crop residue for climate change mitigation.

4. CROP RESIDUE: A SUSTAINABLE FEEDSTOCK FOR BIOCHAR TECHNOLOGY

Biochar conversion of biomass has gain wider global attention for the last decade for climate change mitigation by storing C in soil (Liu et al., 2012). Extensively available crop residues and weeds are regarded as the cheap and easily available feedstock source for biochar formation (Lehmann, 2007a,b) especially in developing

Figure 1: An illustrative representation of integrated application conservation agricultural practices and crop residue biochar incorporation. Later part of the figure represents the various effects of different pathways on environment and related agricultural activities.



countries (Mandal et al., 2013). Biochar, a thermochemical by-product of biomass, has been recommended as a potential soil ameliorant because of its potential to improve soil physical, chemical and biological properties (Woolf, 2008; Lehmann and Joseph, 2009; Jha et al., 2010; Mandal et al., 2013; Jeffery et al., 2015; Singh et al., 2015) and managing GHGs emissions from cropping system (Shen et al., 2014). Biochar conversion of biomass and its application is getting more attention due to its ability to stabilize about 50% atmospheric C to soil for long time, whereas burning and residue retention holds only instant 3% and 10-20% C for 5-10 years until complete biological degradation (Lehmann et al., 2006).

4.1 Positive effects of biochar amendment on soil

After biochar application, the increase in pH, liming effect and CEC enhances nutrient bioavailability (Liang et al., 2006; van Zwieten et al., 2010). Further, direct nutrient supply from biochar itself and reduction in nutrient loss via leaching and run-off (Lehmann et al., 2003; Yuan et al., 2011; Enders et al., 2012; Cheng et al., 2012; Xu et al., 2012; Lee et al., 2013), further supplement its suitability as soil ameliorant (Singh et al., 2015). Inherently concentrated N and its retention on biochar surfaces have been reported in several studies (Spokas et al., 2012). Also, biochar derived from crop residue affects soil NH_4^+-N and NO_3^--N concentrations in soil (Nelson et al., 2011). Thus, its application enhances soil nutrient retention and fertility due to very slow changes in surface structures (Borchard et al., 2012). In addition, nutrient retention capacity of biochar leads to the reduction of fertilizer use, thus it indirectly results in reduction in production, energy and environmental cost of fertilizer manufacturing. Further, crop performance under biochar amended soil has been found to be increased due to direct supply and increase in bioavailability of nutrients in rhizosphere (Prendergast-Miller et al., 2014). Rhizosphere having higher biochar concentration indicates that the roots prefer nutrient acquisition from biochar soil (Prendergast-Miller et al., 2014). Based on several studies, Lehmann (2007b) concluded that: "crops respond positively to biochar addition up to 50 MgC/ha and may show growth reduction only at very high applications". However, in a meta-analysis on biochar soil amendment, Liu et al. (2012) concluded that biochar amendment to <30 t ha^{-1} will increase crop productivity, though responses depend upon the climatic variability.

Further, it is highly stable and resistant to various erosion in soil, thus, has long-life (thousand to millions of years) within soil ecosystem. Its application to soil leads to subdued release of N_2O and CH_4 like potent greenhouse gases (Yanai et al., 2007; Dalal et al., 2008). Shen et al. (2014) studied on comparative assessment of rice straw and its biochar incorporation of soil and found reduction in rice grain yield under straw amendment as compared to biochar amendment. They suggest that modification in soil pH might be a potential cause for CH_4 emission reduction under biochar amended soils. However, N_2O emission was found higher under biochar amended soils whereas lower for straw amended soil possibly due to increased availability of ammonium and nitrate-N contents (Shen et al., 2014). Thus they suggested the application of biochar application instead of straw amendment for effective climate change mitigation in long term (Shen et al., 2014). According to an estimation of Woolf (2008), biochar would sequester about 1 GT carbon to soil if all the crop residue of the world has been converted. Terra Preta soil or Amazonian Dark Earths (ADE), regarded as a type of biochar, is considered as an example for describing the longevity of biochar in soil (Hunt et al., 2010).

4.2 Negative effects of biochar from crop residue conversion pathways

In general, biochar application to soil has multifaceted effects over soil properties; however, the special attention is needed on mechanistic exploration of such benefits over time under varying soil and climate specific conditions (Jeffery et al., 2015; Singh et al., 2015). Several field and modeling studies suggested that residue removal for biochar production may result into significant SOC loss, thus affect agricultural productivity and environmental sustainability in long term (*see*: Smith et al., 2012). Further, Smith et al. (2012) suggested that N fertilization treatments, amount of residue removal and the longevity of soil exposure to direct environment directly affect SOC change. Therefore, Singh et al. (2015) recommended crop residue biochar amendment as a blend with the other organic materials such as crop residue or compost for better crop productivity and agricultural sustainability. The next sections will deal with the integrated approach of the residue-biochar under various climatic conditions.

5. Biochar-crop residue in integration to soil amendment strategy of conservation agriculture for climate change mitigation

Residue retention policies under conservation agriculture systems improves SOM pools, however, its degradation in later stages lead to GHGs (CO_2 and CH_4) emissions (Chidthaisong and Watanabe, 1997). Further, conservation agriculture policies are also facing several constrains like crop residue retention compromising feedstock for livestock population, whereas increasing energy crisis, and deteriorating soil quality are diverting policy makers for a more suitable alternative of crop residue management without affecting the sovereignty of the agro-ecosystems (Lal, 2007; Kassam et al., 2009; Lal and Pimentel, 2009). Therefore, several studies on such systems concludes that instead of crop residue retention, biochar incorporation to soil will facilitate more SOM, thus improve soil fertility and crop productivity (Watanabe et al., 1998; Lou et al., 2007; Zhang et al., 2013). This paves the way for inclusion of biochar technology in conservation agriculture systems as partial residue retention with partial biochar application. After reviewing extensive literature on crop residue management and biochar technology, Singh et al. (2015) suggested that partial retention and partial removal of crop residue under closed loop model of reversion would be a better option under conservation agriculture scenario for agricultural sustainability. The advantage of this system would be more improved soil environment in addition to mitigation in climate change due to locking of a major photo-synthetically trapped atmospheric CO_2 (Woolf, 2008; Woolf et al., 2010) (Figure 1). Therefore, this article will be extension to the proposed partial residue retention and removal approach in closed loop model dealing with various mechanistic aspects of this hypothesis.

5.1 How much residue can be removed?

Blanco-Cancui and Lal (2009) reviewed the effect of crop residue removal from field and concluded that with the removal of crop residue, soil physico-chemical and biological properties are affected differently for soil to soil. Further, Graham et al. (2007) has suggested that 30-50% removal of stover crop residue from U.S. has no significant adverse effect on soil. Blanco-Cancui and Lal (2009) has reported slight increase in pH and EC whereas a decrease in CEC of soil with the removal of stover crop residue from field. In practical terms, a balanced approach as discussed by Blanco-Canqui and Lal (2007) for crop residue retention and removal could lead to felicitation of native SOM content for various soil types in addition to fulfill the dietary requirement of livestock.

5.2 Benefits of integrated strategy to soil

5.2.1 Impact on C mineralization

After an extensive survey on C mineralization, Jeffery et al. (2015) found that interaction of organo-mineral components of soil are the main factors governing turnover of un-charred carbon in soil. Similarly, Junna et al. (2014) performed extensive laboratory-scale study on C mineralization and found that mineralization trend was in the order of crop residue> crop residue and biochar combination> low temperature biochar> high temperature biochar. Low C mineralization of crop residue biochar combination than sole crop residue was possibly due to sorption of water-soluble organic C on biochar surfaces (Luo et al., 2011; Junna et al., 2014). Further, only a few studies dealing with integrated approach of biochar under conservation agricultural systems are available (Cornelissen et al., 2013; Martinsen et al., 2014). Cornelissen et al. (2013) performed a farmer-led field scale study on biochar application under conservation farming systems and found increase in maize yield under low dosage (4 tons/ha) of biochar application in sandy and acidic soils because of nutrient supply from biochar concentrated in rhizosphere. Further, moderate effect was observed for sandy clay loam soil. They concluded that biochar application would be more beneficial under water-limited sandy arid soils having low water holding capacity, though such studies are in great need of establishment for different soils and different crop combinations (Cornelissen et al., 2013).

The positive effect under combined residue and biochar systems was possibly due to increased plant-available water, pH, cation exchange capacity, available K^+ ions, and decreased availability of aluminum (Al) content in acidic tropical soils (Martinsen et al., 2014). Increase in pH under biochar amended soils is generally attributed by higher ash and alkali matter contents of biochar (Singh et al., 2010; Lehmann et al., 2011; Enders et al., 2012). Similarly, alkalinity and CEC increase under biochar amendment was attributed by its higher carbonates and base cations (Singh et al., 2010; Van Zwieten et al., 2010; Lehmann et al., 2011; Yuan et al., 2011), and due to oxidation of biochar surfaces having various anionic functional groups like pyranone, phenolic, carboxylic, lactone and amine (Brennan et al., 2001; Cheng et al., 2006; Liang et al., 2006). Furthermore, high pH biochar addition lead to change in fungal/bacterial growth ratio and stimulate the microbial (especially bacterial) community growth community (Jones et al., 2012) by electrostatic and hydrophobic attraction and porous structure protecting fungal hyphae (Pietikäinen et al., 2000). In addition, change in soil moisture and pH regimes stimulate earthworm activities under biochar added soils (Liesch et al., 2010; Beesley and Dickinson, 2011; Genesio et al., 2012). Therefore, the residue and biochar addition will facilitate more soil biological activity under varying environmental conditions.

5.2.2 Possible constrains for considering biochar as conservation agriculture tool

The most potential risk associated with biochar soil amendment is that once it applied to soil, it would be very difficult to get it removed from soil matrix (Lehmann, 2007a,b). Therefore, in spite of several benefits of biochar to soil and its integration with conservation agriculture systems, one potential question always remain to be answered about the stability of fine and light biochar fractions under no-tillage systems *i.e.,* without physical insertion to soil (Marris, 2006). For example, soil compaction (Cheng et al., 2006; Cheng and Lehmann, 2009; Mukherjee and Lal, 2013), alkalinity decrease and pH change to acidic range (Jones et al., 2012; Cayuela et al., 2014) is projected in long term under biochar applied soils due to changes in surface associated groups of biochar with ageing (Cheng et al., 2006; Jones et al., 2012;

Cayuela et al., 2014). However, animal manure derived biochar is found to retain its liming property for long term (Slavich et al., 2013). In general, a well-studied optimization of biochar economic and environmental values is needed under conservation agricultural systems. Thus, need of the hour is to integrate conservation agriculture along with biochar technology for various soil types in developing world having intertwined problems of decreasing soil fertility and increasing food security. A generalized model of partial residue retention and biochar addition has been presented in Figure 1. Further, the future studies on this integration must include the detailed cost-benefit analyses under varying environmental conditions.

6. Conclusion

Crop residue burning is an environment damaging practice being followed in many countries of the world. It can be minimized by applying various feasible alternatives such as conversion to biochar with its multipurpose utilization as soil ameliorant in a closed loop model as well as green fuels. Its integration with conservation agricultural residue retention would lead to improvement in soil-water-air-plant relationships. Therefore, there is a need to explore and scientifically analyze such multipurpose practices for agricultural sustainability through proper understanding of the concerns of various stakeholders. In addition, such modulations could be well studied for various problem soils having less productivity, significant emissions, and greater scope of soil amendment additions.

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REFERENCES

1. Abhilash, P.C., Dubey, R.K., Tripathi, V., Srivastava, P., Verma, J.P., Singh, H.B., 2013 Adaptive soil management. Curr. Sci. 104, 1275-1276.
2. Barrow, C.J., 2012. Biochar: Potential for countering land degradation and for improving agriculture. Applied Geography 34, 21-28.
3. Beesley, L., Moreno-Jiménez, E., Gomez-Eyles, J.L., Harris, E., Robinson, B., Sizmur, T., 2011. A review of biochars' potential role in the remediation, revegetation and restoration of contaminated soils. Environ. Pollut. 159, 3269–3282.
4. Blanco-Canqui, H., Lal, R., 2007. Soil and crop response to harvesting corn residues for biofuel production. Geoderma 141, 355-362.
5. Blanco-Canqui, H., Lal, R., 2009. Crop residue removal impacts on soil productivity and environmental quality. Critic. Rev. Plant Sci. 28, 139-163.
6. Bonin, C., Lal, R., 2012. Bioethanol potentials and life-cycle assessments of biofuel feedstocks. *Crit. Rev. Plant Sci.* 31, 271-289.
7. Borchard, N., Wolf, A., Laabs, V., Aeckersberg, R., Scheres, H. W., Moller, A., Amelung, W., 2012. Physical activation of biochar and its meaning for soil fertility and nutrient leaching- A greenhouse experiment. Soil Use Manage. 28, 177-184.
8. Brennan, J.K., Bandosz, T.J., Thomson, K.T., Gubbins, K.E., 2001. Water in porous carbons. *Colloids Surfaces A: Physicochem. Eng. Aspects* 187-188, 539-568.
9. Buranov, A.U., Mazza, G., 2008. Lignin in straw of herbaceous crops. Indust. Crops Products 28, 237-259.
10. Cayuela, M.L., van Zwieten, L., Singh, B.P., Jeffery, S., Roiga, A., Sánchez-Monedero, M.A., 2014. Biochar's role in mitigating soil nitrous oxide emissions: a review and meta-analysis. Agric. Ecosyst. Environ. 191, 5–16.
11. Cheng, C.H., Lehmann, J., 2009. Ageing of black carbon along a temperature gradient. Chemosphere 75, 1021–1027.
12. Cheng, C.H., Lehmann, J., Thies, J.E., Burton, S.D., Engelhard, M.H., 2006. Oxidation of black carbon by biotic and abiotic processes. Org. Geochem. 37, 1477–1488.
13. Cheng, Y., Cai, Z., Chang, S.X., Wang, J., Zhang, J., 2012. Wheat straw and its biochar have contrasting effects on inorganic N retention and N_2O production in a cultivated Black Chernozem. Biol. Fert. Soils 48, 941–946.
14. Chidthaisong, A., Watanabe, I., 1997. Methane formation and emission from flooded rice soil incorporated with 13C-labeled rice straw. Soil Biol. Biochem. 29, 1173–1181.
15. Cornelissen, G., Martinsen, V., Shitumbanuma, V., Alling, V., Breedveld, G.D., Rutherford, D.W., Sparrevik, M., Hale, S.E., Obia, A., Mulder, J., 2013. Biochar effect on maize yield and soil characteristics in five conservation farming sites in Zambia. Agronomy 3, 256–274.
16. Dalal, R.C., Allen, D.E., Livesley, S.J., Richards, G., 2008. Magnitude and biophysical regulators of methane emission and consumption in the Australian agriculture, forest and submerged landscapes: a review. Plant Soil 309, 43–76.
17. Delgado, J.A., Groffman, P.M., Nearing, M.A., Goddard,

T., Reicosky, D., Lal, R., Kitchen, N. R., Rice, C.W., Towery, D., Salon, P., 2011. Conservation practices to mitigate and adapt to climate change. J Soil Water Conser. 66, 118A-129A.

18. Enders, A., Hanley, K., Whitman, T., Joseph, S., Lehmann, J., 2012. Characterization of biochars to evaluate recalcitrance and agronomic performance. Bioresour. Technol. 114, 644–653.
19. FAO, 2006. *World Reference Base for Soil Resources 2006*. Food and Agriculture Organization of the United Nations, Rome. pp: 128.
20. Fowles, M., 2006. Black carbon sequestration as an alternative to bioenergy. *Biomass Bioenergy* 31, 426–432.
21. Galaz, V., 2012. Geo-engineering, governance and social–ecological systems: critical issues and joint research needs. Ecol. Soc. 17, 24.
22. Gatere, L., Lehmann, J., DeGloria, S., Hobbs, P., Delve, R., Travis, A., 2014. One size does not fit all: Conservation farming success in Africa more dependent on management than on location. Agricult. Ecosyst. Environ. 179, 200– 207.
23. Genesio, L., Miglietta, F., Lugato, E., Baronti, S., Pieri, M., Vaccari, F.P., 2012. Surface albedo following biochar application in durum wheat. Environ. Res. Lett. 7, 14–25.
24. Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M., Toulmin, C., 2010. Food security: the challenge of feeding 9 billion people. Science 327, 812-818.
25. Graham, R.L., Nelson, R., Sheehan, J., Perlack, R., Wright, L.L., 2007. Current and potential US corn stover supplies. Agronomy J.. 99, 1-11.
26. Houghton, R., House, J. I., Pongratz, J., van der Werf, G. R., DeFries, R.S., Hansen, M.C., Le Quere, C., Ramankutty, N., 2012. Carbon emissions from land use and land-cover change. Biogeosci.. 9, 5125–5142.
27. Hunt, J., DuPonte, M., Sato, D., Kawabata, A., 2010. The basics of biochar: a natural soil amendment. Tera 30, 1-6.
28. IPCC 2014. *IPCC Fifth Assessment Report*. Chapter 1: Introduction chapter. pp: 1-65.
29. Jain, A.K., Tao, Z., Yang, X., Gillespie, C., 2006. Estimates of global biomass burning emissions for reactive greenhouse gases (CO, NMHCs, and NO_x) and CO_2. J. Geophysic. Res. 111, D06304 (Abstr.).
30. Jeffery, S., Bezemer, T.M., Cornelissen, G., Kuyper, T.W., Lehmann, J., Mommer, L., Sohi, S.P. *et al.*, 2015. The way forward in biochar research: targeting trade-offs between the potential wins. GCB Bioenergy 7, 1–13.
31. Jha, P., Biswas, A.K., Lakaria, B.L., Subba Rao, A., 2010. Biochar in agriculture - prospects and related implications. Curr. Sci. 99, 1218-1225.
32. Jones, D.L., Rousk, J., Edwards-Jones, G., DeLuca, T.H., Murphy, D.V., 2012. Biochar- mediated changes in soil quality and plant growth in a three year field trial. Soil Biol. Biochem. 45, 113–124.
33. Junna, S., Bingchen, W., Gang, X., Hongbo, S., 2014. Effects of wheat straw biochar on carbon mineralization and guidance for large-scale soil quality improvement in the coastal wetland. Ecol. Eng. 62, 43–47.
34. Karlen, D.L., Lal, R., Follett, R.F., Kimble, J.M., Hatfield, J.L., Miranowski, J.M., Cambardella, C.A., Manale, A., Anex, R.P., Rice, C.W., 2009. Crop residues: the rest of the story. Environ. Sci. Technol. 43, 8011-8015.
35. Kassam, A., Friedrich, T., Shaxson, F., Pretty, J., 2009. The spread of conservation agriculture: justification, sustainability and uptake. Int. J. Agric. Sust. 7, 292–320.
36. Keiluweit, M., Nico, P.S., Johnson, M.G., Kleber, M., 2010. Dynamic molecular structure of plant-derived black carbon (biochar). Environ. Sci. Technol. 44, 1247-1253.
37. Kim, S., Dale, B.E., 2004. Global potential bioethanol production from wasted crops and crop residues. Biomass Bioenergy 26, 361-375.
38. Lackner, K.S., 2003. A guide to CO2 sequestration. Science 300, 1677–1678.
39. Laik, R., Sharma, S., Idris, M., Singh, A.K., Singh, S.S., Bhatt, B.P., Saharawat, Y., Humphreys, E., Ladha, J.K., 2014. Integration of conservation agriculture with best management practices for improving system performance of the rice–wheat rotation in the Eastern Indo-Gangetic Plains of India. Agric. Ecosyst. Environ. 195, 68–82.
40. Lal, R., 2007. There is no such thing as a free biofuel from crop residues. CSA News 52, 12-13.
41. Lal, R., 2008. Crop residues as soil amendments and feedstock for bioethanol production. Waste Manage. 28, 748-758.
42. Lal, R., 2011. Sequestering carbon in soils of agro-ecosystems. Food Policy 36, S33-S39.
43. Lal, R., Pimentel, D., 2009. Biofuels: beware crop residues. Science 326, 1345-1346.
44. Lee, Y., Euma, P.R.B., Ryu, C., Park, Y.K., Jung, J.H., Hyun, S., 2013. Characteristics of biochar produced from slow pyrolysis of Geodae-Uksae 1. Bioresour. Technol. 130, 345–350.
45. Lehmann, J., 2007a. A handful of carbon. Nature 447, 143-144.
46. Lehmann, J., 2007b. Bio-energy in the black. Front. Ecol. Environ. 5, 381-387.
47. Lehmann, J., Joseph, S., (Eds.) 2009. Biochar for environmental management: Science and technology. Earthscan, USA.
48. Lehmann, J., Rillig, M.C., Thies, J., Masiello, C.A., Hockaday, W.C., Crowley, D., 2011. Biochar effects on soil biota- A review. Soil Biol. Biochem. 43, 1812-1836.
49. Lehmann, J., Gaunt, J. and Rondon, M., 2006. Bio-char sequestration in terrestrial ecosystems – a review. Miti. Adapt. Strat. Glob. Change 11, 403-427.

50. Lehmann, J., Kern, D.C., Glaser, B., Woods, W.I., 2003. Amazonian Dark Earth: Origin, Properties, Management. Kluwer Academic Publishers, The Netherlands.
51. Liang, B., Lehmann, J., Solomon, D., Kinyangi, J., Grossman, J., O'Neill, B., Skjemstad, J.O., Thies, J., Luizão, F.J., Petersen, J., Neves, E.G., 2006. Black carbon increases cation exchange capacity in soils. Soil Sci. Soc. Am. J. 70, 1719–1730.
52. Liesch, A.M., Weyers, S.L., Gaskin, J.W., Das, K.C., 2010. Impact of two different biochars on earthworm growth and survival. Ann. Environ. Sci. 4, 1–9.
53. Liu, X., Qu, J., Li, L., Zhang, A., Jufeng, Z., Zheng, J., Pan, G., 2012. Can biochar amendment be an ecological engineering technology to depress N_2O emission in rice paddies?—a cross site field experiment from South China. Ecol. Eng. 42, 168–173.
54. Lou, Y.S., Ren, L.X., Li, Z.P., Zhang, T.L., Inubushi, K., 2007. Effect of rice residues on carbon dioxide and nitrous oxide emissions from a paddy soil of subtropical China. Water Air Soil Pollut. 178, 157–168.
55. Luo, Y., Durenkamp, M., De Nobili, M., Lin, Q., Brookes, P.C., 2011. Short term soil priming effects and the mineralisation of biochar following its incorporation to soils of different pH. Soil Biol. Biochem. 43, 2304–2314.
56. Mandal, S., Ramkrushna, G. I., Verma, B. C. and Das, A. 2013. Biochar: an innovative soil ameliorant for climate change mitigation in NE India. Curr. Sci. 105, 568-569.
57. Marris, E. 2006. Black is the new green. Nature 442, 624-626.
58. Martinsen, V., Mulder, J., Shitumbanuma, V., Sparrevik, M., Børresen, T., Cornelissen, G. 2014. Farmer-led maize biochar trials: Effect on crop yield and soil nutrients under conservation farming. J. Plant Nutr. Soil Sci. 177, 681–695.
59. McKendry, P., 2002. Energy production from biomass (part 1): overview of biomass. Bioresour. Technol. 83, 37–46.
60. Misselbrook, T.H., Menzi, H., Cordovil, C. 2012. Recycling of organic residues to agriculture: Agronomic and environmental impacts. Agric. Ecosyst. Environ. 160, 1–2.
61. Mukherjee, A., Lal, R., 2013. Biochar impacts on soil physical properties and greenhouse gas emissions. Agronomy 3, 313–339.
62. Murphy, K.M., Campbell, K.G., Lyon, S.R., Jones, S.S., 2007. Evidence of varietal adaptation to organic farming systems. Field Crops Res. 102, 172-177.
63. Mussatto, S.I., Fernandes, M., Milagres, A.M.F., Roberto, I.C., 2008. Effect of hemicellulose and lignin on enzymatic hydrolysis of cellulose from brewer's spent grain. Enzyme Microb. Technol. 43, 124–129.
64. Nelson, N.O., Agudelo, S.C., Yuan, W., Gan, J., 2011. Nitrogen and phosphorus availability in biochar-amended soils. Soil Sci. 176, 218–226.
65. Nguyen, B., Lehmann, J., Hockaday, W.C., Joseph, S., Masiello, C.A., 2010. Temperature sensitivity of black carbon decomposition and oxidation. Environ. Sci. Technol. 44, 3324-3331.
66. Palm, C., Blanco-Canqui, H., DeClerckc, F., Gaterea, L., Grace, P., 2014. Conservation agriculture and ecosystem services: An overview. Agric. Ecosyst. Environ. 187, 87–105.
67. Pandey, K., Sahu, L.K., 2014. Emissions of volatile organic compounds from biomass burning sources and their ozone formation potential over India. Curr. Sci. 106, 1270-1279.
68. Paul, B.K., Vanlauwe, B., Ayuke, F., Gassner, A., Hoogmoed, M., Hurisso, T.T., Koala, S., Lele, D., Ndabamenye, T., Six, J., Pulleman, M.M., 2013. Medium-term impact of tillage and residue management on soil aggregate stability, soil carbon and crop productivity. Agric. Ecosyst. Environ. 164, 14– 22.
69. Pietikäinen, J., Kiikkilä, O., Fritze, H., 2000. Charcoal as a habitat for microbes and its effects on the microbial community of the underlying humus. Oikos 89, 231–242.
70. Prendergast-Miller, M.T., Duvalla, M., Sohi, S.P., 2014. Biochar – root interactions are mediated by biochar nutrient content and impacts on soil nutrient availability. Eur. J. Soil Sci. 65, 173–185.
71. Robertson, F., Nash, D., 2013. Limited potential for soil carbon accumulation using current cropping practices in Victoria, Australia. Agric. Ecosyst. Environ. 165, 130-140.
72. Shen, J., Tang, H., Liu, J., Wang, C., Li, Y., Ge, T., Jones, D.L., Wu, J., 2014. Contrasting effects of straw and straw-derived biochar amendmentson greenhouse gas emissions within double rice cropping systems. Agric. Ecosyst. Environ. 188, 264–274.
73. Sidhu, B.S., Rupela, O.P., Beri, V., Joshi, P.K., 1998. Sustainability implications of burning rice- and wheat-straw in Punjab. Econom. Pol. Week. 33, 163-168.
74. Singh, B., Singh, B., Cowie, A., 2010. Characterisation and evaluation of biochars for their application as soil amendment. Aust. J. Soil Res. 48, 516–525.
75. Singh, H., Pathak, P., Kumar, M., Raghubanshi, A.S., 2008. Carbon sequestration potential of Indo-Gangetic agroecosystem soils. Trop. Ecol. 52, 223-228.
76. Singh, R., Babu, J.N., Kumar, R., Srivastava, P., Singh, P., Raghubanshi, A.S., 2015. Multifaceted application of crop residue biochar as a tool for sustainable agriculture: An ecological perspective. Ecol. Eng. 77, 324–347.
77. Singh, Y.V., 2013. Crop and water productivity as influenced by rice cultivation methods under organic and inorganic sources of nutrient supply. Paddy Water Environ. 11, 531-542.
78. Slavich, P.G., Sinclair, K., Morris, S.G., Kimber, S.W.L., Downie, A., Zwieten, L., 2013. Contrasting effects of manure and green waste biochars on the properties of anacidic ferralsol and productivity of a subtropical pasture. Plant Soil 366, 213–227.

79. Smith, W.N., Grant, B.B., Campbell, C.A., McConkey, B.G., Desjardins, R.L., Kröbel, R., Malhi, S.S. 2012. Crop residue removal effects on soil carbon: Measured and inter-model comparisons. Agric. Ecosyst. Environ. 161, 27– 38.
80. Spokas, K.A., Novak, J.M., Venterea, R.T., 2012. Biochar's role as an alternative N-fertilizer: ammonia capture. Plant Soil 350, 35–42.
81. Stockmann, U, Adams, MA, Crawford, JW, Field, DJ, Henakaarchchi, N, Jenkins, M, Minasny, B, McBratney, AB, *et al.,* 2013. The knowns, known unknowns and unknowns of sequestration of soil organic Carbon. Agric. Ecosyst. Environ. 164, 80–99.
82. Thierfelder, C., Cheesman, S., Rusinamhodzi, L., 2013. Benefits and challenges of crop rotations in maize-based conservation agriculture (CA) cropping systems of southern Africa. Int. J. Agric. Sust. 11, 108-124.
83. Tilmann, D., Socolow, R., Foley, J. A., Hill, J., Larson, E., Lynd, L., Pacala, S., Reilly, J., Searchinger, T., Somerville, C., Williams, R., 2009. Beneficial biofuels- The food, energy, and environment trilemma. Science 325, 270-271.
84. Tubiello, F.N., Salvatore, M., Rossi, S., Ferrara, A., Fitton, N., Smith, P., 2013. The FAOSTAT database of greenhouse gas emissions from agriculture. Environ. Res. Letters 8, 015009.
85. Tullberg, J., 2010. Reduce soil damage for more sustainable crop production. Nature 466, 920.
86. van Zwieten, L., Kimber, S., Morris, J., Chan, K., Downie, A., Rust, J., Joseph, S., Cowie, A., 2010. Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. Plant Soil 327, 235–246.
87. Watanabe, A., Yoshida, M., Kimura, M., 1998. Contribution of rice straw carbon to CH4 emission from rice paddies using 13C-enriched rice straw. J. Geophys. Res. (Atmos.) 103, 8237–8242.
88. Woolf, D., 2008. Biochar as a soil amendment: A review of the environmental implication. University of Swansea. http://orgprints.org/13268/1/Biochar_as_a_soil_amendment_-_a_review.pdf.
89. Woolf, D., Amonette, J. E., Street-Perrott, F. A., Lehmann, J., Joseph, S., 2010. Sustainable biochar to mitigate global climate change. Nat. Comm. 1: 56.
90. Xia, L., Wang, S., Yan, X., 2014. Effects of long-term straw incorporation on the net global warming potential and the net economic benefit in a rice–wheat cropping system in China. Agric. Ecosyst. Environ. 197, 118–127.
91. Xu, G., Lv, Y., Shao, H., 2012. Recent advances in biochar applications in agricultural soils: benefits and environmental implications. CLEAN – Soil Air Water 40, 1093–1098.
92. Yanai, Y., Toyota, K., Okazaki, M., 2007. Effects of charcoal addition on N_2O emissions from soil resulting from rewetting air-dried soil in short-term laboratory experiments. Soil Sci. Plant Nutr. 53, 181-188.
93. Yuan, J.H., Xu, R.K., 2011. The amelioration effects of low temperature biochar generated from nine crop residues on an acidic Ultisol. Soil Use Manag. 27, 110-115.
94. Zhang, M., Gao, B., Varnoosfaderani, S., Hebard, A., Yao, Y., Inyang, M., 2013. Preparation and characterization of a novel magnetic biochar for arsenic removal. Bioresour. Technol. 130, 457–462.

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Fostering Sustainable Practices in Industries: An Action Research on Capacity Development of Managers towards Climate Change Mitigation and Green Industrialization

Gagan Preet Kaur[1*], Puja Gupta[1] and Matt Syal[2]
[1]Dept. of Resource Management and Design Application, Lady Irwin College, University of Delhi, Delhi, India
[2]School of Planning, Design and Construction, Michigan State University, USA
***Corresponding Author:** *gaganpreet66@gmail.com*

Abstract— Sustainability is the crux of development in recent times for mitigation of climate change. Manufacturing operations of industries have resulted in impact on resources, besides creating impacts on human health and wellbeing. This indicates towards a rampant need for the development and adoption of green building rating systems in manufacturing sector which will help in steering growth towards sustainable industrialization. Thus in this context, Indian Green Building Council (IGBC) has developed green factory rating system which can help address issues like energy efficiency, conservation of natural resources, betterment of working conditions and enhanced productivity. Its adoption can be accelerated by generating awareness amongst stakeholders of manufacturing sector to voluntarily adopt green practices for their factory buildings. The research brings out the action oriented approach followed to enhance knowledge and perceptions of stakeholders regarding climate change, sustainable development, green built environment and green rating systems with special reference to Indoor Environment Quality (IEQ) technologies since it has major impact on the health and productivity of the workers. Also, newer technologies used for IEQ by operational green factories were also studied in detail.

Newer technologies employed by existing green factories, as revealed by the study were Building flush out, entryway systems, high efficiency filters and so forth. Taking these as a framework, a training programme was prepared to generate awareness. The training programme, dealt in imparting knowledge on various issues such as sustainable development, green built environment, green factory rating system etc. The training programme resulted in change in knowledge and perception of stakeholders, which was statistically analyzed. This change helped them to understand and appreciate how their practices and preferences in their factory buildings can contribute to good working environment thereby leading to a holistic goal of climate change mitigation and sustainable development. Thus, such interventions can be taken up at a wider scale to motivate community stakeholders to adopt green building guidelines.

Keywords: Climate Change, Green Factory Rating System; Mitigation; Industrial Sector; Indoor Environment Quality Technologies; Training Programme.

1. INTRODUCTION

India has experienced rapid industrial growth since the enactment of the economic liberalization policies in 1991. Industrial processes and activities consume materials and resources for manufacturing products generating emissions, effluents and solid wastes leading to manifold impacts to the environment. The cost of environmental damage has been estimated at approximately $32 billion (Planning commission, 2012). The Indian industrial revolution is also increasing the burden of occupational hazards. Introduction of hazardous machinery, toxic chemicals, high rise construction, unprotected machinery, poisoning and burns form manufacture of chemicals, etc., are the main cause of injuries and deaths in the Indian industries both organized and unorganized sectors (Technology Information, Forecasting and Assessment Council[TIFAC], 2009). The need for sustainable consumption of resources by employing efficient industrial processes and activities also helps alleviating the overall environmental impacts of a company by reducing wastage of resources, which directly reduces the production of wastes, emissions and effluents (Planning commission, 2012). Many people spend their entire working day inside an office, shop, factory, or other facility. Indoor environmental quality (IEQ) and occupational health in factory building directly impacts the human health and productivity of workers. It is one of the major concerns in providing safety and good working conditions in the industrial sector. Promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations is required (*Kats, 2003)*

As a developing country, booming economic activities in last 10-15 years in India has resulted in large-scale building infrastructure activities. India has witnessed major progress in the context of green building guidelines since 2001. The introduction of green building guidelines to establish uniform standards for the application of sustainable practices and their acceptance has been a recent trend in the developing countries (Potbhare and Syal, 2008). According to Augenbro et al (1998), the term green building guidelines refer to the guidelines, which evaluate the environmental performance from the 'whole building' perspective over the building's service life (cited in Potbhare and Syal, 2008). Many countries, both developed and developing, have come up with their own rating systems. United States Green Building Council was among the first few who worked in this area of developing such systems and it came up with Leadership in Energy and Environmental Design (LEED) guidelines (United States Green Building Council [USGBC], n.d.). LEED was afterwards adapted to suit the Indian conditions and thus, Indian Green Building Council (IGBC) was developed as an arm of USGBC. LEED-India (developed by IGBC) provides building owners, architects, consultants, developers, facility managers and project managers the tools they need to design, construct and operate green buildings. India also came up with the formulation of GRIHA (Green Rating for Integrated Habitat Assessment) which has been adopted by The Ministry of New and Renewable Energy and was developed by The Energy and Resources Institute (TERI) (United Nations Environment Programme [UNEP], 2007). In India, the Green Building Movement spearheaded by CII Godrej GBC since 2001 has come a long way. As December 2010, over 825 green building projects have been registered amounting to a total of over 522 Million sq. ft of green building footprint (CII - ITC Centre of Excellence for Sustainable Development, 2013)

IGBC Green Factories rating system is the first of its kind addressing sustainability in industrial buildings. This rating system would facilitate the development of energy efficient, water efficient, healthy, more productive, environment friendly factories. No other rating system in the world has come up with guidelines specifically designed for industrial buildings. To achieve IGBC Green factory certification, buildings must meet all mandatory requirement in the Rating System. The flexibility of the Rating System allows building owners, managers and practitioners to determine which credits to pursue based on performance goals (CII, 2009). The various levels of rating awarded are:

Table 1: Certification Levels of Green Factory Rating System (CII, 2009)

Certification levels	**Points**
Certified	51-60
Silver	61-70
Gold	71-80
Platinum	81-100

The rating system is fundamentally designed to address national priorities, which are as follows (IGBC, 2009):

1. **Energy Efficiency**: The factory building strives in reducing energy consumption through adoption of the latest trends and technologies in enhancing energy efficiency.
2. **Water Efficiency**: Effective water management strategies need to address the crisis. The green factory building rating encourages use of water in a self - sustainable manner through reduce, recycle and reuse strategies.
3. **Handling of Waste:** Segregation of waste at source, diverting the material to the local recycling facilities and reuse of materials, thereby reducing waste dumped in the landfills are some of the strategies are undertaken in a green factory .
4. **Reduced Use of Fossil Fuels:** The green factories encourage the use of alternate fuels for transportation, public transportation, bio fuels for captive power generation, green power and onsite renewable energy generation.
5. **Reduced Dependency on Virgin Materials:** Green factory encompasses recycled & reused material and discourages the use of virgin wood thereby addressing environmental impacts associated with extraction and processing of virgin materials.
6. **Indoor Environment Quality and Occupational Health:** Green factory addresses issues related to occupational health such as avoiding the use of asbestos in construction, provision of breakout spaces etc.,

With the advancement of green building movement in India, many companies evinced a keen interest in having a holistic green design and construction framework for upcoming factory buildings. Even before the code was formally launched, about ten manufacturing companies, both domestic and international, evinced interest in being part of the pilot initiative to conform to the Green Factory compliance norms (CII, 2009). Thus, an effort was made in present research to do case profiling of operational green factories to gain an insight into technologies used, benefits accrued and challenges faced with special reference to IEQ credits. The paper focuses on conducting an intervention through awareness program, which was targeted to motivate stakeholders towards potential improvements in the working conditions in existing non-green factory buildings. This paper can be of immense utility for pioneer organizations promoting sustainability where in such interventions can be used to undertaken to generate awareness and promote the noble cause of sustainable development.

1.1. Objectives

The study was undertaken with the following objectives:

- To do case profiling of operational green factories
- To study the awareness of stakeholders vis a vis green factories
- To develop and conduct a need based training program regarding green factories with reference to indoor environment quality and occupational health
- To study post training change in awareness regarding green factories amongst stakeholders.
- To evaluate the training programme from beneficiaries perspective.

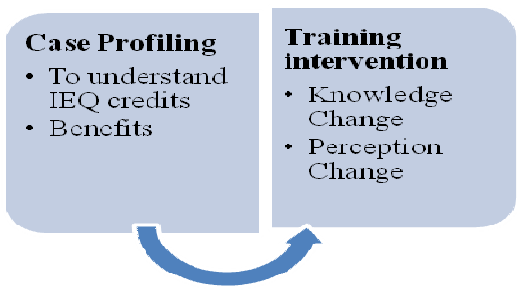
2. MATERIAL AND METHODS

The researcher identified fully operational green factories as case studies (Grundfos Pvt Ltd, Chennai and SKF India Ltd, Haridwar). Data for case profiling was collected using checklist and a questionnaire to elicit in-depth information of the project with special reference to IEQ credits. This case profiling was taken as a base to develop a need based training programme to be used as an intervention to generate awareness amongst managers of non-green factories regarding green factories with special reference to IEQ credits. For intervention non-green factories located in Capital and National Capital Region were selected randomly. The sample selected from these factories comprised of all top and middle level manager who were deputed by the organization for training. Top managers were selected, as they are the chief catalysts for implementation of strategic decisions in an organization. Middle managers apart from playing an important role in organizational decision making also look over the operations in the factories and serve as a link between workmen and top management.

The intervention was a training programme comprising of awareness raising training modules, which were assisted with comprehensive tools. It constituted three modules (awareness generation and motivation, Green built environment, IGBC Green Factory Rating system) each having several sessions. The delivery of training programme was framed into 3 elements introduction, content and recapitulation. The content was delivered using various tools like presentations and videos, session summary handouts, pamphlets, training manual. The awareness level of participants in training program was enhanced by building their knowledge and perception towards green factories. The knowledge level and perception was measured by administering a knowledge testing questionnaire and interview schedule respectively both pre-training and post-training. The difference between the result of the pre and posttest would provide evidence to the knowledge and perception change during the training. A tool for training evaluation was used to get feedback on the overall reaction of the managers to the training program. The information obtained through case study was interpreted and evaluated qualitatively. Tests were analyzed by applying two sample t-test and level of significance. Figure 1 depicts the 2 stages in which methodology was accomplished.

By adopting a participatory approach for training program an effort was made to empower stakeholders so that they can effectively intervene and work towards betterment of work environment quality through adoption of green factory certification for their factory buildings.

Fig 1: The study was accomplished in two stages: Case



Case profile served as a guiding framework for developing intervention developing

Profiling and Training Intervention

Table 2: List of IEQ technologies installed in the green factories

Indoor Environment Quality Credit points		Technologies implemented for achieving credit points
Mandatory Requirement 1	Tobacco Smoke Control	• Smoking was prohibited inside the factory area. • Signages placed in building campus to educate occupants and visitors
Mandatory Requirement 2	Minimum Fresh Air Requirements	• Sensors used to monitor the carbon dioxide level. • Use of high efficiency filters at main HVAC intakes. • Air conditioners system meets ASHRAE guideline of 20% more fresh air.
Mandatory Requirement 3	Avoid Use of Asbestos	No Asbestos is used in the building
IEQ Credit 1	Building Flush Out	The plant was flushed after construction o remove contaminants and clean indoor air
IEQ Credit 2	Day Lighting	• Light shelves and skylight used • Lights are equipped with occupancy sensors
IEQ Credit 3	Low VOC Materials	• Adhesives, sealants, paints and coatings used in the building are low VOC (volatile organic compounds) thereby having minimum organic emissions
IEQ Credit 4	Reduction of Workmen Fatigue (Break out spaces)	Outdoor break out spaces including canteen, sitting space, toilets etc provided for at least 5% of the regular employees per shift
IEQ Credit 5	Eco-friendly House-keeping Chemicals	• The use of chemically-reactive and toxic cleaning products is avoided • Audits - for maintenance of air conditioners, air ducts, vents
IEQ Credit 6	Gymnasium	A gymnasium has been provided to cater a minimum of 2% of occupants in the factory campus

3. RESULTS AND DISCUSSION

3.1 Case Profiling

The case profiling of factories was done to understand the

- IEQ technologies
- The benefits accrued from implementation of these technologies
- Ideology behind going green

3.1.1 IEQ Technologies

The case studies were analyzed on the basis of the IEQ credits and the benefits accrued from their implementation. An attempt was also made to understand ideology behind going green

The selected buildings Grundfos Pvt Ltd (Chennai) and SKF India Ltd. (Haridwar) adhered to norms as given by IGBC green factory rating system and applied for Gold certification. They had taken special initiatives to maintain optimum IEQ in their factory set-ups as indicated by Table 2.

3.1.2 Benefits accrued from implementation of the rating system

The potential impacts of green factories was accessed by understanding the perceived benefits accrued through implementation of IEQ credits as compared to their non green factories (see Table 3)

Table 3: Perceived benefits from implementation of IEQ credit green factories

Perceived benefits from implementation of IEQ credit	Percentage	
	Grundfos Pvt Ltd.	SKF India Ltd.
Reduction in Energy Consumption	20-30%	20%
Reduction in Incidence of sickness	10-20%	15%
Increase in Employee productivity	10-20%	20%
Reduced Incidence of employee absenteeism	5-10%	15%

It was seen that both factories experienced 20-30% reduction in energy consumption, 10-15% reduction in employee absenteeism and incidence of sickness. They also perceived to have experienced an increment of 10-20% in productivity of workers. Thus, the workers perceived that working green factories had a positive impact on them.

3.1.3 Ideology behind implementation of the rating system

Commitment to reducing environmental impacts and ensuring the good workplace for their employees were cited as one of the most important factors in making decisions towards going green by both the companies.

Both the factories used various technologies to maintain an optimum indoor environment. This contributed towards their ultimate goal of providing good work environment for the workers

3.2 Training Programme

Intervention was a training programme, which consisted of awareness raising training modules, which was assisted with comprehensive tools. The training programme developed is discussed with respect to its content and delivery.

3.2.1 Content of training programme

To meet both the aims and objectives, and the differing levels of knowledge and expertise of the target audience, three modules have been formulated which each having 3 sessions as indicated by Figure 2

3.2.2 Delivery of training programme

The training program was framed into 3 elements as indicated by Figure 3

- Introduction – The respondents were made familiar with the subject matter though informal discussions and presentations.
- Content – the subject matter was delivered using various tools which include
  - Presentations and videos
  - Session summary Handouts
  - Pamphlets
  - Training manual
- Recapitulation – Recapitulation was recognized an essential part of training programme. It was administered with purpose to help respondents to recapitulate the content at the end of each session. For this, recapitulation exercises were developed for each session.

3.3 Intervention

The respondents were assessed for their knowledge and perception before and after training various issues: Sustainable development and global warming, green built environment, green rating systems, green factory concept and IEQ

3.3.1 Pre and post training change in knowledge

It was observed that respondents had fairly good idea of the term sustainable development but they could not relate it to other options like green building movement, 4R's use of low cost materials. Respondents had fairly good idea of the issue of global warming as in pre-test, three fourth (75 per cent) could identify its correct meaning. However, in post-test nearly all (90 per cent) respondents chose the right option as indicated by Figure 3. Participants showed keen interest in understanding the

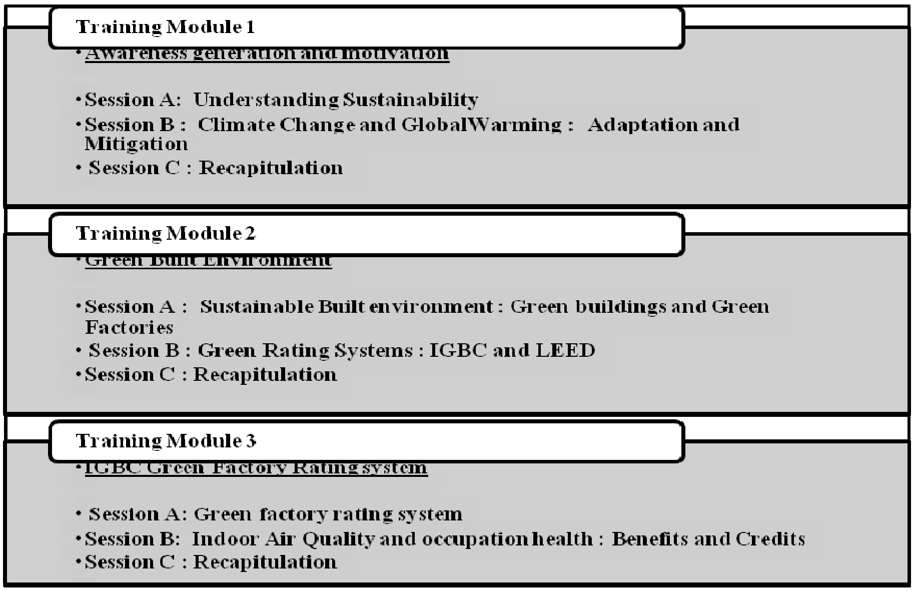
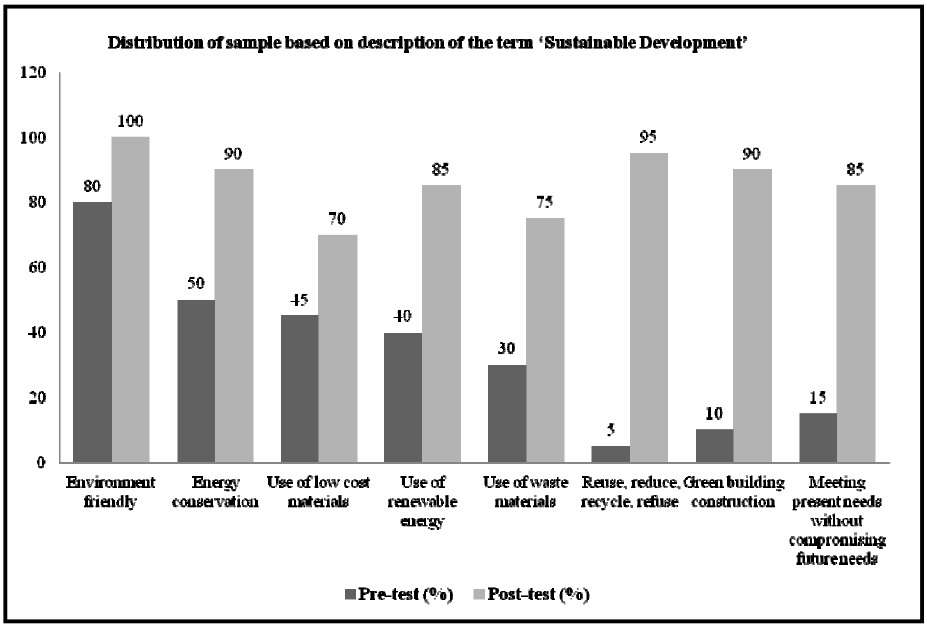
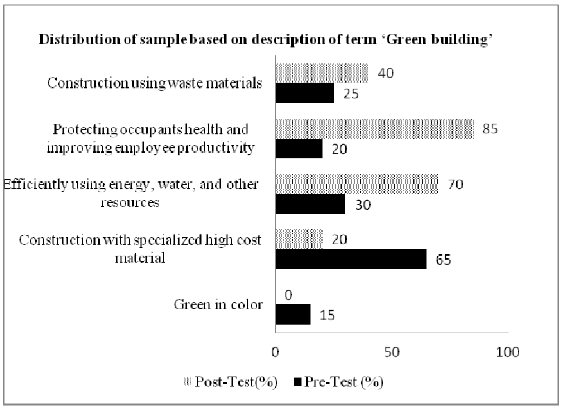


Figure 2: Content of training programme



Total percentage is greater than 100 as more than one response was obtained.

Figure 3: Distribution of sample based on description of the term 'Sustainable Development'



Total percentage is greater than 100 as more than one response was obtained.

Figure 4: Distribution of sample based on description of the term 'Green Buildings'

Figure 4 indicates that in pre-test 65 per cent of responses were received for green buildings being associated with specialized high cost construction. Also, even though the respondents belonged to large manufacturing corporations, surprisingly 15 per cent responses were received relating green buildings with a building, which is green in color. However, these misconceptions were dealt in the training program, they were made aware of the fact that green buildings are high-performance building providing economic, human and community benefits as well as reduced environmental impacts. In post-test respondents were able to comprehend the same as majority of responses (85 per cent) were obtained for option 4 (Protecting occupants health and improving employee productivity). Also, respondents could recognize the resource efficiency of green buildings since 70 per cent responses were attained for option 3 (Efficiently using energy, water, and other resources) and 40% responses were received for waste materials for construction.

In pretest respondents could not comprehend the green factory concept. To bring about a change in knowledge many examples were cited from operational green factories, wherein a special emphasis was laid on IEQ credits employed. Participants were made familiar with IGBC green factory framework, which caters both to existing and new factories. Ensuring proper IEQ is one of the most pertinent component of the rating system, in pretest only 20 per cent responses were received for this option whereas in post-test percentage responses increased to 95 per cent as indicated by Table 4. During training for better understanding of these terminologies examples were drawn from operational green factories on how they have implemented these credits and benefits accrued through thei implementation.

Also, percentage of respondents that could identify green rating systems increased from 10 per cent in pre-test to 100 per cent in post-test.

Table 4: Distribution of sample with regard the knowledge about features of green factory rating system

Features of green factory rating system	Pre-Test percentage	Post-Test percentage
Site Selection and Planning	0	35
Water Conservation	25	50
Energy Conservation	45	80
Material Conservation	15	60
Indoor Environment Quality	20	95
Innovation & Design Process	15	50

Total percentage is greater than 100 as more than one response was obtained

A shift in the average scores from low to high indicated a perceptual change towards sustainable development and climate change. Pre-training respondents were seen to oblivious to the seriousness of climate change, as they perceived it to be exaggerated. Post-test training their perception changed and they showed interest in knowing the contribution of manufacturing sector in climate change. They also showed a positive perception post-training towards sustainable development, as they were interested in knowing how they can access workshops, seminar relating to these issues. One of the participants also pointed out that they needed a trainer in their organization for educate their workers towards sustainable development.

The knowledge towards IEQ technologies was seen to be quite low amongst respondents in pre-test. Respondents also were oblivious to the technologies like airflow and Air Changes per Hour (ACH) less than one fourth responded correctly. They were made aware of the adverse health effects of maintaining of not maintaining an optimum airflow and Air Changes Hour in a factory set up. In post-test 85% responded correctly for both. Respondents also lacked knowledge regarding the VOCs and break out spaces. They were acquainted with these two concepts and their importance by drawing examples from existing green factory set up where implantation of these credits has led to reduced incidence of sickness and greater satisfaction amongst workers.

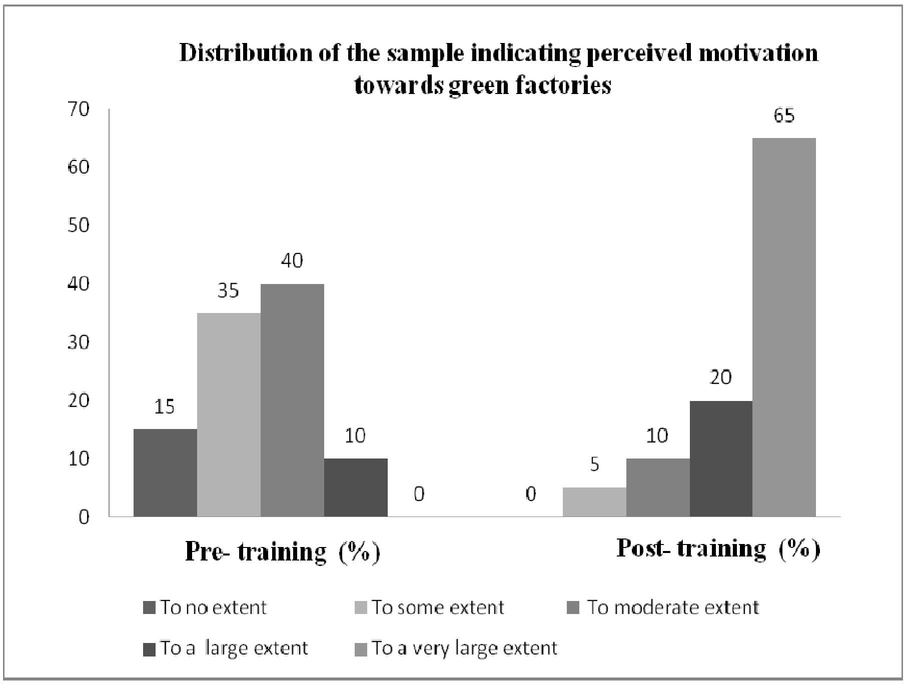


Figure 5: Distribution of the sample indicating perceived motivation towards green factories

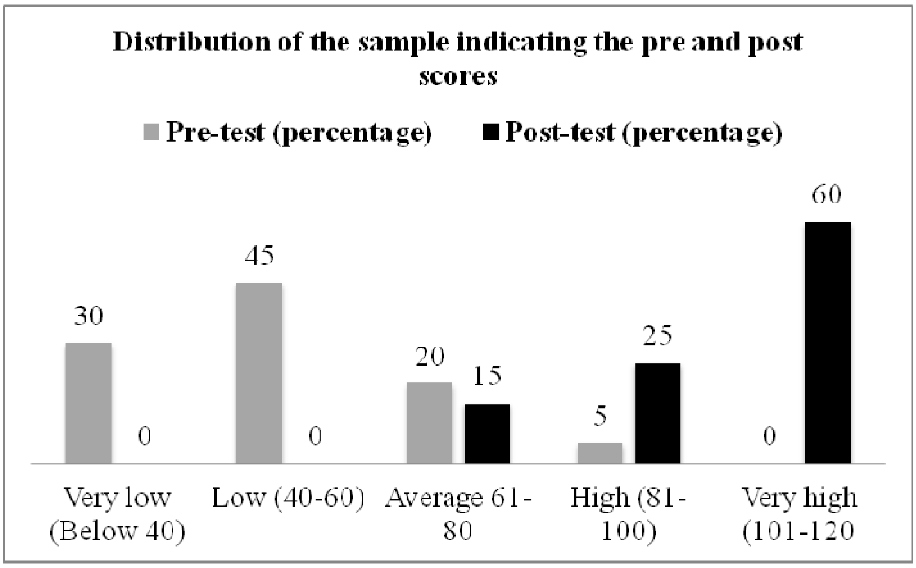


Figure 6: Distribution of the sample indicating pre and post training knowledge scores percentage

3.3.2 Pre and post training change in perception

A shift in the average scores from low to high indicated a perceptual change towards sustainable development and climate change. Pre-training respondents were seen to oblivious to the seriousness of climate change, as they perceived it to be exaggerated. Post-test training their perception changed and they showed interest in knowing the contribution of manufacturing sector in climate change. They also showed a positive perception post-training towards sustainable development, as they were interested in knowing how they can access workshops, seminar relating to these issues. Prior to training respondents perceived the concept of green building to be very complex involving highly specialized construction. However these perceptions saw a shift during training, which is evident through high average scores in post training. They could perceive green building to be energy efficient construction and design that minimizes the total environmental impact while enhancing user comfort and productivity.

3.3.3 Pre and post-training motivation

The respondents also appreciated the efforts made by green factories – case 1 and case 2 were motivated to adopt the certification by observing the benefits perceived by these two organizations. Figure 5 indicates the rise in motivation from pre training to post training. During pre-training only 10 per cent were motivated to adopt the rating system. Post-training 65 per cent of respondents were motivated to adopt the green factory guidelines. Respondents became aware of the benefits, technologies, and importance of all these aspects under green factory system and were thus ready to bring about a change in their existing environment by adoption of green factory certification system.

3.3.4 Comparison of pre- training and post- training scores

Based on the responses obtained in knowledge test, scoring was done. Categories were created and scores were arranged under these categories to determine the number of respondents scoring high or low in pre-test and post-test. Figure 6 indicates a considerable amount of difference between the pre-test and the post-test scores of managers. The paired t-test was calculated for knowledge scores. The means of pre-test and post-test were found to be statistically significantly different as indicated by Table 5. Thus, it was inferred that overall training did have an impact on knowledge level and perception of managers.

The training programme helped in increasing the knowledge and changing perception of stakeholders regarding sustainable development and related issues and also the benefits accrued from working in green environment. The training programme helped stakeholders to understand and appreciate how their practices and preferences in their factory buildings can contribute to good working environment thereby leading to a holistic goal of sustainable development.

Table 5: t-test for knowledge and perception scores

	Post test- Pre-test		
	Difference in Mean	t	Level of significance
Knowledge	49.15	18.34	0.00
Perception	44.75	14.03	0.00

5. CONCLUSIONS

There is a rampant need for the development and adoption of green building rating systems in Industrial sector which will help in steering growth towards sustainable industrialization. To address this, IGBC has developed a new rating system for green factories and industrial structures. The study was carried out in two buildings, both registered under IGBC green factories. These two buildings were developed as case studies. The technologies employed by existing green factories, as revealed by the study were building flush out, entryway systems, high efficiency filters and so forth. The workers perceived that working green factories had a positive impact on them Perception and awareness of stakeholders was studied regarding green movement which revealed the gaps in awareness. To fill these gaps training program was structured, taking case profile of existing green factories as a guiding framework. The training program gave holistic overview towards green movement particularly green factory rating system eliciting in-depth information regarding with special reference to IEQ credits and the benefits accrued through its implementation. The training was statistically tested using two sample t-test and it was found to be statistically significant in bringing about knowledge and perception change. Training program was instrumental in generating awareness and motivating employees, which was spelt by willingness of majority to adopt green factory rating system and take suitable sustainable initiatives for their factory buildings to provide a better work environment to the workers.

Such interventions can be taken up at a wider scale to motivate stakeholders to address the health concerns and productivity of workers along with other environmental concerns through adoption of green factory guidelines. Training programmes can be used as a catalyst in accelerating this adoption. Moving forward towards the ultimate goal of sustainable industrialization, green factory rating system can be incorporated in policy framework to promote greater willingness on part of industries to adopt green practices for their factory buildings. Such interventions are fruitful for targeted beneficiaries and also civil society as a whole and can be used to have far reaching applications to address the issue of sustainability. To achieve the goal of sustainable industrialization globally, it is imperative that such rating systems for industrial buildings are developed and implemented by other leading rating systems like LEED (US), BREEAM (UK), CASBEE (Japan), Gold Star (Australia) and so forth. Future generations can be also empowered towards the goal of green industrialization by incorporating the knowledge regarding the same in school curriculum. This is in the view of the fact that future generations will take on the role of the industrialist, entrepreneur or the workforce in any organization. Hence the knowledge of green industrialization would help them in addressing sustainable development in more responsible manner.

REFERENCES

1. Augenbroe, G.L.M. and Pearce, A.R., Guy, B., and Kibert, C.K, 1998, Sustainable Construction in the USA: A perspective to the year 2010, Paper presented at The CIB World Congress
2. CII - ITC Centre of Excellence for Sustainable Development, 2013, Sustainable Development. Retrieved from http://www.sustainabledevelopment.in/Sustainable%20Development/global_picture.htm,
3. CII, 2009, Green factory rating system, Retrieved from http://igbc.in/site/igbc/testigbc.jsp?desc=191588&event=191580
4. IGBC, 2009, Green factory rating system, IGBC, Hyderabad, India
5. Kats, G. 2003 Green Building Cost and Financial Benefits. Massachusetts Technology Collaborative, MA
6. Planning commission, 2012, Report of the Working Group on "Effectively Integrating Industrial Growth and Environment Sustainability, Planning Commission, Government of India
7. Potbhare, V. and Syal, M. (2008). Adoption of Green Building Guidelines in the Developing Countries Based on U.S. and India Experiences. Masters dissertation, Construction Management, School of Planning, Design and Construction, Michigan State University, MI
8. TIFAC, 2009, Industrial Occupational Health & Safety, 2009, TIFAC Library, India,
9. USGBC, (n.d.) Greening the codes. Retrieved from: http://www.usgbc.org/ShowFile.aspx?DocumentID=7403
10. UNEP, 2007. Buildings and climate change: Status, challenges and opportunities. Retrieved from: http://www.unep.fr/shared/publications/pdf/DTIx0916xPA-BuildingsClimate.pdf

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LEED-EB in India: Initiative towards Greening Existing Buildings

Meenal Jain[1]*, Meenakshi Mital[1] and Matt Syal[2]
[1] Department of Resource Management and Design Application, Lady Irwin College (University of Delhi), Sikandra Road, New Delhi, Delhi-110001, India,
[2] Construction Management, School of Planning, Design and Construction, Michigan State University, 213 HE Building, East Lansing, MI 48824, USA
***Corresponding author:** *meenal_11287@yahoo.co.in*

Abstract— One of the biggest polluters of the environment is the building sector, accounting for almost 30% of the global energy consumption and its associated GHG emissions. At the same time, it has the largest potential for cutting these emissions responsible for global warming. In India, there is a vast chunk of existing buildings that are not so efficient and thus, there is an immense potential for energy efficiency measures. United States Green Building Council has designed LEED-EB which is a rating system for greening existing buildings. But studies have shown that though there are many new green constructions taking place in India, there are very limited existing buildings going in for LEED-EB. Thus, the key objective of the study was to gain insight into the hindrances and catalysts associated with LEED-EB as a tool for greening of existing buildings. The study was undertaken in India in two buildings, one registered and the other certified under LEED-EB. Hindrances and catalysts associated with LEED-EB were studied from the perspective of building managers, architects and green building consultants. On analyzing the data, it was seen that prestige, image and reduction in operational costs were the major catalysts behind LEED-EB. Better rental value, Improved Indoor Environmental Quality (IEQ) etc. emerged as catalysts with medium and minor importance. The major hindrances were found to be high renovation costs, difficulty in meeting prerequisites and unavailability of the required data for LEED-EB submission. Some hindrances with medium and minor importance were resistance to make changes in the existing buildings, lack of awareness among the stakeholders, lack of technology etc.

Keywords: Existing Building; LEED-EB; Catalysts and Hindrances.

1. Introduction

Historically, India has not been a major GHG emitter, but it now has one of the fastest growing economies in the world and the emissions are set to increase dramatically if it has to achieve the developmental priorities (India Climate Portal, 2010). If we look into the construction sector, it can be seen that building construction and operations have many negative impacts on the environment. Buildings use resources such as energy, water and raw materials, generate waste (occupant, construction and demolition) and emit potentially harmful atmospheric emissions which effect the environment negatively and thus, need to be taken care of (WBDG Sustainable Committee, 2010). The way the buildings are designed, built, renovated and operated has an effect on our environment as buildings constitute more than one third of total energy use and its associated greenhouse gas (GHG) emissions throughout the world. At the same time, the buildings have the largest potential for cutting GHG emissions responsible for global warming by incorporating green practices (United Nations Environment Program, 2009).

The mechanisms used in the organizations for lighting, heating, cooling etc. have major emissions and energy utilization which need to be taken care of (Green Rating for Integrated Habitat Assessment, 2010). The building designers and builders have a challenge to provide new and renovated organizations that are healthy and productive and have minimal impact on environment. Also, in the current economic scenario, it is more feasible to have the existing organizations renovated than to have new facilities (WBDG Sustainable Committee, 2010). According to Energy Efficiency in Buildings (EEB) India Forum (2007), "Given the spurt in construction activities in India at present, and a huge stock of existing buildings that are not so efficient, there is immense potential for energy efficiency measures in the country" (as cited in The Energy and Resources Institute, 2010).

A green building, thus, focuses on increasing the efficiency of the resources being used in construction and operations of the buildings. It also reduces the impacts of buildings on human health and environment during the complete life cycle of the building through better siting, designing, construction, operation, maintenance and demolition (Indian Green Building Council, 2007). The last several years have witnessed an explosive growth in the green or sustainable building movement and it is expected to continue until green buildings become the norm for building design, construction and operation. Building owners and managers are realizing that sustainable buildings not only lead to better building performance and healthier indoor environments, but pay off financially as well (Olson et al., 2006).

To foster the green building process and provide a benchmark for green standards, green building guidelines have been developed worldwide. According to Augenbro (1998), the term green building guidelines refers to “the guidelines which evaluates the environmental performance from the ‘whole building’ perspective over the building’s service life”. The US Green Building Council (USGBC) was the first to come up with one such set of guidelines when it launched the Leadership in Energy and Environmental Design (LEED®) guidelines in 2000. At present, LEED has a large number of certified and registered projects across the globe (as cited in Potbhare and Syal, 2008). Since its formulation, LEED has provided a set of standards for environmentally suitable construction. It is transparent and is publicly reviewed by the more than 10,000 membership organizations that currently constitute the USGBC (Natural Resource Defense Council, 2008). The sustainability potential of the buildings does not stop once the buildings are built. To cater to this, USGBC has developed LEED for Existing Buildings (LEED-EB). This system focuses on greening the building’s operations and maintenance procedures so that it can perform to environmental standards over its entire lifetime.

If we look at the data, as much as ninety nine percent of the buildings are already standing today and every year, only 1% of new buildings are added to the existing stock. Hence, the issue of energy efficiency should be tackled immediately to secure our future (Power, 2009). In a developing country like India, where a huge section of organizations is already standing, they can be made green by making various renovations/alterations to the building structure, replacing equipment and changing human behavior (Jain, 2010). In addition, the existing building stock has to be more fully considered, so that fewer resources may be consumed to build new. In any case, in its present state of development, India is not is position to bring down the existing structures and start building afresh. The ratio of buildings that require renovation to the number of all existing buildings is presently so high that the replacement construction is practically impossible. However, combining the reuse of the existing stock with good energy and environmental solutions could result in interesting solutions for sustainable development (Kujawski, 2009).

The LEED for Existing Buildings Rating System is a set of voluntary performance standards for the sustainable upgrades and operation of buildings not undergoing major renovations. The LEED for Existing Buildings (LEED-EB) Rating System helps building owners and operators measure operations, improvements and maintenance on a consistent scale, with the goal of maximizing operational efficiency while minimizing environmental impacts. In addition, LEED for Existing Buildings provides sustainable guidelines for whole-building cleaning/maintenance, recycling programs and systems upgrades to improve building energy, water, IEQ and materials use.

However, it is seen that not many organizations have gone in for LEED-EB in India as compared to LEED-NC. Thus, the present study investigates the hindrances and catalysts, as reported by the organizations, towards greening of existing buildings. Review of literature showed that very few studies of this nature and focus have been carried out. This study therefore adds to the body of knowledge regarding LEED-EB and its implementation.

1.1 Objectives

The study was undertaken with the following objectives:

- To make a profile of the selected buildings in terms of LEED-EB
- To take a detailed account of the technologies and strategies used to implement the IEQ credits under LEED-EB
- To gain insight into the hindrances and catalysts associated with greening the existing buildings

For the present paper, however, only the third objective will be discussed.

2. METHODOLOGY:

It was seen that the number of buildings under LEED-EB in India is very limited. These buildings were contacted and as per their willingness to take part in the study, two buildings were selected and developed as case studies for understanding the catalysts and hindrances associated with LEED-EB certification. One building was registered under LEED-EB and the other certified under LEED-EB at the time of data collection. The sample consisted of Architects/Architectural designers of the building, managers of the building involved in the process of taking the LEED-EB certification and Green Building consultants. Two groups of consultants were taken for the study. The first group consisted of those consultants who had done at least one LEED-EB project and the second group consisted of those associated with green building projects but not necessarily LEED-EB.

Questionnaire was developed for the managers and architects of the buildings for collecting information of the buildings in terms of LEED-EB. A comprehensive checklist was made to take an account of the LEED-EB credits that the buildings had gone for. Questions related to catalysts and hindrances which they had encountered while going for the greening process were also part of the tool. Another questionnaire was developed for the consultants which was divided into two parts. The first part of the questionnaire had questions related to profile of the consultants and their organizations. The second part had questions related to the LEED-EB project(s) that they had undertaken and hindrances and catalysts associated with such projects. For better clarification and a detailed understanding of the LEED-EB buildings, interviews were conducted with the managers of the building who had been involved in the process of documentation and certification.

3. RESULTS AND DISCUSSION

The responses obtained from the three groups of the sample (Green Building consultants, LEED-EB consultants, and architects and managers of the buildings) were compiled together and analyzed to gain an understanding regarding the catalysts and hindrances associated with greening of existing buildings and LEED-EB. The ones reported by all the three groups emerged as the major catalysts/hindrances, the ones reported by two groups came forth as those holding medium importance and the ones reported by only one of the three groups emerged as the minor catalysts/hindrances. The responses are summarized in Table 1:

The major catalysts were revealed to be Prestige and Image and Reduction in Operational Costs. The adoption of LEED-EB certification results in reduction in the operational costs of the building and majority of the respondents felt that this acts as a catalyst for the building owners to go for LEED-EB certification due to several factors like reduced waste generation, reduced energy and water consumption etc. A large percentage of the respondents opined that prestige and image is another catalyst in taking the LEED-EB certification. They further felt that such initiatives towards sustainable development enhanced the company's credibility and demand for its products or services. Catalysts having medium importance were better rental value and social responsibility of organizations and acceleration in the sustainable development movement in the society. The catalysts having minor importance were providing improved indoor environmental quality to occupants and pioneering green building movement in India.

Apart from the catalysts, there are also some hindrances in this process, as per the respondents, which prevent the adoption of LEED-EB certification. Majority of the respondents felt that one of the major hindrances in the LEED-EB process is the high renovation costs required for retrofitting of some of the building systems for certification. Renovation means changing several systems inside the existing building set-up like HVAC, plumbing systems, electrical systems, lighting fixtures, fire systems, sanitation, etc. which are required to be modified as per the LEED-EB standards. Renovation of such systems requires a huge investment. According to the respondents, this is more so in a developing country like India where finance is still an issue and hinders the decision to take the LEED-EB certification.

Most of the respondents also reported unavailability of the data and records required for LEED-EB submission as a hindrance because many of the building are very old and it was often very difficult to retrieve drawings, plans and other documents of these buildings. The documentation process of LEED-EB certification requires all these documents to get the certification and unavailability of such data and documents acts as a hindrance in going for the certification. In existing buildings, sometimes it was difficult to meet all the prerequisites for the certification process as compared to a new construction. In a new construction, you can modify the things as per the requirement but in an existing set-up, you cannot do much and at the same time all the prerequisites also have to be fulfilled which becomes somewhat difficult and proves to be a hindrance in the process of LEED-EB certification. For instance, the first prerequisite in the Indoor Environmental Quality category requires them to modify the outdoor air exhaust introduction and exhaust systems, which is a difficult task to carry out. Another prerequisite under Energy and Atmosphere category - Refrigerant Management: Ozone Protection – is also a difficult one to get. One of the managers of the buildings had reported that many fire extinguishers had to be replaced for this prerequisite. Financially also, it is difficult to achieve.

Apart from these some more hindrances having medium and minor importance were reported by the respondents. Lack of skilled professionals and Facilities Management teams emerged as a hindrance having medium importance. LEED-EB deals with operations & maintenance of the building which is being looked after by facilities management teams. In India, many buildings do not have designated teams for facilities management. Hence, a proper plan of action is not there for operations & maintenance procedures like cleaning etc. Also, the people involved in such processes need to be trained which requires changes in the working pattern. Also, they felt Difficulty in retrofitting is one of the hindrances. As the building is already there, it is difficult to retrofit the systems because one cannot destroy the building and re-do the things. Everything has to be done in the existing building itself. Re-commissioning of existing building's HVAC, controls, and electrical systems is very difficult to carry out. The reason for this is that the building is operational and it is very tedious to evacuate the whole building and re-commission the systems. Evacuating the building means a break in the work being carried out in the building, leading to monetary losses. Some other hindrances were found to be time consuming documentation process, lack of awareness among stakeholders, lack of technology, no immediate benefit and so on.

Table 1: Catalysts and Hindrances associated with LEED-EB

Catalysts

Major Catalysts	***Catalysts with Medium Importance***	***Minor Catalysts***
• Prestige and image • Reduction in operational costs	• Better rental value • Social Responsibility and acceleration of Sustainable development	• Providing Improved Indoor Environmental Quality • Pioneering Green Building Movement in India

Hindrances

Major Hindrances	***Hindrances with Medium Importance***	***Minor Hindrances***
• High renovation costs • Sometimes, prerequisites are difficult to meet • Unavailability of the data and records required for LEED-EB submission	• Resistance to make changes in the existing building and Poor building envelope design • Lack of skilled professionals, Facilities Management teams and their training • Difficult to retrofit, commission and change the internal building planning • Documentation is Time consuming • LEED-EB is most stringent rating system • USGBC website is not compatible with all net users and is not clear	• Lack of awareness among the stakeholders • Lack of technology • No immediate benefit • Changes in policies require change in pattern of working in the building • LEED-EB Guidelines are specific to USA • Required Performance period is long • Clearances from the government

4. SUMMARY AND CONCLUSION

It is perhaps inevitable that society is looking to the real estate sector to play a leading role in reducing the "carbon footprint" of economic activities as this sector has a major potential of reduction of green house gases. In today's scenario, when most of the buildings have already being built, there is an immediate need to make the existing buildings more sustainable and green to reduce their negative impacts on the environment (Power, n.d.). To address this, the USGBC developed LEED for Existing Buildings, or LEED-EB (USGBC, n.d.).

The study was carried out in two buildings, one was certified under LEED-EB and one was registered under LEED-EB which were developed as case studies. The architects and managers of these two buildings were interviewed to have their viewpoint on the hindrances and catalysts associated with LEED-EB. Apart from this, green consultants were taken as the sample to gain insight into the hindrances and catalysts in the LEED-EB process. The study focuses on the catalysts and hindrances associated with greening of existing buildings. The two major catalysts namely increased prestige and image and reduction in operational costs need to be made overt by educating the stakeholders and making more and more people aware of the benefits of greening the existing buildings so that this movement can be taken forward.

The study also indicates some of the areas which need to be worked on, to overcome the hindrances associated with greening of existing buildings. One of the major areas of concern that has been brought forth by the study is difficulty in meeting some of the prerequisites. Thus, these prerequisites should be made easier so that more and more stakeholders find it convenient to take the certification, thus, contributing to a healthier environment. Another major hindrance which emerged out of the study was unavailability of the data and records required for LEED-EB submission. Hence, the submittal requirements for the certification should be less stringent so that less time is spent on retrieving the old data. Also, sometimes the required data is not even retrievable like some old drawings, plans etc. which hinders the process of certification. Similarly, other medium and minor hindrances like longer time period required for documentation, Lack of skilled professionals, Facilities Management teams and their training etc. also need to be worked upon.

The findings of the study will facilitate adoption of LEED-EB guidelines in India. Adopting the green initiatives in the existing buildings and organizations and taking the LEED-EB certification will prove to be a very useful tool in minimizing the negative impact of such a large number of existing buildings on the environment and would ultimately result in the sustainable development of the society in the long run. Also, IGBC is coming up with their guidelines for certification of existing buildings which have been made green and these findings will help them to frame the guidelines in such a manner that it is easy to implement. Hence, the study will help in fostering the adoption of green building guidelines in India and taking this process ahead so that the country has an edge over others in terms of environmental sustainability.

REFERENCES

1. Green Rating for Integrated Habitat Assessment., 2010. The Basics. [Online] Available from: http://www.grihaindia.org/index.php?option=com_content&task=view&id=14. [Accessed: 22nd May 2013].
2. India Climate Portal, 2010. How Climate Change affects India. [Online] Available from: http://www.climatechallengeindia.org/How-Climate-Change-affects-India. [Accessed: 2nd February 2014].
3. Indian Green Building Council, 2007. Green Building Defined. [Online] Available from: http://www.igbc.in/site/igbc/index.jsp. [Accessed: 22nd January 2014].
4. Jain, P. C., 2010. Colour it green. The Hindustan Times Estates. p.13.
5. Kujawski, W., 2009. Canadian Best Practices in Sustainable Retrofit Design. [Online] Available from: http://www.iisbe.org/down/bc/retrofit_3case_studies_canada.pdf. [Accessed: 2nd February 2014].
6. Natural Resource Defense Council, 2008. LEED Certification Information. [Online] Available from: http://www.nrdc.org/buildinggreen/leed.asp. [Accessed: 22nd February 2014].
7. Olson, S., Arny, M., Eisch, E., 2006. Sustainable Building Rating Systems Addressing Building Maintenance and Janitorial Products, Policies and Methods. [Online] Available from: http://www.leonardoacademy.org/download/Janitorial%20Products%20and%20Building%20Certification.pdf. [Accessed: 5th December 2013].
8. Potbhare, V. and Syal, M., 2008. Adoption of Green Building Guidelines in the Developing Countries Based on U.S. and India Experiences. M.S.CM Research Report, Construction Management, School of Planning, Design and Construction, Michigan State University, MI, USA.
9. Power, A., 2009. Built Environment. [Online] Available from: http://www.sd-commission.org.uk/pages/built-environment.html. [Accessed: 9th November 2013].
10. The Energy and Resources Institute, 2010. What is a Green Building? [Online] Available from: http://www.grihaindia.org/index.php?option=com_content&task=view&id=14. [Accessed: 2nd February 2014].
11. United Nations Environment Program, 2009. Buildings and climate change: Status, challenges and opportunities. [Online] Available from: http://www.unep.fr/shared/publications/pdf/DTIx0916xPA-BuildingsClimate.pdf. [Accessed: 16th October 2013].
12. WBDG Sustainable Committee, 2010. Sustainable. [Online] Available from: http://www.wbdg.org/design/sustainable.php. [Accessed: 2nd February 2014].

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Prospects of Organic Farming in Controlling Climate Change

Smita Tripathi*[1], Swati Shukla[2], Misha Yadav[1] and Niharika Bharti[3]
[1]Department of Botany, Shivaji College, University of Delhi, Ring Road, Raja Garden-110027
[2]Lund University, Sweden
[3]Laboratory of Plant Physiology & Biochemistry, Department of Botany, University of Delhi-110007
***Corresponding author:** *sm.trip@gmail.com*

Abstract— Agriculture is the mainstay of Indian economy; however agriculture also contributes significantly towards climate change. It is reported that the land under agricultural use contributes to about 12% of global greenhouse gas emissions. The classical agricultural practices like use of chemical fertilizers lead to emissions of methane and nitrous oxides gases. The emissions of these greenhouse gases from agriculture are only going to increase significantly in near future due to increase in population and in turn food demand. Thus, there are needs to change the agricultural practices and look for mitigation solutions which can be done by reducing the greenhouse gas emission and carbon sequestration. If the greenhouse gas emission is not controlled by strategic and sustainable approach then there are greater risks of fatal temperature rise which affects agriculture production. The rise in temperature and limited water resources affect considerably to the crop yield which is a major food security issue. The paper presents an overview on how agriculture contributes to climate change; the role of organic agriculture in reducing global warming; and its shortcomings. The importance of organic farming systems in utilizing the traditional skills and knowledge; integration of modern skills and innovation in managing the natural calamities (like drought) or weather extremes, and natural resources to enhance productivity in agriculture is presented. There is a need of flexibility in organic agriculture for better mitigation and adaptation potential and solve food crisis. The cultivation of other minor crops having high nutritive potentials and international market but not explored widely like millets etc. is a good alternative. The Intergovernmental Panel on Climate Change (IPCC), reported that considerable amount of nitrogen applied in farming escapes to atmosphere. It is reported that about 3% of total Indian greenhouse gas emissions is solely contributed through fertilizer manufacturing plants. The one of the solutions to this can be alternative farming technologies like "Organic Farming System". The organic farming is self sufficient and does not require external nitrogenous fertilizers. Organic production also aids in better soil organic matter fixation, increasing soil fertility and water-holding capacity and yields. Thus to sum-up organic agriculture has various benefits in controlling climate change as it increases carbon capture, reduces greenhouse gas emission by appropriate use of organic fertilizers and reduction in usage of fossil fuels, improves soil carbon-quality-yield and lastly provides income and food security to people.

Keywords: Climate Change, Organic Farming, Greenhouse Gasses and Crop Yield

1. INTRODUCTION

Global climate change has become a scientific problem in the 21st century. With the recent technological advancements it is quite evident that in near future the human activities will dominate the natural mechanisms of climate change. In the next few decades, the earth's temperature is expected to rise at a much faster rate due to an enhancement of the greenhouse effect. According to the Inter-Governmental Panel for Climate Change (IPCC), the three main causes of the increase in Green House Gases (GHGs) observed over the past century have been fossil fuels, land use and agriculture. The GHGs such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chloro-fluro carbons (CFC's) and sulphur hexafluoride (SF_6) are leading causes of global warming due to anthropogenic activities (Gomiero et al. 2008). The major sectors which contribute to emission of these GHGs are Power Stations (21.3%), Industrial Processes (16.8%), Transportation Fuels (14.0%), Agricultural Byproducts (12.5%), Fossil Fuel Retrieval, Processing & Distribution (11.3%), Residential, Commercial & other sources (10.3%), Land use & Biomass burning (10%), Waste Disposal & Treatment (3.4%). The leading GHGs emitted from these sectors are CO_2 (~72%), CH_4 (~18%) and N_2O (~9%). Agriculture itself is responsible for an estimated one third of global warming and climate change. Agricultural activities release significant GHG_S into the atmosphere. The agriculture sector contributes mainly nitrous oxide and methane emissions in the environment leading to global warming and climate change (http://appinsys.com/globalwarming/GW_5GH_CO2Sources.htm). According to IPCC impacts assessment report if the present increased trend of Green House Gases is not restricted it is expected that there will be rise of 2-3^{0}C by the end of 2050 (https://www.ipcc.ch). The largest shares of emissions originate from agricultural soils (nitrous oxide) and fermentation (the natural digestive processes of ruminants such as cattle and sheep) associated with livestock and rice production (methane). GHGs emissions from agriculture are expected to rise because of increased food demand for growing and more prosperous populations able to afford more varied diets with higher shares of meat and dairy products. This shift will also lead to increased pressure on forests from agricultural expansion. Emissions from both fertilizers and livestock are expected to continue to increase significantly by 2020. In addition, intensive agriculture has led to deforestation; overgrazing and widespread use of practices which result in soil degradation. However, the agriculture- a cause of climate change can also be a part of solution. The change in mode of agriculture which minimizes the use of inorganic fertilizers, chemical pesticides, mechanization etc. will significantly help in lowering the energy consumption and indirectly effecting GHGs emissions in the atmosphere. Organic agriculture can be one of the alternatives to conventional agricultural practices which aids in this indirect lowering of GHGs emissions. In addition by the use of green manures like vermicompost and reduced agrochemicals in organic farming system also aids in soil carbon and nitrogen capture. Most scientists agree that a drastic decrease in global GHG emissions should be undergone to limit global warming. By both reducing and sequestering terrestrial greenhouse gas emissions, interventions in agriculture can reduce human caused net emissions of GHGs.

However, significant hurdles stand in the way of scaling up beneficial practices. Implementing the right policies will be the key to overcoming these hurdles. Reforms are especially required in the areas of land tenure, support for agricultural inputs and international trade policies. The central players in driving a response to climate change are farmers – managing the land, and the food industry – influencing the choice of crops, products consumed, quality standards and the path to profitability. The financial sector has a clear role to play in scaling up the investment for ***climate-smart agriculture***.

2. AGRICULTURE AS A CAUSE OF CLIMATE CHANGE

Among the major challenges currently faced by humanity are food security and climate change. Agriculture plays a significant role in both. Agriculture and food supply chains are heavy emitters of heat trapping greenhouse gases. Agriculture production leads to 14% GHG emissions and the percentage rises to 25% if agriculture-driven deforestation is included, and considerably more if the whole food system is taken into account, which includes food processing, storage and distribution. Thus agriculture contributes both directly and indirectly towards global GHGs emissions, which includes on site or at farm level and off site like production of inputs such as fertilizers etc., processing and transportation. As mentioned earlier the agriculture contributes to the release of the three main GHGs: carbon dioxide CO_2, methane CH_4 and nitrous oxide N_2O. Compared to other sectors, agriculture contributes disproportionately heavily to the emissions of methane and nitrous oxide, possibly in the 40-60% range (Smith et al., 2007). The release of these two GHGs is more at on site or at farm level. These are the two most potent GHGs in terms of global warming potential. Enteric fermentation by ruminant animals produce methane and nitrous oxide is contributed through fertilizer use and manure. About 75% of total agricultural GHG emissions are the result of agriculture in low and middle-income countries and this share is expected to increase in the future (Gomiero et al. 2008).

The main sources of agricultural emissions also vary geographically. As expected, emissions from biomass burning and rice production come almost exclusively from less industrialized countries. Emissions from manure are more evenly spread geographically (Stern, 2006 and Wright, 2010). Agriculture-driven GHG emissions are expected to increase in response to population growth and income growth in developing countries, resulting in increased consumption of meat and dairy products. The other major culprit i.e. CO_2 emissions is mostly at off-site agricultural production. It is majorly released during production of fertilizers & pesticides. The other major cause of its emissions can be attributed to the facts of loss of natural vegetations to agricultural lands due to deforestation coupled with fossil fuel combustion and a range of other industrial processes. The United Nations Framework Convention on Climate Change: the UNFCC member countries adopted the Kyoto Protocol in 1997, a protocol for reducing GHG emissions, which entered into force in 2005.

3. AGRICULTURE AS A PART OF CLIMATE CHANGE MITIGATION

Efforts to limit the magnitude and rate of climate change are underway. Climate change mitigation generally involves reduction in human (anthropogenic) emissions of greenhouse gases (GHGs). Policies towards climate change mitigation can substantially reduce the risks associated with human induced global warming. There are several ways through which mitigation can be achieved. Examples of climate change mitigation include switching to renewable and nuclear energy, which is low carbon energy sources, reforestation to increase the capacity of carbon sinks to remove greater amounts of carbon dioxide from the atmosphere. Energy efficiency and climate engineering are also other approaches that also play a role in climate change mitigation.

3.1. How agricultural practices can be used to capture carbon and reduce emissions?

Sustainable agricultural practices that mitigate carbon can have important co-benefits; including increased soil fertility, soil productivity, enhanced resistance to drought & extreme weather and better capacity to adapt to climate change. Sustainable agriculture can contribute significantly to increased food production, as well as make a significant impact on the welfare and livelihoods of rural people. The main strategies are 1) enriching soil carbon through managing soil and farming practices 2) minimizing the use of inorganic fertilizers and 3) restoring degraded lands and preventing deforestation – which largely occurs for agricultural purposes.

3.2. ***Increasing carbon content in soil:*** Agricultural practices which manage organic matter; and thus build and conserve soil carbon (as plant residues and manure), instead of depleting it provide the long-term carbon captures in soils. This results in improving soil quality which results in requirement of fewer chemical fertilizers in successive farming seasons.

3.3. ***Green manures****:* Bare soil is susceptible to erosion and nutrient leaching and its soil carbon content is very low. Grasses and cereals can be grown during fallows and ploughed into the soil while still green. This increases the soil fertility by adding nutrients and organic matter (FAO, 2009).

3.4. ***Nitrogen fixing cover crops:*** These converts atmospheric nitrogen to biologically available ammonia. These cover crops can be further used as livestock fodder or as compost. Decomposition of plant matter increases carbon content in the soil.

3.5. ***Intercropping***: A system of combining compatible crops to increase the yield of main crop. It also promotes biodiversity by providing a habitat for a larger variety of insects and soil organisms than in a single crop environment.

3.6. ***Reduced or No tilling***: The vastly practiced process of tilling the soil exposes anaerobic microbes to oxygen and suffocates aerobic microbes, which releases carbon dioxide. The practice of no- till has manifold benefits in mitigating climate change. Minimum soil disturbance retains the decomposed crop residues on the surface thereby returning carbon to the soil. In addition to saving fuel it prevents carbon dioxide that would have otherwise escaped from the soil during tillage.

3.7. ***Farming with perennials****:* Increasing the use of perennial crops, shrubs and trees provides an important way of mitigating climate change by storing carbon in soil while crops are growing. Their large roots also help hold soil organic matter and water together, which reduces both soil erosion and GHG emissions. The need for annual tilling, seedbed preparation and application of agrochemicals is reduced, which further reduces emissions. Indeed, their roots allow them to support microorganisms and other biological activity as well as accessing nutrients and water in larger volumes of soil (Glover et al., 2007; Scherr and Sthapit, 2009 and Glover et al., 2010).

3.8. ***Agroforestry****:* Agroforestry was the traditional practice of farming in forest and woodland ecosystems. It is nowadays being introduced into subsistence and commercial systems. It involves planting trees in crop fields and pastures. Agroforestry is an ecosystem in itself. The trees provide products like fruits, nuts, medicines, fodder, firewood, timber etc. and increased crop fertility through nitrogen fixation from leguminous tree species. Agroforestry increase biodiversity, provide habitat for pollinators improve microclimate. Along with reducing pressure on deforestation, it also provides another way of increasing carbon storage in agriculture.

3.9. ***Rice management:*** Cultivated wetland rice soils emit significant amount of methane. These emissions can be reduced by various practices such as draining wetland once or several times during the growing season, adjusting the timing of organic residue additions, producing biogas or keeping the soil as dry as possible between seasons.

3.10. ***Biochar****:* Burning biomass in a low-oxygen environment results in a stable solid rich in carbon content called biochar, which can be used to lock carbon in the soil. It keeps carbon in soil for long and slowly releases nutrients as already experienced by Amerindians some 2,000 years ago (Lehmann et al., 2006). So, planting fast-growing trees in degraded areas, converting them to biochar and adding to soil provides a way of taking carbon from the atmosphere and turning it into a slow-release organic fertilizer benefiting plant and soil. It is a promising option for carbon emission offset payments.

3.11. ***Manure management****:* Manure can be used to produce biogas, which can be burnt for heat or electricity and sludge, a potential fertilizer. Composting, crop rotation with leguminous crops increase increase soil organic content and sequester carbon from atmosphere.

3.12. ***Prevent Deforestation and forest degradation:*** Forests and grasslands are an important reservoir of carbon, protect biodiversity on top of being an important part of the water cycle. Deforestation is one of the biggest contributors to global GHG emission. It is driven by agricultural expansion, conversion to pastureland, infrastructure development, destructive logging, fires, etc. (http://www.un-redd.org).

3.13. ***Peatlands:*** They are a potent carbon sink (containing on average about 10 times more carbon than other soils) is a wetland that over many centuries accumulates acidic peat, a deposit of dead plant material, mostly carbon. To be used for agriculture, the soils are drained, which aerates the soil, promotes decomposition, and emissions of carbon and nitrogen dioxides ensue. Peat areas are also very sensitive habitats, of high importance for biodiversity.

3.14 ***Restoring degraded areas:*** A large amount of agricultural lands have been degraded by excessive disturbance, erosion, loss of organic matter, salinisation, acidification, etc. Restoring part of these degraded areas can be a appealing proposition for the climate, economic development and ecosystems services, particularly wildlife habitat and watershed functions (Scherr and Sthapit 2009). The reversion of cropland to another land use, for instance grassland, is one of the most effective ways to reduce emissions and increase carbon sinks.

3.15. ***Agroecology:*** Agroecology is the result of the convergence of agronomy and ecology. It is highly knowledge-intensive, based on techniques, which are based on farmers' knowledge and not delivered top-down. It involves recycling nutrients and energy on the farm, rather than introducing external inputs; integrating crops and livestocks; diversifying species and genetic resources over time and space and focusing on interactions and productivity across the agricultural system rather than on individual species.

3.16. ***Organic farming:*** Organic agriculture covers farming systems where the use of pesticides, herbicides and chemical fertilizers is prohibited. Organic agricultural methods are likely to increase species richness of weeds, plants in field margins and other agricultural habitats, and may increase the abundance of many species and organism groups compared with conventional methods. Positive effects of organic farming on species richness and diversity appear in intensively managed agricultural landscapes.

4. ORGANIC AGRICULTURE AND CLIMATE CHANE MITIGATION

Organic Agriculture was identified as an important alternative to conventional agriculture and as a part of Climate Change Mitigation by IFOAM, the (International Federation of Organic Agriculture Movements). The head office of this federation is in Bonn, Germany and it leads in uniting and assisting the organic movement in its full diversity. In 2004, IFOAM commissioned a scoping study on "The Role of Organic Agriculture in Mitigating Climate Change". In this study they looked at the possibilities of reducing GHGs. According to IFOAM the organic agriculture contributes significantly towards climate change mitigation by Emission Reductions, Carbon Capture, and Carbon Sequestration. This farming system puts people at the center and helps in increasing resilience, income, and food security. Organic agriculture can reduce global CO_2 emissions by 5-15%. Organic Produce has low off site production of GHGs (electricity, products & services used on farm, transportation, processing, storage, distribution etc.) but high on-site production of GHGs (land, water, labor & fuels used) energy requirement in contrast to conventional farming (Wood et al.,2006). IFOAM, 2009 identified several farm level strategies where organic farming can intervene in emission reductions. The energy can be conserved by reducing pumped irrigation, minimizing crop drying in field, use of biodiesel and fuel efficient farm equipments, use of crop rotations with low energy requirements such as growing perennials, N_2 fixing durable crops, increase plant and livestock production (eg. use of C4 plants or efficient farming system designs). Similarly on farm Nitrogen emissions can also be reduced significantly in organic farming as no synthetic nitrogen fertilizer is used. The N_2 comes from within the system which results in avoiding overdoses and high losses. The livestock diets can also be modified like for dairy cow's low protein and high fiber rich diet .The use of certain crops (sunflower seeds) also aids in reduction of NO_2 emissions. The efficient Carbon dioxide emission reductions can be achieved through avoidance of shifting cultivation, reduction of fossil fuel consumption. The Methane reductions can be achieved by soil management to increased oxidation of methane, use of compost and biogas; the use of locally produced appropriate feeds and controlling grazing in animal husbandry and paddy cultivation with proper aeration periods.

According to the FAO, lower GHG emissions for crop production, enhanced carbon sequestration and lower input of fossil fuel dependent resources give organic agriculture considerable potential for mitigating and adapting to climate change. Life-cycle assessments show that emissions in conventional production systems are higher than those of organic systems (FAO, 2009). Although the potential of organic farming to feed the world is still being debated, there is little dispute about the fact that many farmers can maintain yields while using significantly less inorganic fertilizer, with major benefits to the environment, the climate, farmers' health and the local economy (higher prices/revenues, higher labour requirements (Hoffmann, 2011).

4.1. The key characteristics of organic farming system

By definition organic farming is an approach towards agriculture that relies on ecosystem management rather than external agricultural inputs. It is a system that considers potential environmental and social effects by eliminating the use of synthetic inputs, such as noxious fertilizers and pesticides, veterinary drugs, genetically modified seeds and breeds, preservatives, additives and irradiation. It encompasses a holistic approach with conservation agriculture that maintains and increase long-term soil fertility and prevents pest and diseases. At present organic food contributes to only 1-2% of global food market, but the market is expanding with Europe as the leader of the organic food production. Figure 1 shows some of the components of organic farming system like vermin-composting and integrative farming. Organic farming with its environmental friendly advantages is a favorable mitigation option for climate change. Some of the characteristic benefits are summarized below (IFOAM, 2009):

1. The organic agriculture thus helps in protecting the long term fertility of soils by maintaining organic matter levels and encouraging soil biological activity.
2. The Nitrogen self-sufficiency is achieved through the use of legumes and effective recycling of organic materials like crop residues and livestock manures
3. The biomass acts as a substitute for fossil fuel either directly as a crop or as processing slurry in biogas.
4. The Carbon Capture can further be increased in organic farming systems by integrated approach like planting shade trees in between plantation crops or in croplands, trees as living fences (integration of

hedgerows and pastures into farming systems), fuel wood plantation etc.

5. The weed, disease and pest management involves crop rotations, natural predators (biocontrol), diversity (mixed cropping, crop rotation etc.), organic manuring, use of resistant varieties and minimal thermal, biological and chemical intervention.
6. The extensive management of livestock, paying full regard to their evolutionary adaptations, behavioral needs and animal welfare issues with respect to nutrition, housing, health, breeding and rearing.
7. Clean Development Mechanisms (CDM) approach for compost production is a new methodology intervention in organic production which involves:-
8. Capturing Organic Wastes- Nutrient recycling leading to carbon sequestration.
9. Maintaining soil dynamics- Aerobic compost production and application (capturing N_2O/Soil carbon on farms in a consistent way). Thus nitrate leaching in soil is minimized.
10. Capturing the soil carbon in the institutional framework
11. Adding biomass burning to baseline which again generates sustainable carbon credits
12. Fertilizer Management -Avoidance of synthetic fertilizer, Increased use of compost and mulch

4.2. Certified organic and labeling of organic products

Certified organic products are those which have been produced, processed, packaged and handled according to the precise specifications and certified as "organic" by a certification body. Organic products have wide market potentials (Figure 2).An organic label shows that a product has been certified as “organic”, specific standards that it complies and the name of the certification body. Certification bodies assess the processes according to different organic standards and can be formally recognized by more than one authoritative body. For example in EU, the label bears the standard list of ingredients and nutritional value figures, the name of the producer, processor or distributor who handled the item. The name or the code number of the national certification authority should also be on the label. Many certification bodies can be private and originate in developed countries. At the global level the FAO/WHO Codex Alimentarius Commission (the inter-governmental body that sets standards for all foods) has produced a set of guidelines for production, processing, labeling and marketing of organically produced foods to guide producers and protect consumers.

4.3. Relevance and status of organic farming in India

India has traditionally practiced organic farming but during late 1950s through 1960s India went through “green revolution” through the introduction of high yielding crop varieties, modern agricultural techniques, chemical fertilizers and pesticides. This led to increase in food production and made India self-sufficient to feed its growing population. It also addressed lot of problems associated with agriculture in India like frequent famines, irrigation, consolidation of land holdings, and improved rural infrastructure. In recent years, however, limitations

Fig.: Markets for organic products.

of such agricultural practices have become more apparent. Due to the rise in use of chemical pesticides and fertilizers there were negative effects on the soil and the land, such as land degradation. This combined with rising environmental awareness has led to renewed interest in organic agriculture.

In 2001, Government of India encouraged the promotion of organic farming using organic and bio-inputs and integrated pest management (IPM) practices in its 10th Five-Year Plan. Presently, many government departments at both central and state levels as well as private agencies are involved in the promotion of organic farming in India. The Government of India has also launched the National Programme for Organic Production (NPOP) in the year 2001. The NPOP follows standards for production and accreditation system recognized by the European Commission and the United States Department of Agriculture (USDA). The importing countries accept Indian organic products, which are duly certified by accredited certification bodies of India (European Commission, 2006).

India holds 33rd rank in terms of total land under organic cultivation and 88th in agricultural land under organic crops to total farming area. According to the Agricultural and Processed Food Product Export Development Authority (APEDA), the cultivated land under certification is around 2.8 M ha (2007-08), which includes one million hectares under cultivation and the rest is under forest area. One quarter of this land is traditionally cultivated without using chemical fertilizers and could be eligible for certification under the current practices. **The *states of Uttarakhand* and *Sikkim* have declared their states as ‘organic states’**. Gujrat has been successful in organic production of certain fruits like chickoo, banana and coconut. The Government of Karnataka released a state organic farming policy in

2004. States like Rajasthan, Tamil Nadu, Kerala, Madhya Pradesh, Himachal Pradesh and Gujarat are also promoting organic farming in a robust way. Andhra Pradesh has been a pioneer in sustainable agricultural practices. In early 1980s, Deccan Development Society (DDS) - an internationally well-known NGO working with dalit women groups, has developed a farm on the principles of Permaculture in Zaheerabad region of deccan area. In 2009, there were 50 villages in AP, which had become pesticide free and 7 villages, which have become completely organic.

5. CONCLUSIONS

It is quite clear that transition to Organic Farming could be a viable way of reducing energy use and GHGs emissions. Since Organic Farming considerably lowers OFF-SITE (INDIRECT) energy consumption it has strong mitigation potential. Organic agriculture performs better than other production systems on a per hectare scale. However, the organic production can be increased by making it popular and economically attractive. This can be achieved by subsidizing organic farming, encouraging research on land management and soil conservation techniques, taxing NPK fertilizers. Organic farming also has social benefits of employment & better revenue generation over conventional farming as it is more labor intensive and low machine intensive. Still significant energy use of fuels on-site need to be addressed by organic farmers. Organic farming system has many pros and cons such as listed below:

Pros

Organic farming produces same crop variants by employing use of green manure, no-till, intercropping and crop rotation. This helps to enrich damage soil and prevent soil erosion.

It needs less water, fertilizers, and artificial pesticides hence more economical and profitable compared to other farming techniques.

Organic food is nutrient rich since it is less contaminated with artificial pesticides. This also helps in retaining soil organisms and insects, which increase biodiversity of the system.

Organic farming is environment friendly, non-toxic and gives more employment to farmers as it involves manual weeding, spraying and manure.

Cons

There are several skeptics that argue about sustainability of organic farming and about its ability to feed the world.

Organic farming gives small yields compared to conventional farming methods.

It does reduce CO2 emissions, but there is no drastic contribution

It caters to only small consumer group and is expensive

Most of these arguments are from proponents of industrialized agriculture who dismiss the long-term impact of soil infertility and on human health. Efforts to popularize organic farming and make it mainstream could help in making it more accessible to more people. Longitudinal studies need to be done to access the long-term effect on greenhouse gas emissions. The major reasons for shift towards organic farming include sustained soil fertility, reduced cost of cultivation, higher quality of produce, sustained yields, easy availability of farm inputs and reduced attacks of pest and diseases. The move from conventional to organic farming has not been easy for the farmers. Some of these problems are lack of storage facility and nonpayment of premium price for these products (Lanting, 2007). Government can help out by providing support in the early years to make the transition over to organic farming by providing loans and strengthening rural banking systems. This could also help reduce the dropout rate. India´s wide diversity in climate and ecosystem endows it with various types of naturally viable organic form of nutrients across different regions of the country, which will be helpful in organic cultivation of crops (Butterworth et al., 2003; Reddy, 2010). India already has a strong traditional farming system with innovative farmers, vast drylands and least use of chemicals. Infact, the rainfed tribal, north-east and hilly regions of the country where negligible chemicals are used in agriculture, have been practising subsistence agriculture for a long period.

REFERENCES

1. Butterworth, J., Adolph, B., Reddy, S. B., 2003. How Farmers Manage Soil Fertility. A Guide to Support Innovation and Livelihoods. Andhra Pradesh Rural Livelihoods Programme, Hyderabad /Chattam: Natural Resources Institute, UK.
2. European Commission, 2006. Environmental impact of products: Analysis of life-cycle environmental impacts. Technical report EUR 22284. Brussels.
3. FAO, 2009. Low GHG agriculture. Food and Agriculture Organization of the United Nations. Rome, 2009.
4. Glover, J.D., Cox, C.M., Reganold, J.P., 2007. Future Farming: A Return to Roots? Scientific American, 297, 82-89
5. Glover, J.D., Reganold, J.P., Bell, L.W., Borevitz, J., Brummer, E.C., Buckler, E.S., Cox, C.M., Cox, T.S., Crews, T.E., Culman, S.W., DeHaan, L.R., Eriksson, D., Gill, B.S., Holland, J., Hu, F., Hulke, B.S., Ibrahim, A.M.H., Jackson, W., Jones, S.S., Murray, S.C., Paterson, A.H., Ploschuk, E., Sacks, E.J., Snapp, S., Tao, D., Van Tassel, D.L., Wade, L.J., Wyse, D.L., Xu, Y., 2010. Increased food and ecosystem security via perennial grains. Science 328, 1638-1639.
6. Gomiero, T., Paoletti, M. G., Pimentel, D., 2008 . Energy and Environmental Issues in Organic and Conventional Agriculture. Critical Reviews in Plant Sciences, 27(4), 239-254
7. Hoffmann, U., 2011. Assuring food security in developing countries under the challenges of climate change: Key trade and development issues of a profound development in agriculture. Discussion Paper No. 201, UNCTAD, February 2011.
8. IFOAM, 2009. The contribution of Organic Agriculture to climate change Mitigation. A document prepared by International federation of Organic agriculture movements

(EU group) comprising global organic survey 2009 and various case studies (From: www.ifoam-eu.org, accessed on Feburary 28, 2015).
9. Lanting, H., 2007. Building a farmers owned company (Chetana) producing and trading fair trade–Organic products, Proceedings of the National Workshop on New Paradigm for Rainfed Farming, published by WASSAN, New Delhi.
10. Lehmann, J., Graunt, J., Rondon, M., 2006. Bio-char sequestration in terrestrial ecosystems – A review. Mitigation and Adaptation Strategies for Global Change, 403-427.
11. Reddy, S.B., 2010. Organic Farming: Status, Issues and Prospects – A Review. Agricultural Economics Research Review, 23: 343-358.
12. Scherr, S.J., Sthapit, S., 2009. Mitigating Climate Change Through Food and Land Use. Ecoagriculture Partners and Worldwatch Institute. Worldwatch Report 179.
13. Smith, P.D., Martino, Z., Cai, D., Gwary, H., Janzen, P. ,Kumar, B., McCarl, S., Ogle, F., O'Mara, C., Rice, B., Scholes, O., Sirotenko, 2007. Agriculture. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA
14. Stern, N., 2006. Review on the economics of climate change London HM Treasury.
15. Wood, R., Lenzen, M., Lundie, S., 2006. A comparative study of some environmental impacts of conventional and organic farming in Australia. Agricultural Systems 89: 324-348
16. Wright, J., 2010. Feeding nine billion in a low emissions economy. A review for the Overseas Development Institute and Oxfam.

Web References:

1. http://appinsys.com/globalwarming/GW_5GH_CO2Sources.htm. Accessed on 8th April, 2015.
2. http://www.un-redd.org. Accessed on 8th April, 2015.
3. www.fao.org. Accessed on 8th April, 2015.
4. Climate Change. The IPCC impacts assessment. The report of the working group II of the Intergovermental panel on climate change. (https://www.ipcc.ch/ipccreports/far/wg_II/ipcc_far_wg_II_full_report.pdf, Accessed on 28th February, 2015).

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Green House Effect Reduction by Recovering Energy From Municipal Solidwaste Landfills

Anshu Gupta* and Paulraj R
School of Environmental Sciences (SES), Jawaharlal Nehru University (JNU), New Delhi-110067
***Corresponding author**: *anshu.guptaevs@gmail.com*

Abstract— Landfills around the world are one of the major contributors of global warming and climate change. In developing countries like India, municipal solid waste (MSW) generation is increasing enormously and the waste generated is landfilled in open dumping non-engineered sites. Although landfilling should be the last option in the hierarchy of waste management due to high green house gas (GHG) emissions but still due to its economics, it is still very common around the world. Carbon dioxide, methane, nitrous-oxide are the major GHG's which are emitted from the landfill areas and add significantly to global warming. Methane emissions from landfill are estimated to account for 3-19% of the anthropogenic sources in the world. The global warming potential of methane is 21 times more than that of CO_2 and it has the highest generation (40%-60%) than other gases. At present GHG emission from non-engineered landfills remains a big issue for MSW management in India. The landfill gas utilization as energy resource is not well studied and practiced in India. Where as a large number of studies are available in western countries on landfill gas utilization as renewable energy resource. Therefore, there is a concern for the utilization of CH_4 from the landfill areas. Need to plan, construct a engineered landfill site from where GHG can be trapped and used as a green source of energy as it is done in most of the developed countries which will further reduce the green house effect to some extent.

Keywords: Municipal Solidwaste, Non-engineered Landfills, Green House Gases (GHG's)

1. Introduction

India is one of the most rapidly developing countries in the world. Rapid development of India is not just pressing hard upon its resources but forcing expenditures on the same. Generation of municipal solid waste (MSW) is one of the neglected side effects of this developmental process. Per capita generation of solid waste in India having population of 1.2 billion is 0.5 Kg which leads to a huge pile of waste (Kalyani and Pandey 2014). Landfilling of MSW is one of the cheapest and common methods for waste management in many parts of the world (Jhamnani and Singh, 2009). India generates about 50 million tons of MSW every year from various cities and towns (CPCB, 2005). The typical composition of MSW in India is around 40-60% of organic waste, 30-40% of earthen materials, paper, metals, plastics, leather etc (Ranjan and Ramanathan, 2014). Every city in India has one or two MSW disposal landfills. Most of these landfills in metro cities are operational since more than 10 years or more. The municipal solid waste disposal in most of the landfills is done without segregation so it contains large amount of valuable materials in it (Ranjan and Ramanathan, 2014). Methane gas liberating from landfill is a serious threat to our environment. Methane emission from landfill is estimated to account for 3–19% of the anthropogenic sources in the world. Methane is the second largest contributor to global warming among anthropogenic greenhouse gases, after carbon dioxide. The global warming potential of methane (over a 100 year time horizon) is 21 times greater than that of carbon dioxide. However, due to its shorter atmospheric lifetime (of 12 years), it is estimated that global emissions would only need to be reduced by about 8% from the current levels to stabilise methane concentrations at current levels (IPCC, 1996). Thus, this paper discusses waste to energy as a solution to both Green House Gas (GHG), using which not only can we reduce the amount of waste, but also produce energy from the same, thus achieving our goal of waste management as well as energy security.

2. LANDFILL GAS (LFG)

Landfill gas, a mix of primarily CO_2 and CH_4, is emitted as a result of the restricted availability of oxygen during the decomposition of organic fraction of waste in landfills. Methane emissions from open dumping and improper landfilling of municipal solid waste (MSW) contribute to 3–19% of the anthropogenic sources in the world (Rawat and Ramanathan, 2011). The reduction of CH_4 emissions from landfills would make a significant contribution to the curtailment of greenhouse gas stock (Talyan et al 2007). LFG is produced by the natural anaerobic (oxygen free) decomposition of organic matter in MSW; typically methane (CH_4) and carbon dioxide (CO_2) comprise 99% of LFG, with trace gases including carbon monoxide, hydrogen, nitrogen and oxygen.

3. Green House effect and Landfills

Landfilling has been used as the most economic method of refuse disposal. The organic components in landfill refuse result in GHG emission by microbial decomposition under anaerobic conditions (Rawat and Ramanathan, 2011). Since methane is a potentially explosive gas, and is a more effective greenhouse gas, it has to be controlled at each landfill. Landfills could become major source of atmospheric methane (Kreileman and Bouwman, 1994). Methane at its current atmospheric concentration of 1.7 ppmv accounts for about 15% of anthropogenic green house effect and the atmospheric concentration of Methane is on the increase (Dickinson and Cicerove, 1986; Rawat and Ramanathan, 2011). The approximate estimate of increase of global methane emission from landfill is 30 million tonn/yr. Most of this CH_4 comes from the developed countries, where the level of waste generation per capita is high (Gurjar et al 2004). Thus waste to energy as a solution to Green House Gas (GHG) not only can reduce the amount of waste, but also produce energy from the same, thus achieving our goal of waste management as well as energy security.

4. Methane as an Energy Resource

The methane gas utilization as a energy resource is not well studied and practiced in India. Where as a large number of studies are available in western countries on landfill gas utilization as a renewable resource (Rawat and Ramanathan, 2011). Experiences in many countries of the world show that LFG can be successfully used to replace other energy sources.

The largest number of landfills that recovered biogas or landfill gas existed in US followed by Germany and UK (Themelis and Ullor, 2007). The fuel generated through landfill gas has the capacity ranging from 0.3-4 MW. The highest biogas plant in the world is at Puente Hills Landfill, close to Los-Angeles California, the biogas is collected and combusted in a steam boiler that boils powers a 50 MW turbine generator (California Energy Commission, 2002).

According to MNRE (Ministry of New and Renewable Energy), India has an estimated potential of 1460 MW of power from MSW generated. It has also estimated that approximately 55 MT of MSW are generated in urban areas of India every year and it will increase annually at a rate of 1-1.33%. In this regard waste to energy provides the best solution.

5. Conclusion

Recovering energy from landfills can not only mitigate green house effect by trapping methane which is a potential GHG, but it will also lower the burden on fossil fuels for power generation. This would also lead to landfill management by shifting the open dumps to sustainable landfills which would reduce the effects on water and air also. Waste to energy provides a solution towards complying with government regulations and achieving integrated soild waste management.

References

1. California Energy Commission. Landfill gas-to-energy potential in California; 2002; http://www.energy.ca.gov/reports/2002-09-09_500-02-041V1.
2. CPCB (Central Pollution Control Board), Management of Municipal Solid Wastes, 2005. Details available at http://cpcb.nic.in/pcpdiv_plan4.htm.
3. Dickinson, R. E., and Cicerone, R. J. 1986. Future Global Warming from Atmospheric Trace Gases, Nature, 319,109-115.
4. Gurjar, B. R., Aardenne, J. A. V., Lelieveld, J., and Mohan, M.2004 .Emission Estimates and Trends (1990-2000) for Megacity Delhi and Implications. Atmospheric Environment, 38(33), 5663-5681.
5. IPCC, 1996. IPCC Guidelines for National Greenhouse Gas Inventions: Reference Manual. National Physical Laboratory, New Delhi, India, 6-15.
6. Jhamnani, B. And Singh, S. K. 2009. Groundwater Contamination due to Bhalasawa Landfill site in New Delhi. International Journal of civil Engineering and Environment, 3, 121-125.
7. Kalyani, K. A., & Pandey, K. K.. 2014. Waste to energy status in India: A short review. *Renewable and sustainable energy reviews*, *31*, 113-120.
8. Kreileman, G. J. J., and Bouwman, A. E.1994.Computing Land Use Emission of Greenhouse Gases. Water, Air and Soil Pollution, 76(1-2), 231-258.
9. Ranjan, M. R., and Ramanathan, A. L. 2014. Landfill mining: a case study from Ghazipur landfill area of Delhi. International Journal of Environmental Sciences, 4(5).
10. Rawat, M., & Ramanathan, A. L. 2011. Assessment of methane flux from municipal solid waste (MSW) landfill areas of Delhi, India. Journal of Environmental Protection, 2(04), 399.
11. Rodhe, H. 1990. A Comparison of the Contribution of Various Gases to the Greenhouse Effect. Science, 248 (4960), 1217-1219.
12. Talyan, V., Dahiya, R. P., & Sreekrishnan, T. R. (2008). State of municipal solid waste management in Delhi, the capital of India. *Waste Management*, *28*(7), 1276-1287.
13. Themelis, N. J., & Ulloa, P. A. 2007. Methane generation in landfills. Renewable Energy, 32(7), 1243-1257.

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Development and Validation of ICT for Youth Empowerment towards Efficient Energy Management: A Step towards Climate Change Mitigation through Sustainable Resource Use

Gagan Preet Kaur*[1], Puja Gupta[1] and Matt Syal[2]
[1]Dept. of Resource Management and Design Application, Lady Irwin College,
University of Delhi, Delhi, India
[2]School of Planning, Design and Construction, Michigan State University, USA
***Corresponding author:** *gaganpreet66@gmail.com*

Abstract— India is currently facing a mismatch between demand and supply to the tune of 8.5%. Education with Information, Communication and Technology (ICT) strategies towards efficient use of resources such as energy will guides us on our journey towards the goal of climate change abatement and sustainable development. The study involves designing a need-based capacity building programme and administering it to the sample, the goal is to measure the enhancement of knowledge regarding energy management and energy auditing skills, pre and post intervention. Energy Management was studied in terms of climate change, energy related carbon emissions, energy conservation practices, energy efficient appliances and energy audit. The sample constitutes 470 students from Public school, Government and students from colleges of selected Universities in Delhi.
Firstly, the paper will discuss curriculum analysis, which was done to appraise the inclusion of information on energy management in school and college curriculum, followed by pre intervention outcomes with respect to sample's knowledge towards climate change, energy management and energy auditing skills. The paper also discusses strategies used in designing and administration of the capacity building programme. The capacity building programme comprises of capacity building aids blended with educational technology in an information-sharing mode of instruction. Capacity Building programme aims to make the sample understand the implications of their actions – both positive and negative; enabling them to make informed choices in the future.

Keywords: Youth, Energy Management, Capacity Building, Climate Change, ICT strategies

1. Introduction

Sustainability is the ability to maintain balance of a certain process or state in any system. Resources such as water, energy, forests, mineral etc. are backbone of every economy and provide two basic functions – raw materials for production of goods and services, and environment services. Recycling, reducing waste generation, and conservation of valuable resources are our best hopes so that our ecosystems will still be capable of providing for the generations to come (European Commission, 2002). Energy is central to sustainable development and poverty reduction efforts. It affects all aspects of development -- social, economic, and environmental -- including livelihoods, access to water, agricultural productivity, health, population levels, education, and gender-related issues (United Nations Development Programme[UNDP],2013). It is the prime mover of economic growth and is vital to the sustenance of a modern economy. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible and environmentally friendly (Ram and Selvaraj, 2013). The global demand for energy is rising fast as the population increases and developing countries such as China and India are undergoing dramatic economic growth. The world's energy needs are estimated to be 50% higher in 2030 than they are today (ElBaradei, 2008).

Adolescents" is best understood as a period of transition from the dependence of childhood to adulthood's independence and awareness of our interdependence as members of a community. They are the main stakeholders, future policy makers and a major resource group playing an important role in taking up responsibilities, revolutionizing the other stakeholders, acting as a catalyst for bringing about change. These future leaders have immense potential to mobilize the masses, be adaptable and a link education and action, besides being responsible consumers (Centre for Environment Education [CEE], 2005). The participation of youth in environmental protection can be sought at levels and locations ranging from grass-roots activism and participation in conservation projects to policy-making bodies and NGOs.

Education for sustainable development is a dynamic concept that utilizes all aspects of public awareness, education, training and capacity building to create or enhance an understanding of the linkages among the issues of sustainable development (CEE, 2005). For building momentum towards energy management movement, it thus becomes imperative to build capacity of masses so that they are capable of making decision and taking appropriate steps towards the implementation of suitable energy efficiency measures. According to the Population Council in India, (2012), "India is a young nation with 30% of the country's population being adolescents". High proportion of a young population, could work in India's favour of emerging as one of the four major economies of the world by the year 2020. Their energy and enthusiasm must be guided into productive work. Their ideas and innovations should be tapped for the betterment of the society (President of India Forum, 2010). Building capacity of adolescents may help to reach next four generation, the message to conserve and protect the nature. Thus, towards this end present research has been undertaken.

1.1 Objective

- To assess the inclusion of information on energy management offered in school and college curriculum.
- To assess the knowledge and skills of adolescents towards energy management
- To develop a validated capacity building programme towards energy management for adolescents.

2. MATERIAL AND METHODS

The sample constitutes students from Public school, Government and students from colleges of selected Universities in Delhi. Delhi being a metropolitan city is the educational capital of the country and houses a number of private and government universities attended by students with myriads of background, coming from all over the country and even nationals of other countries and cultures. The knowledge-testing questionnaire was administered to the students to understand their knowledge level. The tool covered the knowledge testing of respondents regarding the following concepts; sustainable development, climate change, energy conservation and energy audit. The data procured was coded, scored and tabulated in accordance with a pre-decided pattern; this was done to calculate scores and comparative data to lead to results and conclusions. The data was analyzed using Microsoft Excel Software. Mean and standard deviation were also used to support the analysis. Pie Charts and Graphs were used to represent the study findings.

3. RESULTS AND DISCUSSION

3.1 Curriculum analysis

Curriculum analysis was done to assess the curriculum of sample. The analysis was done to by taking views from 75 teachers in 28 schools and colleges. The curriculum was assessed with respect to inclusion of energy management, tools and aids used to teach energy and related issues, most preferred and liked method of teaching method.

It was seen that emphasis on energy crisis, energy conservation and efficiency and linking energy use to climate change is seen to be low in school and college curriculum as seen as only 23% responses were obtained for energy crisis and 26.4% on energy and its science and only 15% responses for energy conservation (Fig. 1)

Majority (43.9%) students expressed that information on environment was moderately sufficient. A Large section (29%) found the information to be insufficient. Majority (60%) expressed they found information on energy in curriculum to be insufficient. Also majority 67% indicated that activities on energy/environment were insufficient. A Large number (41%) of responses were obtained for student's projects as the most preferred activities spearheaded in their school and college. A large number of (61%) responses in public school indicated that workshop and seminar were held. However, games, quizzes and activities obtained very low (11.9%) responses. The initiatives taken in Government schools and college were seen to be very low. Majority (62%) responses were obtained for games, quizzes and activities for being the most popular and liked learning method. Workshops and seminars also obtained large (53%) number responses for workshops and seminars. Less (21% and 15%) number of responses were obtained for eco club activities and student projects.

Majority responses (61.1%) from public school respondents expressed that AV aids was used widely as indicated by Fig 2. However in none of the government schools AV aids was being used. Only 30% responses were obtained for use of AV aid in colleges. Another large (61.1.6%) section of responses was obtained for lecture only. Use of tools and aids was seen to be low for Government school and colleges.

3.2 Knowledge level of participants:

3.2.1 Knowledge regarding basics of energy Conservation and Efficiency

It was observed that 53.8% and 46.6% of respondents could identify the correct meaning of energy conservation and energy efficiency. The participants were asked to classify the given actions in to energy conservation and energy efficiency. It was seen, in test 62.3% correct responses were obtained for 'Switching off lights when not in use' and 50.6% for 'Opening the windows in summer instead of turning on the air conditioning' identifying them as energy conservation. For rest of the categories less than 30% correct answers were obtained. It was observed although participants knew the meaning of energy efficiency and energy conservation; they could not differentiate between both terms.

Fig 1: Distribution of sample with respect to inclusion of topics on energy issues in course (N=75)

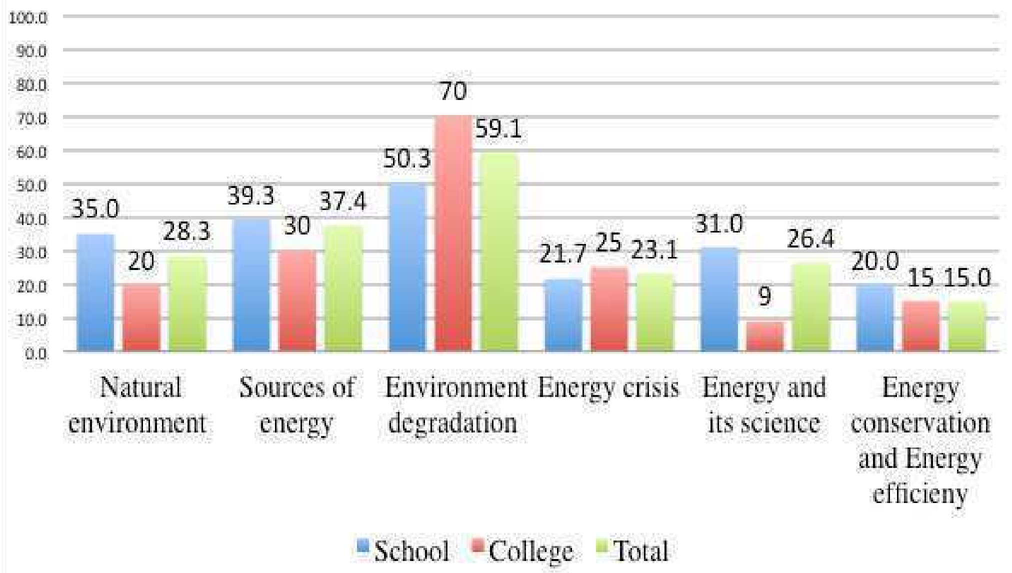
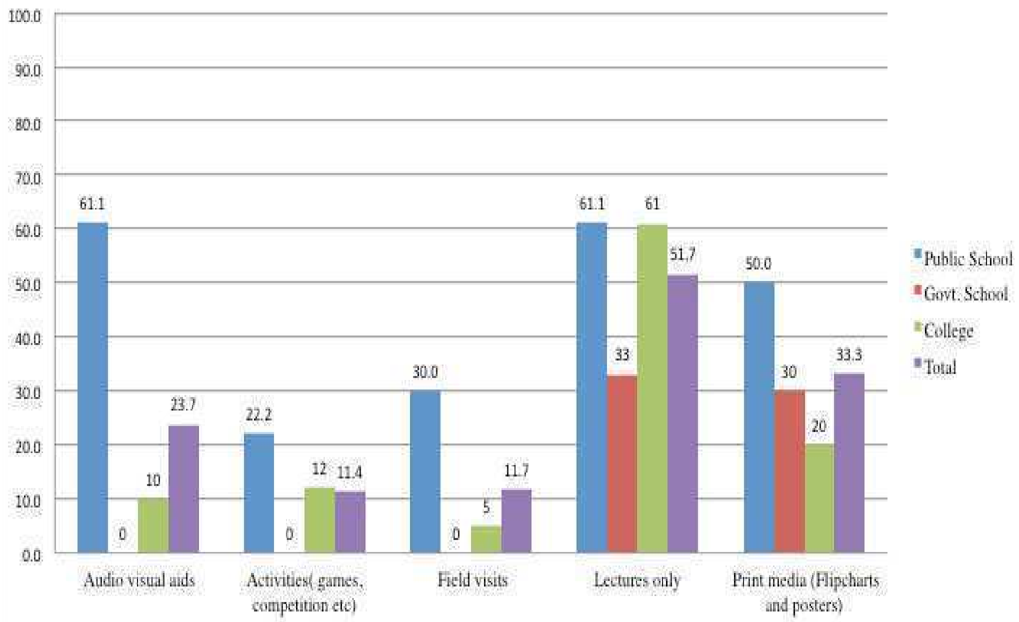


Fig 2: Distribution of sample with respect to teaching tools and aids used at classroom level while addressing energy issues (N=49)



*Total percentage is greater than 100 because more than one option was available

3.2.2 Knowledge regarding energy efficient appliances and practices

The pretest revealed that only 22% and 17% could identify LED and T5 lights to be the most energy efficient respectively. It was seen that majority 71% and 67% indicated CFL and T5 to be the most energy efficient lights respectively. It was surprising to know that most of the students were not aware about LED. Some also opined that it was very expensive as compared to other lighting fixture.

In test a large category (52%) opined that automatic controls lead to reduction in automatic controls. However when they asked to identify some types of automatic controls, merely 10% could name daylight sensors and another small section 7% and 6% indicated dimmers and occupancy sensors respectively. Respondents were asked to identify the meaning of term energy auditing. In pretest only 18% respondents identify the correct meaning. Half (50%) of respondents indicated energy auditing involved checking of energy efficient appliances in a building. Another section (23.3%) comprehended energy auditing to be purchasing energy efficient appliances. Some respondents expressed they had never heard of the term.

3.2.3 Knowledge regarding Electricity bill

It was seen only (26.2%) correct responses were obtained for unit of electricity. It was seen respondents were not very much aware about the electricity rates in the city. Nearly one third (35%) of the respondents identified Rs. 2.7. However, only a small section (13%) could ascertain the correct minimum price of electricity in Delhi. Similarly for maximum rate only 22% could ascertain the correct answer in test. In pretest only 14% knew about sanctioned load. The participants expressed they had not heard this term earlier. Also an attempt was made to ascertain the knowledge towards current electricity slab rates. This parameter obtained very low responses; only 8% could identify the correct slab rate.

3.2.4 Knowledge regarding concept of climate change and causes

It was seen that 35% of respondents knew the meaning of global warming and 30% had the understanding of the concept of green house effect. Responses obtained for identification of greenhouse gases was also seen to be low (4%-28%). Largest category (60%) of respondents answered that transportation led to maximum carbon emissions. A small section (8.3%) considered energy supply to be the sector with most carbon emissions. Respondents were also asked to list some anthropogenic causes of climate change. Very responses were obtained with deforestation being the largest category (22%) followed by use of private transport (17%). A small section (11%) expressed increased use of gadgets and electronics was also one of the causes.

3.2.5 Knowledge regarding concept mitigation and adaptation

In this category the respondents were asked to identify climate changes mitigation agency, only 9% could identify the agency. Knowledge regarding India's commitment to reduction was also seen to be very low (10%). However a considerable section (40%) knew the correct meaning of sustainable development.

The total score attainable in each category and the mean knowledge score attained by sample in each category was evaluated. The average percentage is seen to very low in categories – energy scenario and initiatives (17.29%), electricity bill (13.20%) and mitigation and adaptation (12.43%). This indicates that knowledge in these categories was very low. Also in all other categories average score percentage is seen to lower than 40%. The total Average parentage is computed to 26.34%

Table 1: Distribution of the sample indicating the knowledge scores (N = 470)

Test Scores		**Pre- Test**	**Pre Test (%)**
Very low	0-20	229	48.72
Low	21-40	153	32.55
Average	41-60	56	11.91
High	61-80	23	4.89
Very high	81 and above	9	1.91

The knowledge of youth regarding energy management is tested using a knowledge-testing questionnaire. Table 1 indicates, in pre test largest category (48.72%) of the respondents scored low on the knowledge test and another section of respondents (11.9%) scored average. It was seen small section 4.89% and 1.91% scored high and very high respectively on the knowledge test.

3.3 Skill Level of Participants

A skill-testing questionnaire was used to understand the skills of the sample towards energy management. Several skill-building activities such as: - energy auditing, calculating energy consumption and electricity bill, identifying BEE labels, calculating energy saved by installing energy efficient appliances, will be done during intervention. In pre test very few respondents (5.1%) could calculate the electricity consumption of the room. Only 5 of

the respondents (1.1%) could calculate the electricity bill. It was seen in government schools none of the participants could calculate energy consumption and electricity bill.
The participants revealed that they were excited to learn energy audit calculations and was keen to experiment with more and more sample studies to find solutions for energy savings.

Table 2: Distribution of the sample indicating the Skill test scores of sample (N = 470)

Test Scores	Sample	Percentage
Very low (0-4)	293	62.34
Low (5-9)	151	32.13
Average (10-14)	21	4.47
High (15-20)	5	1.06

Skill test pre-test scores were calculated to understand the skill level of sample before intervention. Table indicates majority (62.34%) scored very low and another large section (32.13%) scored low. A very small section (1.6%) scored high on the skill test.

3.4 Training Programme

Intervention will be a capacity building programme, consisting of awareness raising training modules, which will be assisted with comprehensive tools. The training programme developed is discussed with respect to its content design strategy and delivery.

3.4.1 Design Strategy

Based on the pre assessment results and review of literature the capacity programmes have helped the researcher to identify the following strategy.
The ADDIE model is a systematic instructional design model consisting of five phases: (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation.

- Analysis: During analysis the learning problem, the goals and objectives, the audience's needs, existing knowledge, and any other relevant characteristics will be identified. Analysis will also consider the learning environment, any constraints, the delivery options, and the timeline for the project.

- Design: Detailed prototypes will be prepared and field-tested. Also, suggestions will be sought from experts on the same.

- Development: The actual creation (production) of the content and learning materials will be done in this phase

- Implementation: During implementation, the plan is put into action and a procedure for training the learner and trainer is developed. Materials are delivered or distributed to the student group. After delivery, the effectiveness of the training materials will be evaluated.

- Evaluation: Appraisal of the capacity building programme will be done.

3.4.2 Delivery of training programme

The training program will be framed into 3 elements:

- Introduction – The respondents were made familiar with the subject matter though informal discussions and presentations.
- Content – the subject matter was delivered using various tools which include
  - Presentations and videos
  - Session summary Handouts
  - Pamphlets
  - Training manual
- Recapitulation – Recapitulation was recognized an essential part of training programme. It was administered with purpose to help respondents to recapitulate the content at the end of each session. For this, recapitulation exercises were developed for each session.

Interactive media such as technology based learning (mobile application, game), simulatiton excercises, multimedia, lectures and group discussions, training material like newsletter, manuals, activities etc. is being used motivate youth to integrate energy conservation and efficiency in their everyday life.

4. CONCLUSION

The present study dealt with assessing the awareness amongst adolescents regarding energy conservation with a goal to design and validate the capacity building program, which can be used as a tool to train adolescents across the country. The study involved conducting curriculum analysis to assess the inclusion of information on energy management. It was seen that inclusion of information on energy management was insufficient and very less initiatives were spearheaded by government school and college to promote sustainability and energy efficiency. A knowledge and skill questionnaire was administered to youth targeting issues of paramount importance i.e., sustainable development, climate change, energy conservation and energy audit; the ultimate aim was to comprehend the knowledge and understanding of students towards energy conservation and energy auditing. The paper presents the prevalent awareness and application level of the sample, which was found to be inadequate, and is seen as the first roadblock to overcome as change in behavior can only be based on existing knowledge and understanding in the group. Based on this criteria capacity building and training programme can be developed to generate awareness not only among adolescents, but also other stakeholders.

The capacity building program can be a small input affecting a goal of paramount importance. Developing such need based awareness generating modules which aid in enhancing targeted knowledge base is a resource efficient measure to affect behavioral modifications in the citizens. Energy Conservation both supply side and demand side is dependent on acceptability by the consumers and a youth base which is aware about the implications of the choices will act as an asset for reaching the goal of sustainable development through energy conservation; by increasing demand and affecting supply side conservation in the near future.

There is need to incorporate energy conservation in the value system of the country and capacity building of youth towards energy conservation and related concepts will be a leap towards the right direction.

REFERENCES

1. EE, 2005 *Education for Youth*. Retreived from: http://www.ceeindia.org/cee/youth.html
2. ElBaradei, M 2008. *A Global Agency Needed for Energy Crisis*. Retrieved December 26, 2013 from *http://www.iaea.org/newscenter/transcripts/2008/ft240708.html*
3. European commission. 2002, *Sustainable Development*. Retreived from: http://www.epa.gov/region09/waste/solid/reduce.html
4. Population Council of India, 2012. *Youth in India: Situation and Needs Study.* Retrieved from: http://www.popcouncil.org/projects/101_YouthInIndiaNeedsStudy.asp#/jQueryUITabs1-1
5. Ram, B., & Selvaraj. M. 2013, Entrepreneurship in the Environmentally Friendly and Economically Sound Renewable Energy Conversion System. *WSEAS Transactions on Environment and Development,* 8 (1), 13-22.
6. UNDP (2012), *Sustainable Energy.* Retrieved from: http://www.undp.org/content/undp/en/home/ourwork/environmentandenergy/focus_areas/sustainable-energy.html

Kapoor et al., 2015.
Proceedings of the National Conference on Climate Change: Impacts, Adaptation, Mitigation Scenario & Future Challenges In Indian Perspective, New Delhi, 2-3, March-2015. Pp. 49-52.
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Impact of Economic Activities on Climate Change

Vaishali Kapoor[1]*, Sugandha Poddar[2] and Deepansha[1]

[1]Deen Dayal Upadhyaya College, University of Delhi
[2]Economic Division, Department of Commerce, Ministry of Commerce and Industry

***Corresponding author:** *vaishali2489@gmail.com*

Abstract— This study uses Shapley decomposition technique to analyze the factor weights of select variables on carbon emissions for the period 1980-2011. The level of human activity may it be economic or non-economic, influence climate. In the recent times, there has been growing concerns on climate change since world is witnessing rise in CO_2 emissions. Rising carbon emissions-as explained by Kaya identity- could be due to three factors viz. increasing carbon intensity of economy, rising economic activity and increase in population. The factors responsible for carbon emissions by India, in descending order are: GDP per capita, Population and Carbon intensity of GDP. In the study, we found that India has witnessed reversal of rising trend of carbon intensity of GDP after 1990. Though India decarbonised i.e. experienced reduced carbon intensity of economy, movement of GDP sway carbon emissions.

Keywords: Kaya Identity, Shapley Decomposition, Carbon Intensity of Economy, Decarbonisation

1. INTRODUCTION

With the current trajectory of human activities being unsustainable, evident in the increased CO_2 atmospheric concentration from 280 ppm in the pre-industrial age to a 399.85ppm today (NOAA CO_2 data file dated Wednesday February 4, 2015), there is a question mark for who is to be held accountable for this widening difference. Such alterations are indicative of the change in climate as well. While environmental degradation is seen as an unavoidable cost of industrialisation, it is also a stumbling block in growth trajectories of a developing nation, like India (Das, 2007). There are evidences of decreasing marginal impacts of economic growth on carbon emissions with increasing average income (Ravallion, 2000). It can be said that countries face trade-off between climate control and national growth and development. Quantifying the relationship between income and CO_2emissions can also be analysed using environmental kuznets curve as done by Amy K. Richmond (2006) where he has used EKC to derive a relationship between GDP and energy use. A decomposition of total CO_2emissions over a number of contributing factors shed light on the importance of certain crucial parameters like GDP intensity of the ongoing decarbonisation of energy service or the rate of autonomous energy efficiency improvements- that are used in scenarios to calculate the possible cost of climate policy scenarios for developed (Albrecht, 2002) and developing countries as well. The need for both understanding and governance has been emerging for decades as demonstrated in UNFCC (1992) and Kyoto Protocol (1997). The time has passed by when the environmental degradation used to be widely associated with the developed and industrial economies and the pre-industrial technology of the developing countries used to be considered more environmentally benign. Now the developing countries are seen as culprits as their urge to grow and its materialization many a times at the cost of environment are making the global policy makers, researchers and environmentalists all over the world surprisingly more than ever concerned now about the relationship between economic growth and environmental degradation (Gupta, 2014). Various studies have addressed this important issue, both theoretically as well as empirically. (Stern, 2003, Deacon and Norman, 2004, Martinez-Zarzoso and

Table 1: Data and Data sources

Variables	Definition	Source
gdppc	Gross Domestic Product per capita, measured as $PPP	World Bank
pop	Total population	World Bank
co_2 intens	Carbon intensity using PPP, measured as (Metric Tons of Carbon Dioxide per Thousand Year 2005 U.S. Dollars)	US Energy Administration Information

India, the fifth largest carbon emitter in the world-accounting for 5% of global greenhouse gases- has volunteered to cut its emissions intensity of GDP by 20-25% by 2020 (New Energy Architecture, Executive Summary,2013). This high ranking is partly caused by the size of its population and economy, as per the Trends in global CO_2 emissions (-PBL Netherlands Environmental Assessment Agency, 2013). India has set off on a good course. Currently, the most important contributor to possible human-induced global warming is energy-related CO2, which is emitted during energy production and use. Therefore, nearly all recent integrated assessment models quantify future CO_2 emissions under various assumptions of future development (IPCC, 2014). To differentiate between the main drivers for energy-related CO_2 emissions, CO_2 emissions are often expressed with what is called the Kaya identity (Kaya, 1990) in terms of population, gross domestic product(GDP) per capita, energy intensity (primary energy per unit of GDP in a society), and carbon intensity (energy-related CO2 emissions per unit of primary energy used):

$$CO_2\ Emissions = Population \times \frac{GDP}{Population} \times \frac{Energy}{GDP} \times \frac{CO_2}{Energy}$$

Component growth rates are additive in identity (1).

For example, since the mid-nineteenth century, world energy-related CO_2 emissions have increased by about 1.7% per year. This growth rate can be roughly decomposed into a 1% growth in population, a 2% growth in GDP per capita, a 1% decline in energy intensity of world GDP, and a 0.3% decline in the carbon intensity of primary energy (SAR, 1996; Nakicenovic et al., 1993). In other words, in the past, population and average income have grown much faster than the energy efficiency and shifting in the economic, however switching to less carbon intensive energy fuels in the later phase (e.g. coal with the highest carbon content per unit of energy was replaced by oil, then by gas, and also by zero-carbon options such as wind.). This has led to ever-increasing energy-related global CO_2 emissions since the nineteenth century. Most likely, this trend will continue in the twenty-first century, provided no human intervention in the form of climate policies will occur.

2. METHODOLOGY

Rising carbon emissions-as explained by Kaya identity- could be due to three factors viz. increasing carbon intensity of economy, rising economic activity and increase in population. Carbon emissions are taken as product of Population, GDP per capita and Carbon Intensity of GDP (Raupach, 2007).

$$CO_2\,(F) = \text{Population}\,(P) \times \text{GDP per capita}\,(G) \times \text{Carbon intensity of GDP}\,(H)$$

Growth rates of population, GDP per capita and carbon intensity of GDP adds to the rate of growth of carbon emissions (Kaya, 1990).

$$r\,(F) = r\,(P) + r\,(G) + r\,(H)$$

Shapley decomposition technique is then applied to analyze the factor weights of select variables on carbon emissions for the period 1980-2011. Shapley decomposition indicates the marginal contribution of each regressor in explained variation. Shapley Decomposition technique decomposes the share of explained variation into contributions by each regressor. This technique uses concept of shapley value and hence results are robust in the sense that decomposition results aren't altered even when order of variables change. Decomposition techniques are widely used in decomposing IPAT equation by Sun (1996), Ang (2004) and others. The source of following variables for the period 1980-2011 is given in Table 1.

3. RESULTS

India has witnessed reversal of rising trend of carbon intensity of GDP after 1990 as can be seen in Figure 1. The variables are normalised at 1990 (value at 1990 is equal to 1). The values are normalised at year 1990 since it is only after formation of IPCCC that reforms are initiated by countries. Though India decarbonised i.e. experienced reduced carbon intensity of economy, movement of GDP sway carbon emissions.

Similar analysis for China, US, UK and total of all the countries (World) does not alter the results. Carbon intensity of economy has been on the downturn; though the speed of the fall (slope of Co2intens) varies. It is GDP and population of each economy that is leading to rising carbon emissions.

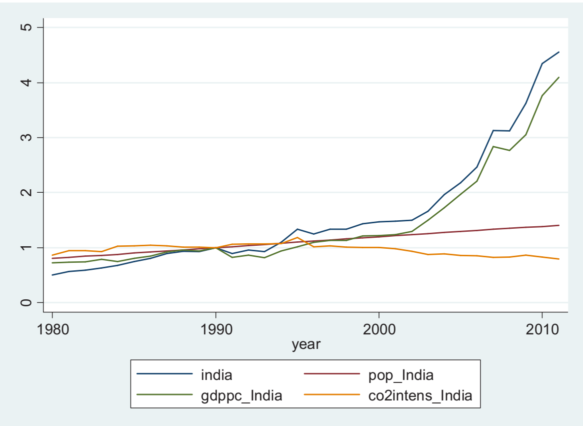

Figure 1: Carbon emissions and its factors for India

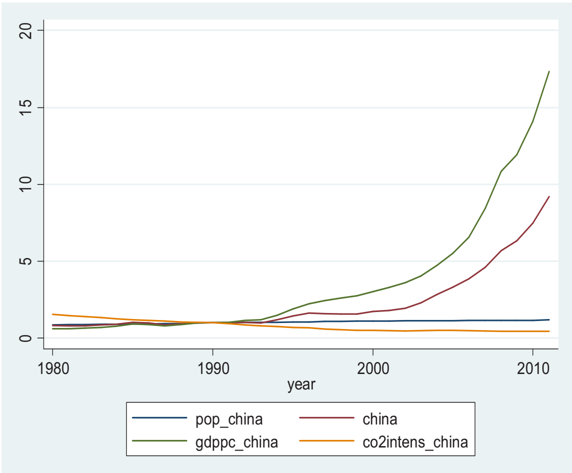

Figure 2: Carbon emissions and its factors for China

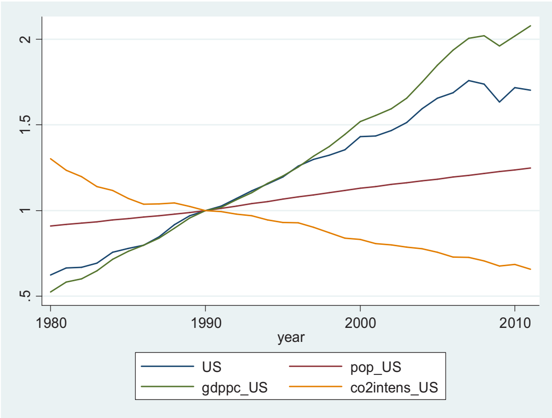

Figure 3: Carbon emissions and its factors for US

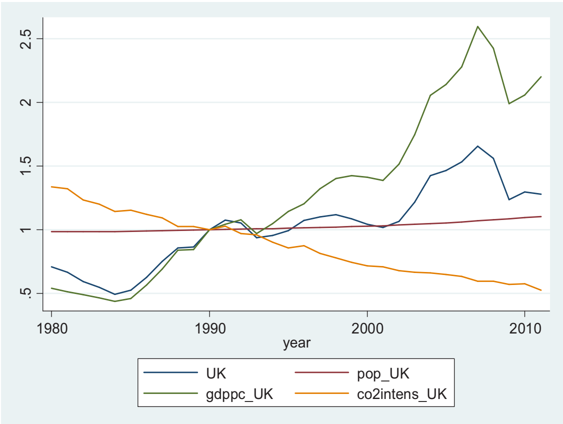

Figure 4: Carbon emissions and its factors for UK

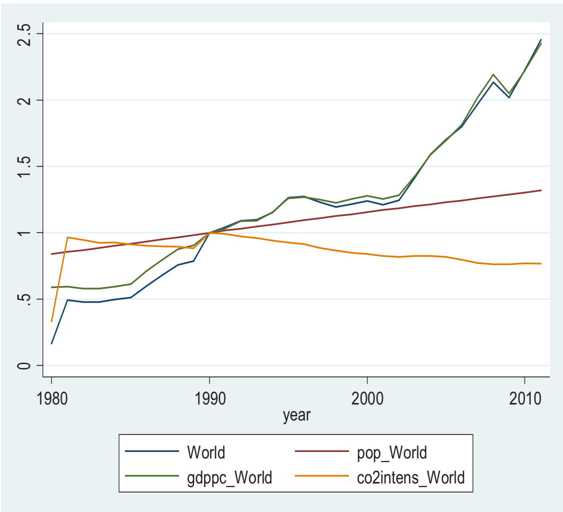

Figure 5: Carbon emissions and its factors for World

The Shapley decomposition results (presented in Table 2) show the contribution of each variable in explaining carbon emissions. The factors responsible for carbon emissions by India, in descending order are: GDP per capita, Population and Carbon intensity of GDP. If a cross country analysis is made, the major contributor, with varying degree of explained variation, remains GDP per capita. The result holds for all the countries viz. China, US, UK and even for the entire world. Carbon intensity explains the smallest portion of the total variation.

Table 2: Shapley decomposition results

Countries	Population	GDP per capita	Carbon intensity of GDP
India	40.7198	45.3911	13.8891
China	24.8701	50.7614	24.3685
UK	23.2485	48.5331	28.2184
US	32.9004	35.3455	31.754
World	39.0567	42.0972	18.8461

The entire study period of 1980-2011 is then divided into two overlapping reference periods i.e. 1980-1995 and 1990-2011. Then applying Shapley decomposition of carbon emissions for these two periods; makes clear that contribution of carbon intensity fell from 27.5% to less than 15% and at the same time GDP and Population's contribution increased. The results are shown in Figure 6 below.

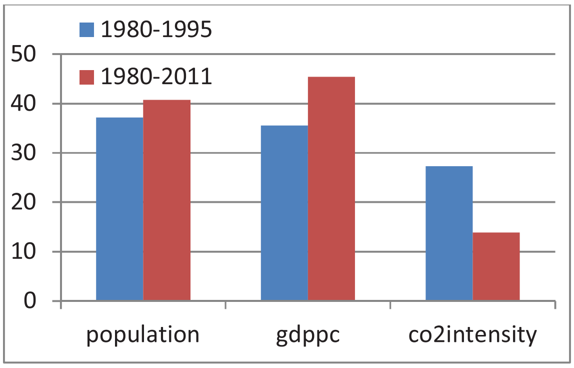

Figure 6: Shapley Decomposition of carbon emissions of India for two reference periods

4. CONCLUSIONS

Though India decarbonised i.e. experienced reduced carbon intensity of economy, movement of GDP sway carbon emissions. The result for India seems consistent since India is leading in services production since 1990s and per unit of GDP from services has smaller carbon intensity. Though India has low carbon footprint but India, being populous country and one amongst the fastest growing economy, requires transformations to address rising energy demands on account of GDP acceleration. Low carbon energy sources: solar power, nuclear power etc. should be adopted at a faster pace. But with the current adoption of 'Make in India', carbon emissions may witness a steady rise.

REFERENCES:

1. Vijaya Gupta and Utkarsh Yadav, (2014), Understanding CO2 Emissions in India: Going beyond GDP Per Capita, 5 th World Congress of Environmental and Resource Economists (WCERE 2014)
2. New Energy Architecture, Executive Summary,2013
   Sachs, Jeffery; 2006; Common Wealth: Economics for a crowded planet
   Samantak Das, Dripto Mukhopadhyaya and Sanjib Pohit; 2007; Role of Economics Instruments in Mitigating Carbon Emissions; An Indian Perspective; Economic and Political Weekly
3. Martin Ravallion, Mark Heil and Jyotsana Jalan; 2000; Carbon Emissions and Income Inequality; Oxford Economic Papers, Vol. 52
4. Yamaji, K., Matsuhashi, R., Nagata,Y., Kaya, Y., An Integrated System of CO2/ Energy/ GNP Analysis: Case studies on Economic Measure of CO2 Reduction in Japan. Workshop on CO2 Reduction and Removal: Measures for the Next Century,March 19, 1991, International Institute for Applied Systems Analysis, Laxenburg, Austria. Amy K. Richmond and Robert K. Kaufmann; 2006; Energy Prices and Turning Points: The Relationship between Income and Energy use/ Carbon Emissions; The Energy Journal
5. Grossman G M and Krueger A B. (1995), Economic growth and the environment, Quarterly Journal of Economics, 110, 353–377.
6. Harbaugh W, Levinson A, and Wilson D. (2000), Reexamining the Empirical Evidence for an Environmental Kuznets Curve [Working Paper 7711] Cambridge, MA: National Bureau of Economic Research.
7. Agras J and Chapman D. (1999), A dynamic approach to the Environmental Kuznets Curve hypothesis, Ecological Economics, 28(2): 267–277.
8. Busa Julianne H. Mills, (2013), Dynamite in the EKC tunnel? Inconsistencies in resource stock analysis under the environmental Kuznets curve hypothesis,Ecological Economics, 94, 116–126.
9. Caviglia-Harris Jill L, Chambers Dustin and, Kahn James R. (2009), Taking the "U" out of Kuznets A comprehensive analysis of the EKC and environmental degradation, Ecological Economics, 68, 1149–1159
10. Diao X.D., S.X. Zeng, C.M. Tam, Vivian W.Y. Tam, (2009), EKC analysis for studying economic growth and environmental quality: a case study in China, Journal of Cleaner Production, 17, 541–548.
11. Dinda S. (2004), A theoretical basis for the Environmental Kuznets Curve, Ecological Economics, 49(4), 431–455.
12. Focacci A. (2005), Empirical analysis of the environmental and energy policies in some developing countries using widely employed macroeconomic indicators:the cases of Brazil, China and India, Energy Policy, 33, 543–554.
13. Lantz V., Feng Q. (2006), Assessing income, population, and technology impacts on CO2 emissions in Canada: Where's the EKC?, Ecological Economics, 57 (2006) 229–238.
14. Lindmark M. (2002), An EKC-pattern in historical perspective: carbon dioxide emissions, technology, fuel prices and growth in Sweden 1870–1997, Ecological Economics, 42 , 333–347.
15. Martinez-Zarzoso I and Bengochea-Morancho A. (2003), Testing for an Environmental Kuznets Curve in Latin-American countries, Revista de Análisis Económico, 18(1): 3–26.
16. Miah Md. Danesh, Masum Md. Farhad Hossain, and Koike Masao, (2010), Global observation of EKC hypothesis for CO2, SOx and NOx emission: A policy understanding for climate change mitigation in Bangladesh, Energy Policy, 38, 4643–4651.
17. Stern D I. (2003), The Environmental Kuznets Curve, [International Society for Ecological Economics]
18. Sun J W. (1999), The nature of CO2 emission Kuznets Curve, Energy Policy, 27: 691– 694.
19. Tisdell C. (2001), Globalization and sustainability: Environmental Kuznets Curve and the WTO, Ecological Economics, 39(2): 185–196.
20. Diao X.D., S.X. Zeng, C.M. Tam, Vivian W.Y. Tam, (2009), EKC analysis for studying economic growth and environmental quality: a case study in China, Journal of Cleaner Production, 17, 541–548.

Sharma and Bhatia 2015.
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Food Security: An Infometric Analysis for Last 25 Years

Sukriti Sharma*[1] and Smriti Sharma Bhatia[2]
[1]Department of Library Science, Madurai Kamaraj University
[2]Miranda House, University of Delhi, Delhi-110007
***Corresponding author:** *Sukriti1223@rediffmail.com*

Abstract— In this paper, we have tried to identify upcoming trends in the field of *food security* with the help of bibliometrics, knowledge systems and data mining for the last 25 years (1989-2014). The corpus was defined by building logical conclusions and observations and user-directed expert elicitation from the said field which was combined with appropriate boolean logic and queries emphasizing research groups, research lines, and institutions. All this was examined statistically accompanied by tabulation and network mapping. This was done with efficient tools to perform automatic textual analysis. According to our findings, publishing in this field increased linearly over these two decades and this trend appears to continue. In terms of subject area, most papers are published under the agricultural and biological sciences followed by social sciences. We have also tried to analyze the factors leading to erosion of food security in India due to climate change. Disasters like floods, cyclones and droughts and freak weather patterns affect agricultural output and food security. They have been discussed.

Keywords: Food Security, Infometric Analysis, Boolean Logic, Agriculture, Disasters

1. INTRODUCTION

The World Food Summit (1996) defined food security as existing "*when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life*". It includes two parameters physical and economic access to food that meets people's dietary needs and their food preferences. It may sound preposterous but health problems related to dietary excess are also a problem and come under the ambit of food security in some countries. So along with commonly perceived problems related to food security like malnutrition and foodborne diarrhea, dietary excess related problems like obesity and cardiovascular diseases become a double edged sword [Maxwell, S. & Smith, M. 1992].

Three main components of food security are [http://www.who.int/trade/glossary/story028/en/]:

- **Food availability**: Food availability means sufficient quantities of food are available on a consistent basis i.e. it should be available throughout.
- **Food access:** Food access means having sufficient and necessary resources to obtain appropriate foods for a nutritious and wholesome diet.
- **Food use**: Food use is the appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

We have to understand that food security is a complex sustainable development issue and is linked to health and sustainable economic development. It is a subset of health as malnutrition leads to many health problems and it is an issue of sustainable economic development, environment, and trade because all these are directly affected by the patterns in food security. The problem is not the lack of food but the distribution of food. It also has to be seen if future needs can be met by the current levels of production. According to an FAO report [FAO Food security 2012" by UN Food and Agricultural Organization (FAO)], the following figure represents the number of people affected by undernourishment, 2010–12 (by region, in millions).

With its prevalence of undernourishment (PoU) indicator, the FAO reported that almost 870 million people

were chronically undernourished in the years 2010-2012. This represents 12.5% of the global population, or 1 in 8 people. Higher rates occur in developing countries, where 852 million people (about 15% of the population) are chronically undernourished. The report noted that Asia and Latin America have achieved reductions in rates of undernourishment that put these regions on track for achieving the Millennium Development Goal of halving the prevalence of undernourishment by 2015

[FAO, WFP, and IFAD (2012)]. Also, according to report [http://commons.wikimedia.org/wiki/File:Food_production_per_capita_1961-2005], growth in food production has been greater than population growth as shown in the following figure.As can be seen food per person has increased during the 1961–2005 period.

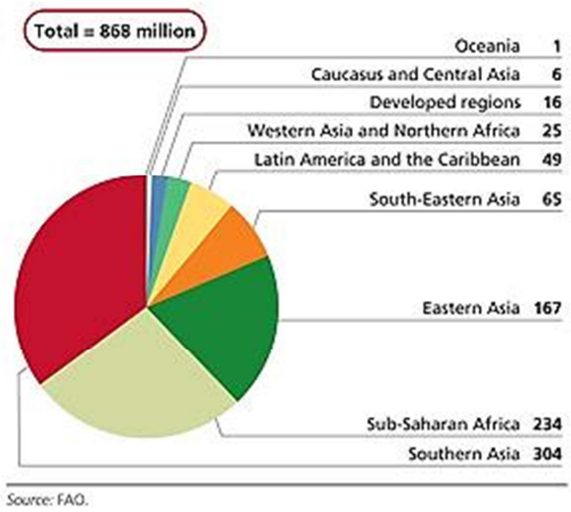

Figure 1: Number of people affected by undernourishment, 2010–12 (by region, in millions). Data source: FAO

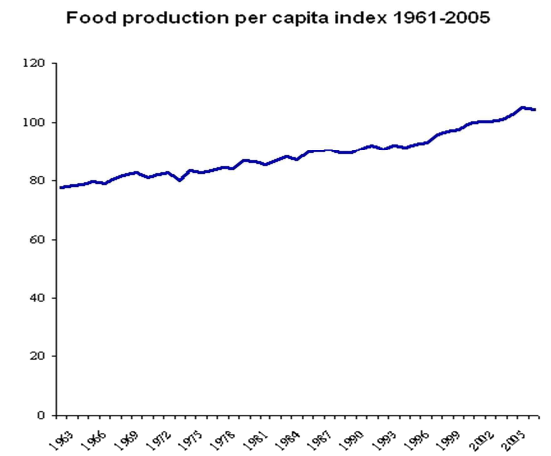

Figure 2: Growth in food production has been greater than population growth. The y-axis is percent of 1999–2001 average food production per capita. Data source: World Resources Institute.

This study is an attempt to make the quantitative study of research output on food security. Data of this study is obtained from Scopus (http://www.scopus.com) online database for the period 1989-2014, and analyzed with different viewpoints. A bibliometric study in this area will help the scientists to understand the progress in this field. In particular, the study was limited to the following objectives:

A. To examine the chronological growth of literature on Food security during the period1989-2014.
B. To identify food security in context of different research areas.

2. MATERIAL AND METHODS

The data for this study has been obtained from Scopus multidisciplinary database for a period during 1989-2014. Data were analyzed as per the objectives of this study. Various statistical tools like MS-Excel and SPSS were also used to quantify the data. We consider whether our findings signify the maturation of a scientific field and the extent to which this denotes the emergence of a shared scientific understanding regarding food security. As fields develop, the trend toward increasing specialization produces an ever more specialized and fragmented vocabulary.

3. RESULTS AND DISCUSSION

3.1 Year-Wise Growth of Food security Literature

Agricultural and Biological Sciences, Social Sciences, Environmental Science and Medicine are the four major subject areas identified in terms of research output. This trend is very obvious as food security concerns itself primarily with agriculture. All the problems, issues and concerns related to food security are basically the concerns of agriculture also. Agriculture is followed by Social sciences which is obvious as the problem of food security is a social one. There is a great divide between people who consume and waste food and people who donot get a chance to have food daily. However, Environmental Science and Medicine showed the lowest number of publications in this area.

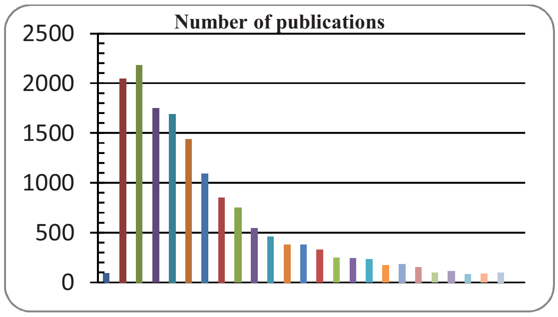

Figure 3: Growth of food security literature over the years

As can be seen from the data there has been an increase in the number of publications more so in the last decade where there is almost an exponential rise. This is commensurate with the attention that this field has generated in the last decade or so. Food security is a flexible concept as reflected in the many attempts at definition in research and policy usage. Even a decade ago, there were about 200 definitions in published writings.

3.2 Distribution of food Security in terms of subject areas

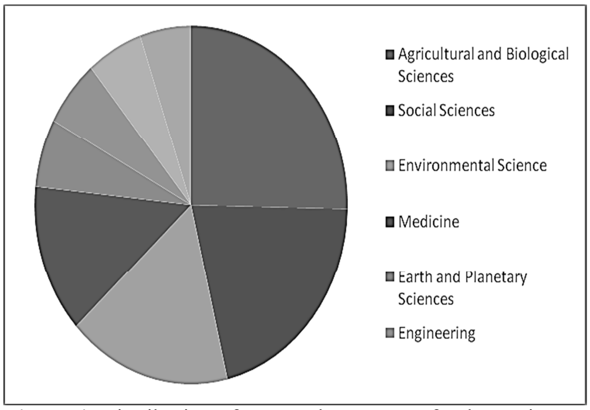

Figure 4: Distribution of Research output on food security in terms of subject area

REFERENCES

1. Maxwell, S. & Smith, M. 1992. Household food security; a conceptual review. In S. Maxwell & T.R. Frankenberger, eds. Household Food Security: Concepts, Indicators, Measurements: A Technical Review. New York and Rome: UNICEF and IFAD.
2. http://www.who.int/trade/glossary/story028/en/
3. "FAO Food security 2012" by UN Food and Agricultural Organization (FAO) -

http://www.fao.org/docrep/016/i2845e/i2845e00.pdf. Licensed under Copyrighted free use via Wikimedia Commons http://commons.wikimedia.org/wiki/File:FAO_Food_security_2012.jpg#/media/File:FAO_Food_security_2012.jpgMaxwell, S. 1996. Food security: a post-modern perspective. Food Policy. 21 (2): 155-170.

4. FAO, WFP, and IFAD (2012). The State of Food Insecurity in the World 2012. Rome: FAO

5. "Food production per capita 1961-2005" by Original uploader was Ultramarine at en.wikipedia - Transferred from en.wikipedia. Licensed under Public Domain via Wikimedia Commons. http://commons.wikimedia.org/wiki/File:Food_production_per_capita_1961-2005.png#/media/File:Food_production_per_capita_1961-2005.png

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Protease Activity in Pineapple Fruits

Janaki Subramanyan[1]*, Arlene[1], Disha Gupta[1], Nidhi Nagar[1], Nikanshi Yadav[1] and Sweta Bharti[1]
[1]D S Kothari Centre for Research and Innovation in Science Education, Miranda House,
University of Delhi, Delhi 110 007 (India)
***Corresponding author:** *janaki.subramanyan@gmail.com*

Abstract— The pineapple plant has several uses. Most commonly the plant is grown for its delicious fruits. The leaves are used to extract a durable textile fibre. Bromelain, a mixture of proteases usually extracted from the stem, has health benefits and finds use in folk medicine, and as a meat tenderizer. The present study was carried out to understand protease activity in pineapple fruits using gelatine (1%) as the substrate. An aqueous extract of the ripe fruit or cylinders of uniform size bored out from the ripe fruit was used as the crude protease. The biuret test was conducted to study the extent of protein (gelatine) degradation by observing the intensity of violet colour that developed visually or colorimetrically at wavelength 590 nm. The progression of protease action on gelatine was studied by two methods, firstly by the biuret test and secondly by the conductivity probe, in separate experiments. The effects of enzyme (E) and substrate (S) concentration on protease activity were also studied using the biuret test.The results showed that the pineapple fruit is rich in protease activity. Interestingly, the protease activity was retained to some extent on boiling the fruit juice. Also, the fruit juice lacks proteins. The absorbance of the pineapple fruit juice + gelatine (E+S) mixture containing biuret reagent decreased gradually from 0 min to 40 min, reflecting the progression of degradation of gelatine. The conductivity of the E+S mixture increased gradually up to 50 min from incubation. As the digestion of gelatine proceeds, peptides and amino acids form and contribute to the increase in conductivity of the E+S mixture. When the concentration of the enzyme was increased by increasing the number of pineapple fruit cylinders keeping the substrate concentration constant, there was a concomitant decrease in the absorbance of the E+S mixture. This was because of the fact that as the enzyme concentration increased, more was the substrate degradation and less the intensity of violet colour on adding biuret reagent, resulting in a decrease in the absorbance. When the substrate concentration was increased keeping the enzyme concentration constant, there was a corresponding increase in the absorbance of the E+S mixture. The increased concentrations of gelatine and oligopeptides formed as a result of protease action on gelatine contribute to the increase in the absorbance. The pineapple plant grows in tropical and near tropical regions, and India is a major producer of the fruit. The plant is hardy and adapted to grow in a fairly wide range of temperatures. It is suggested that pineapple, a multipurpose crop, could replace the traditionally cultivated crops in areas where climate change has an impact. Estimating the protease activity would also be an easy and quick method to determine the effect of changes in climatic conditions on the pineapple crop.

Keywords— Pineapple fruit, protease, biuret test, colorimeter, conductivity probe, climate change

1. Introduction

Pineapple [*Ananas comosus* (L.) Merr., family Bromeliaceae] is an important fruit crop. The ripe fruits are consumed fresh, in salads and desserts. Fruits are used while preparing curries and meat dishes, cooked in pies, cakes, puddings, or made into sauces or preserves (Kochhar, 2011). The skinned fruit is canned, and the fruit juice is made into marmalade and preserved as juice as well. Pineapple fruit essence is used as a flavouring agent in biscuits and ice-creams. In the Philippines, the pulp is fermented and made into a sweetmeat. The plant has several other uses. The fibres extracted from the leaves are used as a textile fibre. Bromelain, a mixture of thiol proteases, is most commonly extracted from the stem. It is used as a digestive aid, a meat tenderizer, in chill-proofing beer, and in stabilizing latex-based paints, and in the leather-tanning process. Owing to the anti-inflammatory and antiseptic properties bromelain is used after surgery, to treat burns, injuries, insect bites, sinusitis and arthritis. The use of bromelain in cancer treatment is being explored. However, bromelain may increase bleeding, and therefore, should be administered only by qualified healthcare professionals. Bromelain is commercially available in the form of powder, capsules and tablets.

2. MATERIAL AND METHODS

The following have been conducted in this investigation: detection of protease activity in pineapple juice using biuret test (Plummer, 1998; Sawhney & Singh, 1996); study of the progression of protease activity on the substrate gelatine using biuret assay, and by determination of the change in conductivity of gelatine solution in presence of pineapple juice using a conductivity probe; and study of the effects of enzyme concentration and substrate concentration on protease activity. All experiments were conducted thrice. Gelatine (1%) was used as the substrate. The rind of ripe pineapples was removed and the fruit tissue was ground in distilled water (1:5 w/v) to obtain a homogenate, which was filtered and used as the crude enzyme extract. Alternatively, 1-cm-long cylinders were prepared from the fruit tissue using a cork-borer and used as the enzyme.

3. RESULTS AND DISCUSSION

3.1 Detection of protease (bromelain) activity in pineapple fruit

Pineapple fruit juice was used as the crude protease. The enzyme and substrate were added as shown in the table and incubated for 20 min. Then biuret reagent was added and the test tubes were shaken. The intensity of violet colour that developed was noted. Test tube 1 containing pineapple juice and gelatine solution had +2 intensity. As protease degraded the gelatine the protein concentration decreased and, therefore, the intensity of violet colour (Table 1). The intensity of violet colour was highest in test tube 2. This was because without the protease the gelatine could not be degraded. Therefore, the violet colour was intense (+5).

Table 1. Detection of protease activity in pineapple fruits

S.NO.	DISTILLED WATER (ML)	PINEAPPLE JUICE (ML)	1% GELATINE (ML)	BIURET REAGENT (ML)	INTENSITY OF VIOLET COLOUR*
1.	--	2	2	2	+2
2.	2	--	2	2	+5
3.	2	2	--	2	--
4.	--	2 (BOILED + COOLED)	2	2	+3

*Similar results were observed when commercially available gelatine capsules were used instead of 1% gelatine.

Therefore, the violet colour was intense (+5). The intensity of violet colour was +3 where boiled and cooled enzyme was used (test tube 4) to act on gelatine solution which showed that boiling did not completely denature the enzyme. No violet colour developed in test tube 3, meaning thereby that pineapple juice lacks proteins that can be detected by biuret test.

Table.3. Conductivity of 1% gelatine solution and pineapple juice

	Conductivity (µS/CM)			
	Replicate I	Replicate II	Replicate III	Average
1% Gelatine Solution	200	201	182	194.3
Pineapple juice	906	900	904	903.3

3.2 Progression of protease activity on gelatine

3.2.1 Using the biuret test

The biuret reagent reacts with proteins and gives a violet Cu^{++}-coordination complex. More the complex formed, more intense would be the violet colour of the reaction mixture. The intensity of the violet-coloured complex can be measured using a colorimeter at 590 nm.

Using a cork-borer, 1-cm-long cylinders were prepared from the fruit tissue. Four such cylinders were put into each tube containing 2 mL of 1% gelatine using a pair of forceps. Care was taken that the cylinders were completely immersed in the gelatine solution. The period of incubation of pineapple cylinders in gelatine solution was varied from 0 min to 60 min. The difference in the incubation period was 10 min between consecutive test tubes. At the completion of the required incubation period 2 mL of biuret reagent was added and the tube was shaken. The solution was carefully decanted into the cuvette and the absorbance of the solution was recorded at 590 nm.

The general trend was that the absorbance measured at 590 nm decreased as the incubation time given for the enzyme to act on the substrate increased from 0 to 40 min [Table 2, Fig. 1 (i)]. Protease hydrolyses gelatine into peptides. As the digestion progresses, less and less gelatine is available to react with biuret reagent, and, therefore the absorbance decreased up to 40 min in replicates II and III and up to 50 min in replicate I (Table 2). Following the decrease in absorbance, there was a gradual increase in absorbance up to 60 min. This can be explained on the basis of the fact that the peptides being formed as a result of protease activity on gelatine also start to react with biuret reagent and contribute to the intensity of violet colour in the reaction mixture. It is also possible that the amino acids and peptides react and start forming polypeptides which react with biuret reagent and give the violet colour.

3.2.2 Using the conductivity probe

To 60 mL of gelatine solution 15 mL of pineapple juice was added. The mixture was stirred and the conductivity was recorded immediately. This was the zero minute reading. The probe was kept dipped in the mixture and the conductivity was measured at 5-min intervals up to 60 min. The initial conductivity of 1% gelatine, and of pineapple juice were 194.3 µS/cm and 903.3 µS/cm, respectively (Table 3). Pineapple juice would contain abundant ions and dissolved solids. Therefore, pineapple juice had a much higher conductivity than gelatine solution. The gelatine and pineapple juice mixture showed a conductivity of 379.6 µS/cm at 0 min [Table 4, Fig. 1(ii)]. The conductivity of the mixture increased gradually and at 60 min the conductivity was 406.7 µS/cm. This showed that with time the protease present in pineapple juice digested gelatine. The peptides and amino acids being formed which due to their free charges contribute towards the increase in conductivity of the solution. The conductivity increased up to 50 min which is evidence of rapid enzymatic activity. The conductivity was nearly the same at 50, 55 and 60 min. interestingly, the trend of results for the progression of protease activity on gelatine when studied using the conductivity probe matched that when the biuret reagent was used.

Table 2. Colorimetric estimation of the progression of protease activity on gelatin

S. No	1% Gelatine (mL)	No. of cylinders	Incubation Time (min)	Biuret Reagent (mL)	Absorbance (590 nm)			
					Replicate I	Replicate II	Replicate III	Average
1.	blank	4	0	2	0	0	0	0
2.	2	4	0	2	0.50	0.50	0.39	0.46
3.	2	4	10	2	0.45	0.42	0.28	0.38
4.	2	4	20	2	0.39	0.38	0.27	0.33
5.	2	4	30	2	0.37	0.35	0.23	0.32
6.	2	4	40	2	0.33	0.32	0.21	0.29
7.	2	4	50	2	0.32	0.34	0.27	0.31
8.	2	4	60	2	0.35	0.36	0.29	0.33

Table 4. Conductivity of the gelatine and pineapple juice mixture up to 60 min

S. No.	Time (min)	Conductivity(µS/CM)			
		Replicate I	Repli-cate II	Replicate III	Average
1.	0	412.7	369.0	357.0	379.6
2.	5	420.0	380.0	365.0	388.3
3.	10	423.1	385.0	369.0	392.4
4.	15	426.2	387.0	370.0	394.4
5.	20	428.3	390.0	373.0	397.1
6.	25	429.3	393.0	374.0	398.8
7.	30	430.3	394.0	375.0	399.8
8.	35	431.3	395.0	378.0	401.4
9.	40	432.4	396.0	379.0	402.5
10.	45	433.8	398.0	380.0	403.9
11.	50	434.1	401.0	383.0	406.0
12.	55	435.8	401.0	383.0	406.0
13.	60	436.2	401.0	383.0	406.7

Table 5. Effect of enzyme concentration on protease activity

S. no.	No. of Cylinders	1% Gelatine (ml)	Distilled water (ml)	Biuret reagent (ml)	Absorbance (590 nm)			
					Replicate I	Replicate II	Replicate III	Average
1.	0	0	5	5	0	0	0	0
2.	0	5	0	5	0.54	0.52	0.52	0.53
3.	1	5	0	5	0.52	0.46	0.48	0.49
4.	2	5	0	5	0.47	0.42	0.46	0.45
5.	5	5	0	5	0.42	0.39	0.40	0.40
6.	6	5	0	5	0.38	0.33	0.34	0.35
7.	8	5	0	5	0.34	0.29	0.27	0.30
8.	10	5	0	5	0.31	0.24	0.25	0.27

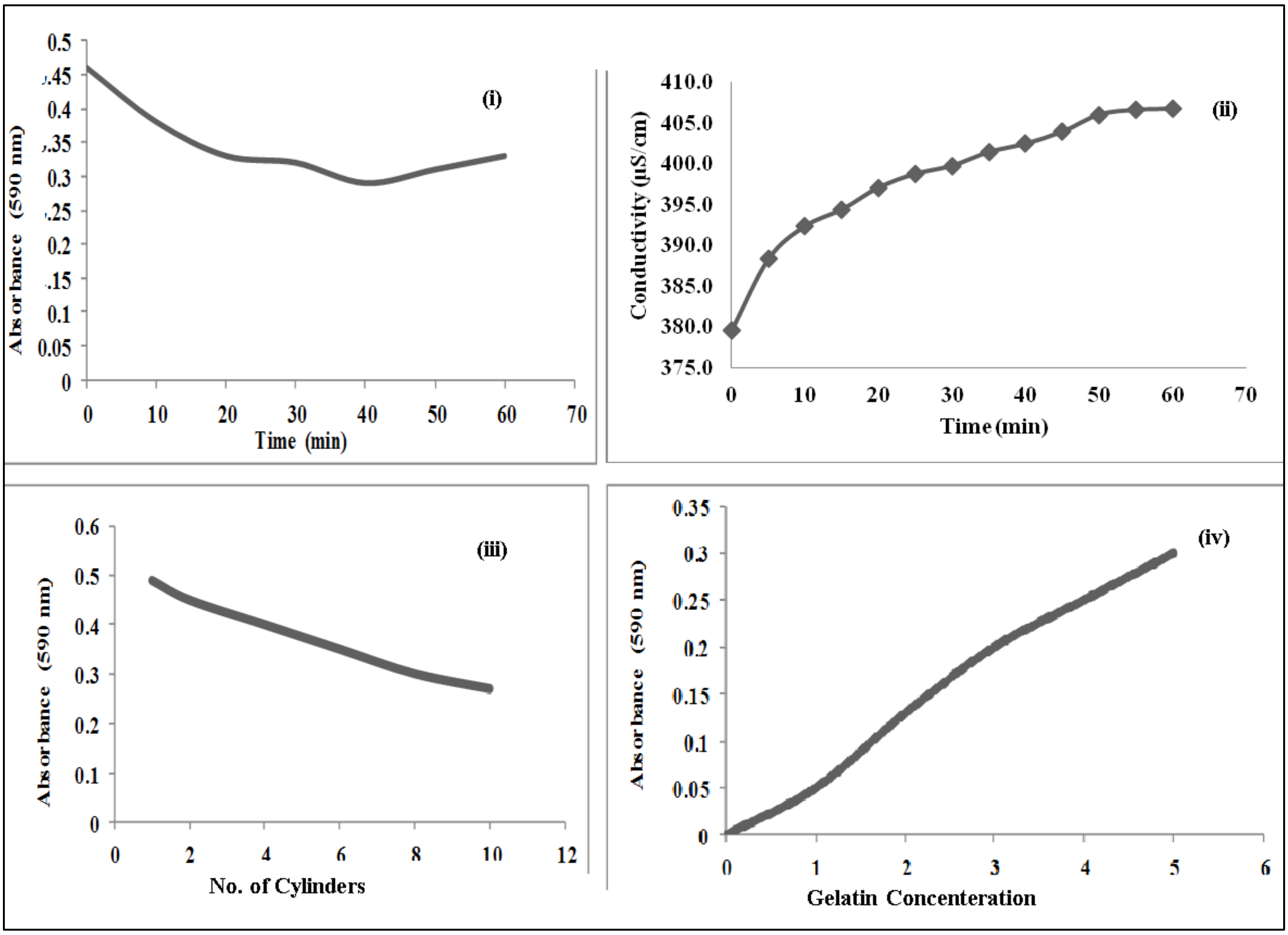

Figure 1. (i) Colorimetric estimation of the progression of protease activity on gelatine (ii) Conductivity of the gelatine and pineapple juice mixture up to 60 min (iii) Effect of enzyme concentration on protease activity (iv) Effect of substrate concentration on protease activity.

3.3 Effect of enzyme concentration on protease activity

The protease concentration was varied by increasing the number of 1-cm-long pineapple cylinders from 0 to 10 while keeping the volume of 1% gelatine constant, i.e., 5 mL. The pineapple cylinders and gelatine were then incubated for 20 min. Then biuret reagent (5 mL) was added and shaken. The absorbance of the solution at 590 nm was recorded immediately. biuret reagent. The tube having 10 cylin- The tube having no cylinders had the maximum average absorbance (0.53) but as the number of cylinders was increased, the amount of gelatine degraded also increased and the absorbance decreased. Gelatine degradation resulted in a decrease in the amount of protein and peptides available to complex with biuret reagent. The tube having 10 cylinders had maximum protease activity and the minimum average absorbance of 0.27. Thus, the relationship between enzyme concentration and absorbance was inversely proportional.

3.4 Effect of substrate concentration on protease activity

Three 1-cm-long pineapple cylinders were incubated in 5 mL of gelatine solution of varying concentrations. A 1 % gelatine solution was used and suitably diluted using distilled water to vary the substrate concentration. Biuret reagent (5 mL) was added to the enzyme and gelatine mixture 20 min from incubation, the test tubes were shaken, and the absorbance of the solutions was measured at 590 nm.

Table 6. Effect of substrate concentration on protease activity

S. N.	No. of cyls	1% Gelatine (mL)	dd-H_2O (mL)	Biuret Reag. (mL)	Absorbance (590 nm)			
					Repl. I	Repl. II	Repl. III	Avg
1	3	0	5	5	0	0	0	0
2	3	1	4	5	0.08	0.04	0.04	0.05
3	3	2	3	5	0.17	0.11	0.11	0.13
4	3	3	2	5	0.24	0.17	0.19	0.20
5	3	4	1	5	0.30	0.22	0.24	0.25
6	3	5	0	5	0.34	0.28	0.28	0.30

As the gelatine (substrate) concentration increased, the intensity of violet colour increased on adding biuret reagent. In test tube 1 with no gelatine, there is no violet colour development on adding biuret reagent. With increase in gelatine concentration, there was an increase in absorbance [Table 6, Fig. 1(iv)].

This is because of two reasons, the first is the increase in amount of

ders had maximum protease activity and the minimum average absorbance of 0.27. Thus, the relationship between enzyme concentration and absorbance was inversely proportional. With an increase in the concentration of the enzyme, i.e. the number of pineapple cylinders, there was an increase in the degradation of gelatine. As a result the absorbance decreased as the enzyme concentration increased [Table 5, Fig. 1(iii)].

protein in the solution and the second is the increase in the amount of oligopeptides formed as a result of protease action on gelatine. Both The increased protein and oligopeptide concentrations contribute to the increase of the intensity of violet colour from test tube 2 to 6. The drawback of this experiment is that the biuret assay would give a violet colour with any compound having two or more peptide bonds, and would not help in demarcating the protein (substrate used) from the oligopeptides (product) formed as a result of protease action on gelatine.

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REFERENCES

1. en.wikipedia.org/wiki/Bromelain
2. https://www.hort.purdue.edu/newcrop/morton/pineapple.html#Climate
3. Kochhar, S. L.2011. Economic Botany in the Tropics, 4th edn, Macmillan Publishers India Ltd, New Delhi.
4. nhb.gov.in/report_files/pineapple/PINEAPPLE.htm
5. Plummer, D. T. 1998. An Introduction to Practical Biochemistry, 3rd edn, TataMcGraw-Hill edn, New Delhi.
6. Sawhney, S. K., Singh, R. (ed). 1996. Introductory Practical Biochemistry, Narosa Publishing House, New Delhi.
7. www.kau.edu/prsvkm/Html/PineapplesectorinKerala.html.

Tayal and Mal 2015.
Proceedings of the National Conference on Climate Change: Impacts, Adaptation, Mitigation Scenario & Future Challenges In Indian Perspective, New Delhi, 2-3, March-2015. Pp. 61-69.
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Mitigatory Measures under Climate Change

Pamil Tayal[1]* and Anuradha Mal[1]

[1]Shivaji College, Department of Botany, University of Delhi, Delhi – 110 027

***Corresponding Author:** *pamiltayal@gmail.com*

Abstract— Climate change is referred to changes in weather conditions over long period of time, caused by a number of factors such as biotic processes, variation in solar radiations received by Earth, plate tectonics and volcanic eruptions. However, anthropogenic activities have also been considered as the significant cause for climate change that is often referred to as global warming. Climate change mitigation involves reductions in anthropogenic activities that may be achieved by increasing the capacity of carbon sinks and its sequestration. Efforts are underway to prevent emission of greenhouse gases using new technologies and use of low-carbon energy resources. The present mitigation activities involve multidisciplinary approach through science and technology along with climate engineering. These strategies include energy conservation, carbon-neutral energy conversions, carbon advanced combustion processes that produce no greenhouse gases and that enable carbon capture and its sequestration. Mitigation may also be achieved by increasing the capacity of carbon sinks by improving energy efficiency in buildings through greenhouse construction methods, reducing agricultural waste during storage, distribution, marketing and household use; producing recyclable industrial products; promoting green tourism and establishment of sustainable practices that preserve resources and reduce pollution. To enable these innovations, regulatory reforms and new policies will need to be set in motion and mechanisms that ensure environmental cost should be factored into producer's calculations.

Keywords— Buildings; Climate Change; Greenhouse Gases; Mitigation; Renewable Energy Resources; Transport; Travel

1. Introduction

Climate change is a global problem that arises due to increasing average temperature and trapping of greenhouse gases importantly carbon dioxide emissions from various agents (individual, company and country). It is predicted from the prevailing scenarios that by 2100, average global surface temperatures will likely rise by 2-8.6 ^{o}F (IPCC, 2014). The temperature increase will be accompanied by other environmental changes disrupting the functioning of the ecosystem thereby imbalance in nature. In the recent five-year assessment report of IPCC (2014), it was assessed that among many factors influencing today's climate, anthropogenic activities have now become the predominant force causing climate to change very rapidly. Global impacts of the issue include declining crop yield in many areas particularly developing nations, significant decrease in water availability, and rise in sea water level that threatens many cities, extensive damage to coral reefs, number of species face extinction, rising intensity of forest fires, droughts, storms and flooding; and large scale irreversible shifts in climate change (IPCC, 2014).

Climate change mitigation strategies consists of actions to limit the magnitude and/or rate of long-term climate change, generally involves reductions in anthropogenic emissions of greenhouse gases (GHG). Mitigation may also be achieved by increasing the capacity of carbon sinks through reforestation, carbon sequestration, fuel switching and use of renewable energy resources. Mitigation policies can be substantially introduced by policymakers to reduce the risks associated with human-induced global warming and implies the need for international cooperation with local, national and regional policies on many matters (Morita et al., 2001; IPCC, 2014). Among many Asiatic countries, India is committed to promote voluntary measures such as energy efficiency, renewable energy and cleaner conventional energy technologies to mitigate climate change.

Climate change mitigation can be categorized in two ways: (i) Economic potential that takes into account social costs and benefits including social discount rates, assuming that market efficiency is improved by policies and measures and barriers are removed (ii) Market potential which is based on private costs and private discount rates that expected to occur under forecast market conditions and includes policies and measures currently in place along with noting that barriers limit actual uptake (IPCC, 2007).

United Nations Framework Convention on Climate Change (UNFCCC) aims to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate change (UNFCCC, 2002). Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, to enable sustainable economic development and to achieve sustainable development, better quality of life and well-being.

The review highlights all the necessary mitigation measures that are practised in developed as well as developing nations to reduce emission. This will help in gaining better understanding about climate change and its mitigation measures, adoption of mitigation measures by developing countries that have previously been implemented in developed nations, will help policymakers to design new effective strategies against increasing climate change for economic and sustainable development.

2. MITIGATION STRATEGIES FOR SUSTAINABLE DEVELOPMENT IN DIFFERENT SECTORS

Heavy energy consumption in industries, buildings and cities with utilization of non-renewable energy resources and deforestation practices causes heavy GHG emission in different sectors (Figure 1). Climate change mitigation strategies can be designed under these different sectors for their effective monitoring, functioning and balance of the ecosystem. The different mitigation sectors are as follows:

1. Energy
2. Industry
3. Agriculture, Forest, and Land use
4. Transport
5. Buildings and cities
6. Waste management

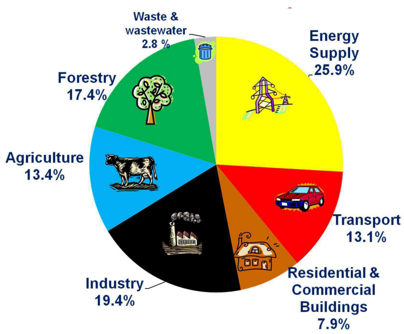

Figure 1: Global GHG emissions from different sectors (IPCC, 2007). In developing nation like India, contribution of different sectors varied. Energy consumption leads to 61% GHG emission followed by agriculture (28%), industries (8%) and waste with 2% GHG emission (MoEF, 2014).

3. ENERGY EFFICIENCY AND CONSERVATION

In 2010, the energy sector was responsible for 46% of energy-related GHG emissions (IEA, 2012c) and 35% of anthropogenic GHG emissions; elevated at the rate of 1% per annum (IPCC, 2007). The majority of global anthropogenic GHG emission occurs due to consumption of fossil fuel. In developing nations like India, emissions are low as compared to major economies (20-40% lower than China and United states). However, since 1990's the energy demand has tremendously increased GHG emission; The Integrated Energy Policy estimated that energy requirements will increase by more than 50% every decade.

There are multiple options for lowering GHG emissions from the energy system while still satisfying the global demand for energy services (Bashmakov, 2009). Some of these possible options, such as energy conservation and efficiency, fossil fuel switching, renewable energy (RE), nuclear and carbon capture and storage were mentioned in the annual report of IPCC in 2007 (Verbruggen et al., 2011; Fischedick et al., 2011; Moriarty and Honnery, 2012). The utilization of RE technologies can play an effective role within such mitigation options (Allen et al., 2009; Meinshausen et al., 2009). Having a large potential to mitigate climate change, RE can also provide wider benefits that can contribute to social and economic development, energy access, secure energy supply, energy security and reducing negative impacts on the environment and health (Chester, 2009; Winzer, 2012). RE can also help in decoupling of the correlation between energy use and economic development thereby contributing to sustainable development (Kuik et al., 2011; Cherp et al., 2012). Another important areas of potential technological advancement in energy sector include: new and improved feedstock production and supply systems, biofuel produced via new processes (also called as next-generation or advanced biofuels) and advanced biorefining; advanced photovoltic technologies and manufacturing processes; enhanced geothermal systems; multiple emerging ocean technologies; and foundation and turbine designs for offshore wind energy.

In India, a number of policies have been framed since 1990's that contribute to the decline in energy intensity include improved energy efficiency, increased use of renewable and nuclear power, expanded public transport and energy pricing reform (Government of India, 2008). In 2008, First national Action Plan on Climate change was released by Prime Minister identifying eight core "national missions" highlighting directional shifts, demand site management, form the core of the Action Plan and four deals with mitigation. Besides the overarching missions, more policies aiming enhancing energy efficiency were worked by Indian government i.e. Jawaharlal Nehru National Solar Mission (increasing solar energy sources), National Mission on Sustainable Habitat (promotes energy efficiency in residential and commercial sectors) and National Mission for Green India (by enhancing afforestation).

Energy requirements cannot be met simply by using present traditional energy sources; it rather requires modification of industrial processes to decrease energy consumption, diversification towards renewable energy resources and recognizing multipronged strategy for sustainable development (Pandey, 2010; MoEF, 2014).Significant advances in RE technologies, their applications and associated long-term cost reductions have been proved successful (IPCC, 2007; 2014). Further cost reductions are expected, resulting in greater potential use and consequent climate change mitigation.

4. AGRICULTURE, FOREST AND LAND USE

Agriculture, forestry and other land-use (AFOLU) change, mainly deforestation of tropical forests, contribute greatly to anthropogenic GHG emissions and are expected to remain important during the 21st century. Annual GHG emissions (mainly CH_4 and N_2O) from agricultural production in 2000 – 2010 were estimated at 5.0 – 5.8 $GtCO_2eq$ / yr, comprising 10 – 12% of global anthropogenic release; however annual GHG flux from land use and land-use change activities (9-11%). Thus it was estimated that the total contribution of AFOLU sector to anthropogenic emissions is around one quarter of the total anthropogenic GHG emission (Smith et al., 2014). In India, different agricultural sectors such as enteric fermentation (59%), rice cultivation (23%), emission from soils (12%) and manure management contributes in GHG emissions (MoEF, 2014).

CO_2 and other non-CO_2 GHG, largely methane and nitrous oxide, are released to the atmosphere by plant respiration, combustion and by decomposition of dead plant biomass and soil organic matter. In Indian agriculture system, climate change projected impacts on cereal productivity to decrease by 10-40% by 2100. It has been estimated that greater losses are expected in rabi crops especially in wheat production; drought and floods are likely to increase production variability; increase water temperature is likely to affect fish breeding, migration and harvest; and an imbalance in food trade will occur. Other effects such as reduced frequency of frost damage will tend to cause less damage to potato, peas and mustard.

Mitigation activities in AFOLU sector can reduce climate forcing in different ways: (i) Reductions in CH_4 or N_2O emissions from croplands, grazing lands, and livestock (ii) Conservation of existing carbon stocks, conservation of forest biomass, peatlands, and soil carbon that would otherwise be lost (iii) Reductions of carbon losses from biota and soils through management changes within the same land-use type or by reducing losses of carbon-rich ecosystems, reduced deforestation, rewetting of drained peat lands, (iv) enhancement of carbon sequestration in soils, biota, and long-lived products through increases in the area of carbon-rich ecosystems such as forests, increased carbon storage per unit area, increased stocking density in GHG emissions according to IPCC methodologies (IPCC 2003, 2006). Demand-side options by lifestyle changes, reducing losses and wastes of food, changes in human diet, changes in wood consumption, though known to be difficult to implement, may also play a role in mitigation (IPCC, 2014). Key adaptation strategies such as assisting farmers in coping with current climatic risks, improving land and water management and strengthening adaptation research will prove to be beneficial (Pathak, 2010; Aggarwal et al, 2009; IPCC, 2007). The development and implementation of mitigation strategies in forest ecosystems require a longer response time to adapt (Leemans and Eickhout, 2004; Ravindranath, 2007). Some examples of mitigation practices are as follows (Murthy et al., 2011): anticipatory planting of species along latitude and altitude, assisted natural regeneration, mixed-species forestry, species mix adapted to different temperature tolerance regimes, fire protection and management practices, thinning, sanitation and other silvicultural practices, in situ and ex situ conservation of genetic diversity, drought and pest resistance in commercial tree species, adoption of sustainable forest management practices, increase in protected areas and linking them wherever possible to promote migration of species, forests conservation and reduced forest fragmentation enabling species migration, and energy-efficient fuelwood cooking devices to reduce pressure on forests (IPCC, 2007; 2014).

Many mitigation practices implemented locally for soil carbon sequestration have increased the ability of soils to hold soil moisture, better withstand erosion, enriched ecosystem biodiversity by establishing more diversified cropping systems and also helped cropping systems to better withstand drought and floods (Rosenzweig and Tubiello, 2007). AFOLU mitigation promotes conservation of biological diversity (Smith et al., 2013) both by reducing deforestation (Chhatre et al., 2012; Murdiyarso et al., 2012), and by using reforestation / afforestation to restore bio-diverse communities on previously developed farmland (Harper et al., 2007). Contrarily, promoting land-use changes (through planting monocultures on biodiversity hot spots) can have adverse side-effects, reducing biodiversity (Pandit and Grumbine, 2012; Gardner et al., 2012).

The implementation of AFOLU mitigation measures may result in an improvement in land management and therefore have socio-economic, health, and environmental benefits, reducing deforestation, causing reforestation, and afforestation can improve local climatic conditions, water quality, biodiversity conservation, and help to restore degraded or abandoned land. Soil management to increase soil carbon sequestration may also reduce the amount of wind and water erosion due to an increase in surface cover. Further considerations on economic cobenefits are related to the access to carbon payments with UNFCCC agreements and new income opportunities especially in developing countries (IPCC, 2014).

5. INDUSTRY

GHG emissions from industry grew at an average annual rate of 3.5% globally since 2005 due to conversion of natural resources into material stock (Bajzelj et al., 2013; World Bank, 2013; Kelly and Matos, 2013). It was reported that over half (52%) of global direct GHG emissions from industry and waste / wastewater are from the Asia particularly china (Kelly and Matos, 2013;

UNCTAD, 2008; Ghosh and Roy, 2011). Energy-intensive industries are growing more in developing countries where infrastructure is greatest. By 2015, total GHG emission in developing countries estimated to equal that of developed nations that eventually will surpass energy consumption and GHG emission (IPCC, 2014).

Industrial GHG emission has been categorized into two: direct energy related sources producing 5.3 $GtCO_2eq$ and indirect from production of electricity and heat required for industry (2.6 GtCO2eq). Also fluorinated gases were also considered as the most important non-CO_2 GHG source in manufacturing industry sector (IEA, 2012a; de la Rue du Can and Price, 2008). Most industry sector scenarios indicate that demand for materials (steel, cement) will increase by 60% in 2050 relative to 2010 production levels (Allwood et al., 2010; Saygin et al., 2011).

The four industrial sub-sectors i.e. iron and steel, non-metallic minerals, chemicals and petrochemicals and pulp and paper have significantly contributed in GHG emissions in India (FAO, 2013).In addition to other drivers such as population growth, urbanization, and income increase, the rise in the proportion of trade has been an important factor contributing to GHG emissions (Liu and Ang, 2007; Reddy and Ray, 2010; OECD, 2011). Mitigation technology at industry level is associated with the identification and defining the problems in different chemical, food processing, leather and mining industries and to achieve an absolute reduction in emissions from the industry sector will require a broad set of mitigation options going beyond current practices. United Nations Industrial Development Organization has initiated green industry approach i.e. greening of the industries through the adoption of resource-efficient, cleaner production technologies and practices; and supporting the growth of green industries that provide environmentally friendly products and services, including renewable energy technologies.

Different options for mitigation of GHG emissions from industry fall into the following categories: energy efficiency, emissions efficiency (including fuel and feedstock switching, carbon dioxide capture and storage), material efficiency (through reduced yield losses in production), re-use of materials and recycling of products, more intensive and longer use of products, and reduced demand for product services (Velavan et al., 2009). These strategies includes enhancing energy efficiency, shift in raw material use to less carbon intensive alternatives, fuel mix options or fuel switching, use of decarbonized electricity. Since Indian manufacturing is strong in energy intensive sectors, it is imperative to increase energy efficiency for greater competitiveness. Greater capacity building is needed at institutional and individual levels with adoption of renewable energy resources by factories. Energy Conservation Act implemented by government of India has provided regulatory impetus to energy efficiency activities in industries.

Implementation of mitigation measures in industries and related policies might gain momentum if co-benefits are considered along with direct economic costs and benefits (IPCC, 2007; 2014). Mitigation actions can improve cost competitiveness, lead to new market opportunities, wider environmental gains such as reduced air and water pollution and reduced extraction of raw materials and enhance corporate reputation through indirect social and environmental benefits at the local level. Associated positive health effects can enhance public acceptance.

6. TRANSPORT

Transport activity serves as a key component of economic development and human welfare around the world. The most pressing problems associated with this increasing transport activity are traffic fatalities and injuries, congestion, air pollution and petroleum dependence (Ribeiro et al., 2007; IEA, 2006a). These problems are acute in rapidly growing economies of the developing world. Transport sector is the second largest consumer of energy (16%) after industry and accounted for 31.14 mtoe energy consumption. Transport predominantly relies on a single fossil resource, i.e. petroleum (supplies 98% of the total energy). In 2004, transport was responsible for 23% of world energy-related GHG emissions with about three quarters coming from road vehicles (IEA, 2006d; Lee et al., 2005). Over the past decade, road transport's GHG emissions have increased at a faster rate than any other energy using sector inspite of more efficient vehicles on roads, rails, watercrafts and aircrafts. Transport activity will continue to increase in the future due to increase in economic growth (Bose and Sperling, 2001; Beers et al., 2001; EEA, 2003).

Assessment of mitigation potential in the transport sector through the year 2030 is uncertain because the potential depends on:

(i) World oil supply and its impact on fuel prices with economic viability of alternative transport fuels (IEA, 2001; 2003),

(ii) Research and development outcomes in several areas, especially biomass fuel production technology and its sustainability in massive scale, as well as battery longevity, cost and specific energy (JHFC, 2006; Sanyo, 2005; Yuasa, 2000).

In developing countries like India, impacts of climate change can be decreased by adopting key strategies such as by improving technology in road vehicles, management of growth in vehicle use, avoiding journeys, modal shift to low carbon transport systems such as walking and cycling, lowering energy intensity by enhancing vehicle and engine performance and reducing carbon intensity of fuels by substituting oil based products with natural gas (Skjolsvik, 2005; IEA, 2003), enhancing travel alternatives to serve diversity of needs and coordinate with government policies and activities based on transport and land use, infrastructure investments and industrial policies (Bose and Sperling, 2001). To combat climate change impacts, new initiatives have been laid by Indian government such as switch to CNG public transport mainly in metropolitan cities like Delhi, introduction of separate lanes for buses; initiation of Metro rail for public transport and development of electric vehicles by REVA motors and Hero Honda fro mitigating GHG emission.

Wide arrays of transport demand management (TDM) strategies have been employed in different circumstances around the world, primarily to manage traffic congestion and reduce air pollution. TDMs can be effective in reducing private vehicle travel if rigorously implemented and supported (Litman, 2003; Gwilliam et al., 2004; VTPI, 2005). The use of current and advanced biofuels would give an additional reduction potential of another 600–1500 $MtCO_2$-eq in 2030 at costs <25 US$/$tCO_2$.Since currently available mitigation options will probably not be enough to prevent growth in transport's emissions. Technology research and development is essential to create the significant reduction in transport GHG emissions via implementation of hydrogen fuel cell, advanced biofuel conversion and improved batteries for electric and hybrid vehicles (Jones, 2004; McKinley et al., 2003).

Global tourism and climate change scenarios are scarce (Peeters et al., 2007; Dubois and Ceron, 2007). The tourism transport sector currently accounts for 5% of global GDP and continues to grow, particularly in developing countries. While this sector may be beneficial for national economies in export earners, however if not properly managed it can be awful for the environment and local populations. Unsustainable practices, such as excessive water use, waste generation, and habitat encroachment are threatening ecosystems, biodiversity, and local culture contributes to climate change (UNEP, 2010). Green tourism aims to reduce poverty by creating local jobs and stimulating local business, while establishing ecologically sustainable practices that preserve resources and reduce pollution (UNEP, 2010).

7. BUILDINGS AND CITIES

It was estimated that 32% of the world's energy use takes place inside buildings. This has earned the building sector the dubious honour of being the Earth's biggest contributor to GHG emissions (8.8 $GtCO_2$) and generates huge quantities of solid waste (IEA, 2013).This energy demand growth results from improvements in wealth, lifestyle change, access to modern energy services and adequate housing, and urbanisation (WBCSD, 2007). There are significant lock-in risks associated with the long life spans of buildings and related infrastructure, and these are especially important in regions with high construction rates (Doig and Adow, 2011). Clearly, attempts to improve resource efficiency must consider buildings into account for achieving green future. The broad mitigation strategy for buildings by integrated models includes emphasis on low-carbon energy carriers i.e. reducing energy demand (Bertoldi and Ciugudeanu, 2005).

Recent advances in technologies provide opportunities to stabilize global buildings sector energy use by mid-century. For new buildings, the adoption of very low energy building codes is important and has progressed substantially (Musall et al., 2010). Retrofits form a key part of the mitigation strategy in countries with established building stocks, use of biomass, and reductions of heating / cooling energy use by 50 – 90% in individual buildings have been achieved (Harvey, 2008; IEA, 2012a). Improving energy efficiency in buildings through greener construction methods and retrofitting existing structures can make an enormous difference in reducing GHG emissions (Fawcett, 2011). Moreover, many of these improvements can be realized at low cost, using existing technologies. Green construction can also have a positive effect on productivity, public health, and employment (Scott et al., 2008; Koppl et al., 2011). In India, Bureau of Energy efficiency has already formulated and announced Energy Conservation Building code; Energy audits for nine government buildings have been completed including Rashtrapati Bhawan and Prime Minsiter's office. Characterized by proximity, variety, and density, cities can be fertile ground for collaboration between local and national governments, civil society, private partnerships, and academia—all of whose input will be essential to the greening of the urban areas. With the right policies, practices, and infrastructures in place, cities can be green models for efficient transport; water treatment, construction, and resource use (Mequignon et al., 2013). UNEP's Sustainable Buildings and Climate Initiative (SBCI) is a partnership of major public and private stakeholders in the buildings sector working to promote sustainable building policies and practices worldwide (Bertoldi, 2011; UNEP SBCI, 2007).

Most mitigation options for buildings have considerable and diverse co-benefits in addition to energy cost savings such as lower demand for water (Bansal et al., 2011). These include improvements in energy security, health (such as from cleaner wood-burning cook stoves), environmental outcomes, workplace productivity, health benefits, fuel poverty reductions and net employment gains (Miller et al., 2009; Zhang and Smith, 2007; WHO, 2009).

8. WASTE MANAGEMENT

The waste management sector makes a relatively minor contribution to GHG emissions, estimated at approximately 3-5% of total anthropogenic emissions in 2005 (Bogner et al., 2007; Astrup et al., 2009). UNEP (2010) has directed its International Environmental Technology Centre (IETC) branch to take action in the area of waste management, and considered it as the major saver of GHG emissions.

Every waste management practice generates GHG, both directly by emissions from the process itself and indirectly through energy consumption (ISWA, 2009). However, the overall climate impact or benefit of the waste management system depends on net GHG, accounting for both emissions and indirect, downstream GHG savings (IPCC, 2007). Currently developed nations generate the highest levels of methane, while those of developing are anticipated to increase significantly as better waste management practices lead to more anaerobic, methane producing conditions in landfills (Fruergaard et al., 2009).

There are substantial co-benefits of waste management in the context of climate change (Bahor et al., 2009; IPCC, 2014). To realize these co-benefits, the first step seeks (a) to examine the potential climate impacts and benefits of different waste management activities, and (b) to present a UNEP-led framework strategy to assist member countries in prioritising their resources and efforts for waste management and climate change mitigation (IPCC, 2014). Such programmes and projects include Integrated Solid Waste Management based on the 3R's (reduce, recycle, and reuse) approach, sustainable consumption and production, e-waste management, converting waste agriculture biomass and waste plastics into useful energy and/or material resources, and management of hazardous waste (UNEP, 2010). The framework strategy is intended to align with the internationally recognised waste management hierarchy, in which waste prevention receives the highest priority with reduction in environmental impacts and decrease methane emission, to optimise the co-benefits for climate change mitigation (UNEP, 2010; Bogner et al., 2008).

Waste management technologies have been implemented in Asian countries like Thailand, Cambodia and India with the aim of low GHG emission, efficient resource recovery, low energy inputs, low monetary investment, low environmental impacts and simple and easy to handle technology. In India, "waste to energy project" has been initiated by BIOTECH Ltd. in 2008 in Kerala and Trivandrum. The agency got success in use of waste food material as a resource for generation of biogas that eventually saved 30-50% of cooking gas.

The climate benefits of waste practices result from avoided landfill emissions, reduced raw material extraction and manufacturing, recovered materials and energy replacing virgin materials and fossil-fuel energy sources, carbon bound in soil through compost application, and carbon storage due to recalcitrant materials in landfill gas capture (US EPA, 2006; Monni et al., 2006). The informal waste sector makes a significant, but typically ignored, contribution to resource recovery and GHG savings in cities of developing nations (Sharholy et al., 2008; UN ESCAP, 2009).

Therefore, a central mechanism is needed to collaborate with existing organisations to ensure accessibility and dissemination of relevant information across the globe, effective use of resources to achieve climate benefit through integrated waste management, promotion of best practice, and rapid transfer of simple, effective, proven technologies and knowledge to developing countries (Sharholy et al., 2008; UN ESCAP, 2009). The waste sector has the potential to become a net contributor to global GHG reductions by promoting sustainable waste management (Smith et al., 2001; Kim and Dale, 2004; Boldrin et al., 2009).

9. CONCLUSION

The review highlights vital mitigation strategies that can be employed in different sectors (energy consumption, industrial level, in agricultural, forests and land ecosystems, construction of buildings and waste management sector)to overcome alarming climate change effects raised mainly by anthropogenic activities. Strategies planned in different sectors include carbon sequestration by capture increase, fuel switching, and use of renewable energy, enhancing environmental services, forest management, agro-forestry systems and reforestation. The direct impact of adopting such mitigation measures will promote sharing of responsibilities among sectors and will recognize the importance of preserving the biodiversity and scenic beauty of ecosystems. Also, systemic collaborative activities can reduce the total consumption of materials and energy and can contribute to the reduction of GHG emissions. Climate change mitigation helps in improving understanding of interactions among different sectors and economic sectors for sustainable development, better quality of life and well-being and international financial recognition for early actions.

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REFERENCES

1. Aggarwal, P. K., Joshi, H. C., Singh, S. D., Bhatia, A., Jain, N., Shiv, Prasad., Chaudhary, A., Gupta, N., Pathak, H., 2009. Agriculture and environment, In: Hand Book of Agriculture, Directorate of Information and Publication Agriculture, ICAR, New Delhi, pp. 62-92.
2. Allen, M. R., Frame, D. J., Huntingford, C., Jones, C.D., Lowe, J. A., Meinshausen, M., Meinshausen, N., 2009.Warming caused by cumulative carbon emissions towards the trillionth tonne.Nature 458, 1163 – 1166.
3. Allwood, J.M., Cullen, J.M., Milford R.L.,2010.Options for achieving a 50% cut in industrial carbon emissions by 2050. Environmental Science & Technology 44, 1888 – 1894.
4. Astrup, T., Mollee, J., Fruergaard, T., 2009.Incineration and co-combustion of waste: accounting of greenhouse gases and global warming contributions.Waste Management &Research 27, 789–799.
5. Bahor, B., Van Brunt, M., Stovall, J., Blue, K., 2009. Integrated waste management as a climate change stabilization wedge.Waste Management and Research27, 839–

849.
6. Bajželj, B., Allwood, J. M., Cullen, J. M., 2013. Designing climate change mitigation plans that add up.Environmental Science & Technology 47, 8062 – 8069.
7. Bansal, P., Vineyard, E., Abdelaziz, O., 2011.Advances in household appliances — a review. Applied Thermal Engineering 31, 3748 – 3760.
8. Bashmakov, I., 2009. Resource of energy efficiency in Russia: scale, costs, and benefits. Energy Efficiency 2, 369 – 386.
9. Beers, C., van, J.C.J.M., van den Bergh., 2001.Perseverance of perverse subsidies and their impact on trade and environment.Ecological Economics36, 457–486.
10. Bertoldi, P., 2011. Assessment and experience of white certificate schemes in the European union. JRC European Commission.
11. Bertoldi, P., Ciugudeanu, C. N., 2005. Successful examples of efficient lighting.European Commission, DG JRC, Institute for Environment and Sustainability, Renewable Energies Unit, Ispra, Italy.
12. Bogner, J., Pipatti, R., Hashimoto, S., Diaz, C., Mareckova, K., Diaz, L., et al., 2008. Mitigation of global greenhouse gas emissions from waste: conclusions and strategies from the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report. Waste Management and Research26,11–32.
13. Bogner, J., Abdelrafie Ahmed, M., Diaz, C., Faaij, A., Gao, Q., Hashimoto, S., Mareckova, K., Pipatti, R., Zhang, T., 2007. Waste management, in climate change - Mitigation. Contribution of working group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
14. Boldrin, A., Andersen, J. K., Moller, J., Favoino, E., Christensen, T. H., 2009. Composting and compost utilization: accounting of greenhouse gases and global warming potentials. Waste Management and Research27, 800–812.
15. Bose, Sperling., 2001. 'Transportation in Developing Countries – GHG Scenarios for Delhi'. Pew Centre on Global Climate Change. May.
16. Cherp, A., Adenikinju, A., Goldthau, A., Hernandez, F., Hughes, L., Jansen, J., Jewell, J., Olshanskaya, M.,Soares de Oliveira, R., Sovacool, B., Vakulenko, S., 2012. Energy and Security. In: Global energy assessment: toward a sustainable future. N. Nakicenovic, A. Patwardhan, L. Gomez-Echeverri, T. Johansson (eds.). Cambridge Univeristy Press, Laxenburg, Austria; Cambridge, UK & New York, USA, 325 – 384.
17. Chester, L. 2009. Conceptualising energy security and making explicit its polysemic nature. Energy Policy 38, 887 – 895.
18. Chhatre, A., Lakhanpal, S., Larson, A. M., Nelson, F., Ojha, H., Rao, J., 2012.Social safeguards and co-benefits in REDD+: a review of the adjacent possible. Current Opinion in Environmental Sustainability 4, 654 – 660.
19. de la Rue du Can, S., Price, L., 2008. Sectoral trends in global energy use and greenhouse gas emissions. Energy Policy 36, 1386 – 1403.
20. Deng, Y.Y., Blok, K., van der Leun, K., 2012. Transition to a fully sustainable, global energy system.Energy Strategy Reviews 1 (2), 109 – 121.
21. Doig, A., Adow, M., 2011.Low-carbon Africa: leapfrogging to a green future. christian aid. Available at: http: / / www.christianaid.org.Uk/resources/policy/climate/low-carbon-africa.aspx.
22. Dubois, G., Ceron, J.P., 2007. How heavy will the burden be? Using scenario analysis to assess future tourism greenhouse gas emissions. In: Peeters, P.M. (Ed.), Tourism and Climate Change Mitigation. Methods, Greenhouse Gas Reductions and Policies. NHTV, Breda.
23. EEA, 2003. Europe's Environment: The Third Assessment. Environmental assessment report No 10. European Environment Agency, Copenhagen.
24. FAO,2013. FAOSTAT. Available at: http://faostat.fao.org/site/626 DesktopDefault. aspx?626.
25. Fawcett, T., 2011.The future role of heat pumps in the domestic sector. In: Energy efficiency first: the foundation of a low carbon society. European council for an energy efficient economy summer study.ECEEE, Presqu'ilede Giens, France, 1547 – 1558.
26. Fischedick, M., Schaeffer, R., Adedoyin, A., Akai, M., Bruckner, T., Clarke, L., Krey, V., Savolainen, I., Teske, S., Ürge-Vorsatz, D., Wright, R., 2011. Mitigation potential and costs. In: IPCC special report on renewable energy sources and climate change mitigation. prepared by working group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlomer, C. von Stechow (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
27. Fruergaard, T., Astrup, T., Ekvall, T., 2009.Energy use and recovery in waste management and implications for accounting of greenhouse gases and global warming contributions. WasteManagement & Research 27, 724–737.
28. Gardner, T. A., Burgess, N. D.,Aguilar-Amuchastegui, N., et al.,2012.A framework for integrating biodiversity concerns into national REDD+ programmes. Biological Conservation 154, 61–71.
29. Ghosh, D., Roy, J., 2011. Approach to energy efficiency among micro, small and medium enterprises in India: results of a field survey. United Nations Industrial Development Organization, Vienna, 42.
30. Government of India, 2008. National Action Plan on climate change. Prime Minister's Council on Climate change.
31. Gwilliam, K., Kojima, K., Johnson, T., 2004: Reducing air pollution from urban transport. The World Bank 16.
32. Harper, R. J., Beck, A. C.,Ritson, P., Hill, M. J., Mitchell, C. D., Barrett, D. J., Smettem, K. R. J.,Mann, S. S., 2007. The potential of greenhouse sinks to underwrite improved land management. Ecological Engineering 29, 329 – 341.
33. Harvey, L. D. D., 2008. Energy savings by treating buildings as systems. In: Physics of sustainable energy: using energy efficiently and producing it renewably. American Institute of Physics, Berkeley, California. 67 – 87.
34. IEA, 2013. IEA Online Data Services. Available at: http: / / data.iea.org / ieastore / statslisting.asp.
35. IEA, 2012 a.CO_2emissions from fuel combustion.Beyond 2020 Online Database.International Energy Agency, Paris, 83. Available at: http: / / data.iea.org.
36. IEA, 2012c. Energy technology perspectives: Pathways to a Clean Energy System. International Energy Agency, Paris, France, 700.
37. IEA, 2006a. Energy technology perspectives: Scenarios & Strategies to 2050. International Energy Agency, Paris, 479.
38. IEA, 2006d: CO_2 Emissions from fuel combustion 1971-2004. International Energy Agency, Paris, 548.
39. IEA, 2003: Transport technologies and policies for energy security and CO_2 reductions. Energy technology poli-

cy and collaboration papers, International Energy Agency, ETPC paper no 02/2003.
40. IEA, 2001: Saving oil and reducing CO_2 emissions in transport. International Energy Agency, OECD, 194.
41. India's Initial National Communication on climate change, 2004.
42. International Solid Waste Association (ISWA), 2009.Waste and Climate Change – ISWA White Paper.
43. IPCC, 2014.Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
44. IPCC, 2007.Climate Change Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, L. A. Meyer (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 862pp. Available at: http: / / www.ipcc. Ch / publications_and_data / ar4 / wg3 / en / contents.html.
45. IPCC, 2006. National greenhouse gas inventory guidelines [S. Eggelston, L. Buendia, K. Miwa, T. Ngara, K. Tanabe (eds.)]. Institute of Global EnvironmentalStrategies (IGES), Kanagawa, Japan, 20.
46. JHFC, 2006. JHFC well-to-wheel efficiency analysis results. JARI, Tsukuba, 114.
47. Jones, P., 2004.Comments on the roles of soft measures in achieving EST.In communicating environmentally sustainable transport: the role of soft measures. OECD, 63-66.
48. Kelly, T. D., Matos, G. R., 2013. Historical statistics for mineral and material commodities in the United States (2013 version): U. S. Geological Survey Data Series 140. Available at: http://minerals.usgs.gov/ds/2005/140/.
49. Kim, S., Dale, B.E., 2004.Global potential bioethanol production from wasted crops and crop residues. Biomass and Bioenergy 26(4), 361–375.
50. Köppl, A., Kettner, C., Kletzan-Slamanig, D.,Schnitzer, H., Titz, M.,Damm, A., Steininger, K., Wolkinger, B., Artner, H., Karner, A., 2011.Energy transition 2012\2020\2050 strategies for the transition to low energy and low emission structures (Final Report). ÖsterreichischesInstitutFürWirtschaftsforschung, Vienna, Austria, 38.
51. Kuik, O. J., Bastos-Lima, M., Gupta, J., 2011.Energy security in a developing world.Climate Change 2, 627 – 634.
52. Lee, D.S., Owen, B., Graham, A., Fichter, C., Lim, L.L., Dimitriu, D., 2005. International aviation emissions allocations - present day and historical. Manchester Metropolitan University, Centre for Air Transport and the Environment, Report CATE 3(C)-2.
53. Leemans, R., Eickhout, B., 2004. Another reason for concern: regional and global impacts on ecosystems for different levels of climate change. Global Environmental Change Part A 14, 219 – 228.
54. Litman, T., 2003. The online TDM Encyclopedia: mobility management information gateway. Transport Policy, 10, 245–249.
55. Liu, N., Ang, B. W., 2007. Factors shaping aggregate energy intensity trend for industry: Energy intensity versus product mix. Energy Economics 29, 609 – 635.
56. McKinley, G., Zuk, M., Hojer, M., Ávalos, M., González, I., Hernández, M., Iniestra, R., Laguna, I., Martínez, M.A., Osnaya, P., Reynales, L.M., Valdés, R., Martínez, J., 2003. The local benefits of global air pollution control in Mexico City. InstitutoNacional de Ecologia, InstitutoNacional de SaludPublica, Mexico.
57. Meinshausen, M., Meinshausen, N., Hare, W., Raper, S. C., Frieler, K., Knutti, R., Frame, D. J., Allen, M. R. 2009. Greenhousegas emission targets for limiting global warming to 2 °C.Nature 458, 1158 – 62.
58. Mequignon, M., Ait Haddou, H., Thellier, F., Bonhomme, M., 2013. Greenhouse gases and building lifetimes.Building and Environment68, 77 – 86.
59. Ministry of Environment, Forests and climate change, Government of India, 2014. India's progress in combating climate change. Briefing paper for UNFCCC COP 20 Lima, Peru.
60. Miller, N. G., Pogue, D., Gough, Q. D., Davis, S. M., 2009. Green buildings and productivity.The Journal of Sustainable Real Estate 1, 65 – 89.
61. Monni, S., Pipatti, R., Lehtilla, A., Savolainen, I., Syri, S., 2006. Global climate change mitigation scenarios for solid waste management. Technical Research Centre of Finland.VTT Publications, Espoo.
62. Moriarty, P., Honnery, D., 2012. What is the global potential for renewable energy? Renewable and Sustainable Energy Reviews 16, 244 – 252.
63. Morita, T., et al., 2001. Greenhouse gas emission mitigation scenarios and implications.Storylines of post-SRES mitigation scenarios missing or empty in IPCC TAR WG3 149–150.
64. Murdiyarso, D., Brockhaus, M., Sunderlin, W. D., Verchot, L., 2012.Some lessons learned from the first generation of REDD+ activities. Current Opinion in Environmental Sustainability 4, 678 – 685.
65. Murthy, I. K., Tiwari, R., Ravindranath, N. H., 2011. Climate change and forests in India: adaptation opportunities and challenges. Mitigation and Adaptation Strategies for Global Change 16, 161 – 175.
66. Murthy, I. K., Tiwari, R., Ravindranath, N. H., 2011. Climate change and forests in India: adaptation opportunities and challenges. Mitigation and Adaptation Strategies for Global Change 16, 161 – 175.
67. Musall, E., Weiss, T., Lenoir, A., Voss, K., Garde, F., Donn, M., 2010.Net zero energy solar buildings: an overview and analysis on worldwide building projects. In: EuroSun conference.
68. OECD, 2011.OECD Science, technology and industry scoreboard 2011: Innovation and growth in knowledge economies.Paris, France, 204.
69. Pandey, R. S.., 2010. Need to diversity the energy basket livemint.com.
70. Pandit, M. K.,Grumbine, R. E., 2012.Potential effects of ongoing and proposed hydropower development on terrestrial biological diversity in the Indian Himalaya.Conservation Biology 26, 1061 – 1071.
71. Pathak, H., 2010. Mitigating greenhouse gas and nitrogen loss with improved fertilizer management in rice: Quantification and economic assessment. Nutr. Cycling Agroecosys. 87: 443-454.
72. Peeters, P.M., Middel, J., 2007. Historical and future development of air transport fuel efficiency. In: Sausen, R., Blum, A., Lee, D.S., Brüning, C. (eds.), Proceedings of an International Conference on Transport, Atmosphere and Climate (TAC); Oxford, United Kingdom, 26th to 29th June 2006.
73. Ravindranath, N. H., 2007. Mitigation and adaptation synergy in forest sector.Mitigation and Adaptation Strategies for Global Change 12, 843 – 853.
74. Reddy, B. S., Ray, B. K., 2010.Decomposition of energy consumption and energy intensity in Indian manufacturing industries. Energy for Sustainable Development 14, 35 – 47.

75. Ribeiro, K.S., Kobayashi, S., Beuthe, M., Lee, D. S., Muromachi, Y., Newton, P. J., Plotkin, S., Sperling, D., Wit, R., Zhou, P. J., 2007. Transport and its infrastructure. In: Climate Change Mitigation. Contribution of Working Group III to the IPCC Fourth Assessment Report. [B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, L. A. Meyer (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, USA, 324 – 385.
76. Rosenzweig, C., Tubiello, F. N., 2007. Adaptation and mitigation strategies in agriculture: an analysis of potential synergies. Mitigation, Adaptation Strategies to Global Change 12, 855 – 873.
77. Sanyo, 2005.On-line catalog, <http://www.sanyo.co.jp/energy/english/ product/lithiumion_2.html> accessed 30/05/07.
78. Saygin, D., Worrell, E., Patel, M. K., Gielen, D. J., 2011. Benchmarking the energy use of energy-intensive industries in industrialized and in developing countries.Energy 36, 6661 – 6673.
79. Scott, M. J., Roop, J. M., Schultz, R. W., Anderson, D. M., Cort, K. A., 2008.The impact of DOE building technology energy efficiency programs on US employment, income, and investment. Energy Economics 30, 2283 – 2301.
80. Sharholy, M., Ahmad, K., Mahmood, G., Trivedi, R.C., 2008.Municipal solid waste management in Indian cities – A review. Waste Management 28, 459–467.
81. Skjølsvik, K.O., 2005. Natural gas used as ship fuel; Norway heads the development. In Navigare.Oslo, Norway.
82. Smith, P., Bustamante, M., Ahammad, H., et al., 2014: Agriculture, Forestry and Other Land Use (AFOLU). In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R.Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
83. Smith, P., Ashmore, M. R., Black, H. I. J., Burgess, P. J., Evans, C. D., Quine, T. A., Thomson, A. M., Hicks, K. Orr, H. G., 2013. The role of ecosystems and their management in regulating climate, and soil, water and air quality.Journal of Applied Ecology 50, 812 – 829.
84. Smith, et al., 2001. Waste management options and climate change – final report to the European Commission, DG Environment; and Dehoust et al (Oko-Institute.V.) AEA Technology.
85. UNEP, 2010. Are you a green leader? Business and biodiversity: making the case for a lasting solution. Paris, United Nations Environment Programme.
86. UN ESCAP, 2009. Economic and social survey of Asia and the Pacific – addressing triple threats to development.
87. UNCTAD, 2008. World Investment Report 2008.Transnational Corporations and the Infrastructure Challenge. United Nations, New York, 294.
88. UNFCCC, 2002. Full text of the convention, Article 2: objectives.
89. UNEP, SBCI, 2007. Assessment of policy instrument for reducing greenhouse gas emissions from buildings. United Nations Environment programme sustainablebuildings and construction initiative, Paris, France, 12.
90. US Environmental Protection Agency (US EPA), 2006. Global Anthropogenic Non-CO_2greenhouse gas emissions: 1990-2020. U.S. Environmental Protection Agency, Office of Atmospheric Programs, Climate Change Division.
91. Velavan, R., Rudramoorthy, R., Balachandran, S., 2009.CO_2 emission reduction opportunities for small and medium scale textile sector in India. Journal of Scientific and Industrial Research 68, 630 – 633.
92. Verbruggen, A., Moomaw, W., Nyboer, J., 2011. Annex I: glossary, acronyms, chemical symbols and prefixes. In: IPCC special report on renewable energy sources and climate change mitigation. Prepared by working group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlomer, C. von Stechow (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
93. VTPI (Victoria Transport Policy Institute), 2005.TDM encyclopedia, transportation elasticities.http://www.vtpi.org/tdm/tdm11.htm accessed 30/05/07.
94. WBCSD, 2007.Energy efficiency in buildings facts and trends.World business council for sustainable development, Geneva, Switzerland.
95. WHO, 2009.Global health risks: mortality and burden of disease attributable to selected major risks. World Health Organization, Geneva, Switzerland, 62.
96. Winzer, C., 2012.Conceptualizing energy security.Energy Policy 46, 36 – 48.
97. World Bank, 2013. World Bank data — Economic Policy and External Debt. Available at: http: / / data.worldbank.org / topic / economic-policy-and-external-debt.
98. Yuasa, 2000.Development of high capacity Li batteries with Mn type cathode (in Japanese).4.20.
99. Zhang, J. J., Smith, K. R., 2007. Household air pollution from coal and biomass fuels in China: measurements, health impacts, and interventions. Environmental Health Perspectives 115, 848.

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Climate Change Adaptation-Mitigation Technologies and the Problem of Electronic Waste

Anwesha Borthakur*
Centre for Studies in Science Policy, Jawaharlal Nehru University (JNU),
New Delhi-110067, India.
***Corresponding Author:** anweshacug@gmail.com

Abstract— Climate change and its relation to waste menace is relatively an unexplored area of research, deprived of its due attention. In the era of assorted anthropogenic activities which take an inevitable toll on the earth's climate, adaptation and mitigation measures towards combating climate change become utmost priority. Most of the climate change alleviation attempts involve some form of technological intervention(s). Be it the early warning systems or improved water treatment facilities, solar panels and earth observation systems towards accurate weather forecasts- all are reliant on technological interventions. *As technological solutions become central to climate change combating interferences, the burgeoning problem of **Electronic waste (E-waste)** arises.* E-waste is nothing but a form of technological waste consisting of obsolete electronic and electrical appliances. In this paper, we argue that although climate change technologies have contributed significantly towards combating climate change, at the same time, it is responsible for contributing to the ever growing mount of E-waste globally. An attempt has been carried out to figure out a range of climate change adapting technologies, their material composition and eventual outcome as E-waste. Major E-waste management challenges in India have been addressed with special focus to the *city of **Pune, Bangalore and the State of Assam***. An analysis of the informal recycling sector involving a large number of urban poor (especially in countries like ***India and China***) and its socio-economic-environmental-health hazards are assessed. Basically secondary sources of data were evaluated. Results show that a significant number of the initiatives towards combating climate change involve some form of technology. The electrical and electronic equipments involved with these technologies will become obsolete after a specific period of time and eventually would contribute to the E-waste stream. Thus, while ***combating** a serious global issue* in the form of climate change, we are ***creating** another* by generating the toxic pile of E-waste. Climate change and its relation to waste menace have the potential to challenge the notion of climate justice. It calls for an integrated approach where climate change and waste, both could be dealt with sustainably.

Keywords: Climate Change; E-waste; Management; Climate Change Technologies; Health

1. INTRODUCTION

Debates around climate change and its potential detrimental consequences have been discussed extensively in the last two decades. International commitment to sustainable development (meeting the needs of the present without compromising the ability of future generations to meet their needs) took a new direction following the 1992 United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil (Stringer et al , 2009). Along with Agenda 21 (1992), three multi-lateral environment conventions were ratified and entered into force: the United Nations Framework Convention on Climate Change (UNFCCC); the United Nations Convention on Biological Diversity (UNCBD); and the United Nations Convention to Combat Desertification (UNCCD) (Stringer et al , 2009). The objective of UNFCCC (Article 2) is "to stabilize greenhouse gas (GHG) concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system within a time frame sufficient enough to allow ecosystems to adapt naturally to climate change, to ensure that the food production is not threatened and to ensure that economic development proceeds in a sustainable manner" (Singh, 2008). In brief, the UNFCCC attempts to stabilise greenhouse gas concentrations at a level which would avert perilous anthropogenic interventions with the climate system. In order to achieve this goal, climate change adaptation and mitigation measures have become central themes of the debates surrounding the issues related to climate change. It is evident that many of the climate change adaptation and mitigation measures are based on technological interventions. For instance, be it the early warning systems or improved water treatment facilities, solar panels and earth observation systems towards accurate weather forecasts- all are reliant on technological interventions. These technological interventions, in turn, have vast potential to produce "technological waste" in the form of "E-waste". E-waste is a problem encountered by almost all the countries across the globe today. However, developing countries face much bigger problem from E-waste due to various reasons like: (1) technological upgradation either from advancement or import, (2) increased production of electronic products year after year and, (3) developed countries continuously dump their E- waste to these countries (Pant, 2013).

In this paper, we argue that as technological solutions become central to many climate change combating initiatives, the burgeoning problem of Electronic waste (E-waste) arises. The electrical and electronic equipments involved with these technologies will become obsolete after a specific period of time and eventually would contribute to the E-waste stream. Thus, while ***combating*** *a serious global issue* in the form of climate change, we are ***creating*** *another* by generating the toxic pile of E-waste.

2. The Problem of E-waste

The development of science and technology stimulates the production of electrical and electronic equipment (EEE), and continuous product updates and short lifespan are driving forces for the large amounts of waste EEE (WEEE) (Pant, 2013). In recent years, achieving efficient Waste Electrical and Electronic Equipment (WEEE) management has become a key goal, not only due to the pollution that could potentially result from the hazardous substances its components contain but also because reusing its materials can be an important potential supply of resources (Perez-Belis et al, 2013). The generation of reliable data on the exact amount of E-waste generated in different regions of the world is difficult to achieve as the amount of used E-waste reaching their end-of-life cannot be measured directly with some reliability (Pariatamby & Victor, 2013). Lack of dependable data regarding the generation of E-waste further complicates the problem as it is difficult to devise appropriate management and policy initiatives without data on the generation. Most of the estimates available are based upon predictions made towards production or sales data and estimated life span of E-waste (Pariatamby & Victor, 2013). However, in most of the times, such data are difficult to gather and analyse. According to studies conducted in the European Union, E-waste is growing at a rate of 3–5 % per annum or approximately three times faster than other individual waste streams in the solid waste sector (Perez-Belis et al., 2013). Apart from the domestic generation, one of the major E-waste problem in developing countries arises from the importation of E-waste and electronic goods from developed countries because it is the older, less ecologically friendly equipment that is discarded from these Western countries (Kiddee et al, 2013). Poor legislative measures, cheap labour and lack of health and safety protocols in these countries encourage such exports. E-waste is one of the most rapidly growing problems throughout the world, which has serious future concerns over its management and recycling (Pant, 2013). Greater attention needs to be paid to this issue given the rate at which the production of this type of waste is growing, as a direct consequence of the accelerated technological progress, the drop in prices of consumer electronic goods and the new needs of users (Perez-Belis et al., 2013). Otherwise, E-waste will continue to grow at a faster pace causing serious intimidation to the mankind.

3. Climate Change Adaptation and Mitigation Technologies

Climate change adaptation and mitigation measures become central to most of the climate change combating initiatives. With the increasing impacts of climate change being experienced by the world, such initiatives are exceedingly significant. As stated earlier, many of the climate change adaptation and mitigation technologies involve technological interventions.This is evident from the list of such technologies and strategies formulated by Intergovernmental Panel for Climate Change (IPCC). Especially, climate change mitigation measures involve increasing technological interventions. Table 1 and Table 2 are showing some of the sector-wise climate change adaptation and mitigation strategies and technologies as suggested by IPCC.

4. Climate Change: Adaptation/Mitigation Technologies and its Relation to E-waste

It has been observed from the lists of the preceding section that many of the climate change adaptation and mitigation technologies are based on the following components:

1. Centralised data processing units

2. Other products or equipments of transmitting sound, images or other information by telecommunications,

3. Products or equipment for the purpose of recording or reproducing sound or images, including signals or other technologies for the distribution of sound and image than by telecommunications.

All these three components are listed among the categories of products resulting in E-waste according to the European Union's (EU) WEEE directive (EC, 2003) which is the most widely accepted framework related to E-waste at a global scale. For instance, as per the list of technologies for mitigation of current and future climate change provided by EPA, several of such technologies are based on the above components listed in the EU's WEEE Directive. Further, ICT is an important component of many of the climate change combating initiatives for dissemination of information. Be it agriculture, animal husbandary or energy and transport, ICT is an integral component of several such sectors. There are whole sets of ICT equiments listed in the European Union's WEEE directive. These equipments are nothing but potential E-waste stored at several different areas which are currently being used for climate change combating initiatives. One suitable example to describe the relationship between climate change mitigation technologies and E-waste is electric cars.

Table 1: Climate Change Adaptation Strategies

Sector	**Adaptation Options/Strategies**	**Underlying policy framework**	**Key constraints and opportunities to implementation (Normal font = constraints; italics = opportunities)**
Water	Expanded rainwater harvesting; water storage and conservation techniques; water reuse; desalination; water-use and irrigation efficiency	National water policies and integrated water resources management; water-related hazards management	Financial, human resources and physical barriers; *integrated water resources management; synergies with other sectors*
Agriculture	Adjustment of planting dates and crop variety; crop relocation; improved land management, e.g. erosion control and soil protection through tree planting	R&D policies; institutional reform; land tenure and land reform; training; capacity building; crop insurance; financial incentives, e.g. subsidies and tax credits	Technological and financial constraints; access to new varieties; markets; *longer growing season in higher latitudes; revenues from 'new' products*
Infrastructure/Settlement	Relocation; seawalls and storm surge barriers; dune reinforcement; land acquisition and creation of marshlands/wetlands as buffer against sea level rise and flooding; protection of existing natural barriers	Standards and regulations that integrate climate change considerations into design; land-use policies; building codes; insurance	Financial and technological barriers; availability of relocation space; *integrated policies and management; synergies with sustainable development goals*
Human Health	Heat-health action plans; emergency medical services; improved climate-sensitive disease surveillance and control; safe water and improved sanitation	Public health policies that recognise climate risk; strengthen health services; regional and international cooperation	Limits to human tolerance (vulnerable groups); knowledge limitations; financial capacity; *upgraded health services; improved quality of life*
Tourism	Diversification of tourism attractions and revenues; shifting ski slopes to higher altitudes and glaciers; artificial snow-making	Integrated planning (e.g. carrying capacity; linkages with other sectors); financial incentives, e.g. subsidies and tax credits	Appeal/marketing of new attractions; financial and logistical challenges; potential adverse impact on other sectors (e.g. artificial snow-making may increase energy use); *revenues from 'new' attractions; involvement of wider group of stake-*

			holders
Transport	Realignment/relocation; design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Integrating climate change considerations into national transport policy; investment in R&D for special situations, e.g. permafrost areas	Financial and technological barriers; availability of less vulnerable routes; *improved technologies and integration with key sectors (e.g. energy)*
Energy	Strengthening of overhead transmission and distribution infrastructure; underground cabling for utilities; energy efficiency; use of renewable sources; reduced dependence on single sources of energy	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources; incorporating climate change in design standards	Access to viable alternatives; financial and technological barriers; acceptance of new technologies; *stimulation of new technologies; use of local resources*

Source: IPCC, 2007 (Climate Change 2007: Synthesis Report)

Table 2: Climate Change Mitigation Strategies/Technologies

Sector	**Key mitigation technologies and practices currently commercially available. Key mitigation technologies and practices projected to be commercialised before 2030 shown in italics**	**Policies, measures and instruments shown to be environmentally effective**	**Key constraints and opportunities to implementation (Normal font = constraints; italics = opportunities)**
Energy	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO2 from natural gas); *CCS for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy*	Reduction of fossil fuel subsidies; taxes or carbon charges on fossil fuels, Feed-in tariffs for renewable energy technologies; renewable energy obligations; producer subsidies	Resistance by vested interests may make them difficult to implement, *May be appropriate to create markets for low emissions technologies*
Transport	More fuel-efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning; *second generation*	Mandatory fuel economy; biofuel blending and CO2 standards for road transport Taxes on vehicle purchase, registration, use and motor	Partial coverage of vehicle fleet may limit effectiveness, Effectiveness may drop with higher incomes, *Particularly appropriate for countries*

	biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries	fuels; road and parking pricing, Influence mobility needs through land-use regulations and infrastructure planning; investment in attractive public transport facilities and non-motorised forms of transport	*that are building up their transportation systems*
Building	Efficient lighting and day lighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycling of fluorinated gases; *integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar photovoltaics integrated in buildings*	Appliance standards and labelling, Building codes and certification, Demand-side management programmes, Public sector leadership programmes, including procurement, Incentives for energy service companies (ESCOs)	Periodic revision of standards needed, Attractive for new buildings. Enforcement can be difficult, Need for regulations so that utilities may profit. *Government purchasing can expand demand for energy-efficient products, Success factor: Access to third party financing*
Industry	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-CO2 gas emissions; and a wide array of process-specific technologies; *advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture*	Provision of benchmark information; performance standards; subsidies; tax credits Tradable permits Voluntary agreements	*May be appropriate to stimulate technology uptake*, Stability of national policy important in view of international competitiveness, Predictable allocation mechanisms and stable price signals important for investments, Success factors include: clear targets, a baseline scenario, third-party involvement in design and review and formal provisions of monitoring, close cooperation between government and industry
Agriculture	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH4 emissions; improved nitrogen fertiliser application techniques to reduce N2O emissions; *dedicated energy crops to replace fossil fuel use; improved energy efficiency; improvements of crop yields*	Financial incentives and regulations for improved land management; maintaining soil carbon content; efficient use of fertilisers and irrigation	May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation
Forestry	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use; *tree species improvement to increase biomass productivity and carbon sequestration; improved remote sensing technologies for analysis of vegetation/soil*	Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests; land-use regulation and enforcement	Constraints include lack of investment capital and land tenure issues. *Can help poverty alleviation.*

	carbon sequestration potential and mapping land-use change		
Waste	Landfill CH_4 recovery; waste incineration with energy recovery; composting of organic waste; controlled wastewater treatment; recycling and waste minimisation; *biocovers and biofilters to optimise CH_4 oxidation*	Financial incentives for improved waste and wastewater management, Renewable energy incentives or obligations, Waste management regulations	*May stimulate technology diffusion*, Local availability of low-cost fuel Most effectively applied at national level with enforcement strategies

Source: IPCC, 2007 (Climate Change 2007: Synthesis Report)

Table 3: Component and Compositions of Computers

Computer Component	Element/Compound	Mineral Source of Element
Monitor		
Phosphorescent Coating - Transition Metals:		
ZnS - Zinc Sulfide	Zn, S	Sulfur, Hemmimorphite, Zincite Smithsonite, Franklenite
Ag - Silver	Ag	Ag, Pyrargyrite, Cerargyrite
Cl - Chlorine	Cl	Halite
Al - Aluminum	Al	Bauxite
Cu - Copper	Cu	Chalcopyrite, Boronite, Enargite, Cuprite, Malachite, Azurite, Chrysocolla, Chalcocite
Au - Gold	Au	Gold
Y2O2S - Yittrium Sulfate	Y	
Eu - Europium	Eu	
(KF, MgF2): Mn Potasium-Magnesium Floride: Manganese	K, F, Mg, Mn	Alunite, Orthoclase, Nephelite, Leucite, Apophullite; Flourite, Cryolite, Vesuvianite; Lepidolite: Dolomite, Magnesite, Espomite, Spinel, Olivine, Pyrope, Biotite, Talc
(Zn,Cd)S - Zinc Cadmium Sulfate	Cd	
Zn2SiO4:O4: Mn, As - ZincSilicate, Manganese, Arsenic	As	Realgar, Orpiment, Niccolite, Cobalite, Arsenopyrite, Tetrahedrite
Gd2O2S: Tb - Gadolinium Sulfate: Tebrium	Gd, Tb	
Y2SiO12:Ce - Yitrium Silicate: Cerium	Ce	Monzanite, Orthite
CRT Glass:		
Pb - Lead	Pb	Galena, Cerussite, Anglesite, Pyromorphite
SiO2	Si	Quartz
Plastic Case, Keyboard		
Thermoplastic - Polypropylene, PVC		
CaCO2 - additive	Ca	Calcite, Gypsum, Apatite, Aragonite
TiO2 - White Pigment	Ti	Rutile, Ilmenite, Titanite
Amonium Polyphosphate	P	Apetite, Pyromorphite, Wavellite

Liquid Crystal Display (LCD) Monitors		
Pb - Lead	Pb	Galena, Cerussite, Anglesite, Pyromorphite
Thin Film Transistors	Si	Quartz
Ferro Electric Liquid Crystal	Fe	Hematite
Indium Tin Oxide	Sn	Cassiterite,
	In	Sphalerite (Commonly found with Zinc)
Metal Case		
Iron	Fe	Magnetite, Limonite
Flat Screen Plasma Display Monitors		
Glass	Si	Quartz
Pb - Lead	Pb	Galena, Cerussite, Anglesite, Pyromorphite
ZnS - Zinc Sulfide	Zn, S	Sulfur, Hemmimorphite, Zincite, Smithsonite, Franklenite
Ag - Silver	Ag	Ag, Pyrargyrite, Cerargyrite
Cl - Chlorine	Cl	Halite
Al - Aluminum	Al	Bauxite
Cu - Copper	Cu	Chalcopyrite, Boronite, Enargite, Cuprite, Malachite, Azurite, Chryssocolla, Chalcocite
Au - Gold	Au	Gold
Y2O2S - Yittrium Sulfate	Y	Euxenite
Eu - Euopium	Eu	Euxenite
(KF, MgF2): Mn Potasium-Magnesium Florite: Manganese	K, F, Mg, Mn	Alunite, Orthoclase, Nephelite, Leucite, Apophullite; Flourite, Cryolite, Vesuvianite; Lepidolite: Dolomite, Magnesite, Espomite, Spinel, Olivine, Pyrope, Biotite, Talc
(Zn, Cd) S - Zinc Cadmium Sulfate	Cd	
Zn2SiO4: Mn, As - ZincSilicate, Manganese, Arsenic	As	Realgar, Orpiment, Niccolite, Cobalite Arsenopyrite, Tetrahedrite
Gd2O2S: Tb - Gadolinium Silicate: Tebrium	Gd, Tb	
Y2SiO12: Ce - Yitrium Silicate: Cerium	Ce	Monzanite, Orthite
Printed Circuit Boards, Computer Chips:		
Silicon	Si	Quartz
Cu - Copper	Cu	Chalcopyrite, Boronite, Enargite, Cuprite, Malachite, Azurite, Chrysocolla, Chalcocite
Au - Gold	Au	Gold
Ag - Silver	Ag	Ag, Pyrargyrite, Cerargyrite
Tin	Sn	Cassiterite
Al - Aluminum	Al	Bauxite

There are 66 individual minerals that contribute to the typical computer that are identified above. There are others, in addition to those listed above, but it should be evident that without many minerals, there would be no computers, or televisions, for that matter.

Source: Mine-Engineer.com

Electric cars are being popularised as a less polluting transportation option. However, once become obsolete, these cars will add to the E-waste stream. Similar is the case with components of solar energy, geothermal energy, early warning systems, health surveillance systems and earth observation systems etc. Again, be it wind, geothermal or any other form of energy, all require generators having electrical component and thus have the potential to contribute to the problem of E-waste.

Considering the simplest of examples, computers are integral part of early warning systems and earth observation systems along with many other technologies for addressing climate change. Then again, it is one of the most omnipresent equipments in the E-waste stream. Compositions of computers are incredibly miscellaneous involving a large of number of chemical toxicants, including heavy metals, which pose serious threats to the human health and the environment (MoEF, 2008). With more surveillance systems in place for attempting serious climate change challenges, the number of computers and related hardware are expected to experience a rapid rise. Thus, it has the potential to be a serious threat to the earth's existing toxic waste stream.

5. Conclusion

It has been observed that there is a relationship between climate change combating technologies and E-waste. This is evident from the increasing use of ICT equipments especially in surveillance systems, electric cars, etc which will subsequently add to the E-waste stream. The uses of these technologies are growing at a rapid pace. These technologies are popularised by the climate change advocates and such technologies will definitely grow unabated in the near future. It is true that we cannot do without these technologies. These technologies are increasingly essential to safeguard the planet and mankind. However, today, it is high time to think about the impacts of these technologies and their associated equipments once become obsolete. Technological waste in the form of E-waste is already a severe problem across the globe. One would never want to add to this toxic waste stream. Therefore, today, it is essential to address the technological interventions on climate change from its roots. For instance, several indigenous knowledge and technologies might be useful in this context of combating climate change. We should focus on such initiatives along with other sustainable options. It is because while ***combating*** *a serious global issue* in the form of climate change, we do not want to ***create*** *another* by generating the toxic pile of E-waste.

REFERENCES

1. IPCC (2007). *Climate Change 2007: Synthesis Report.* Available at: http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms4.html#table-spm-4)
2. Kiddee, P., Naidu, R., & Wong, M. H. (2013). Electronic waste management approaches: An overview. *Waste Management, 33*(5), 1237-1250. doi: DOI 10.1016/j.wasman.2013.01.006

3. MoEF (2008). *Guidelines for environmentally sound management of e-waste (MoEF Letter No. 23-23/2007-HSMD). Delhi, India: Ministry of Environment & Forests, Central Pollution Control Board*.
4. Pant, D. (2013). E-waste projection using life-span and population statistics. *International Journal of Life Cycle Assessment, 18*(8), 1465-1469. doi: DOI 10.1007/s11367-013-0596-y
5. Pariatamby, A., & Victor, D. (2013). Policy trends of e-waste management in Asia. *Journal of Material Cycles and Waste Management, 15*(4), 411-419. doi: DOI 10.1007/s10163-013-0136-7
6. Perez-Belis, V., Bovea, M. D., & Gomez, A. (2013). Waste electric and electronic toys: Management practices and characterisation. *Resources Conservation and Recycling, 77*, 1-12. doi: DOI 10.1016/j.resconrec.2013.05.002
7. Stringer L.C., Serban Scrieciu S., & Reed M.S. (2009). Biodiversity, land degradation, and climate change: Participatory planning in Romania. *Applied Geography,* 29, 77–90
8. Singh, P.P. (2008). Exploring biodiversity and climate change benefits of community-based forest management. *Global Environmental Change*, 18, 468– 478

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Women as Key Agents of Climate Change Adaptation

Sakshi Saini [1*] and Savita Aggarwal[1]
[1]Department of Communication and Extension
Institute of Home Economic, University of Delhi (Delhi)
***Corresponding author:** sakshi.saini.02@gmail.com

Abstract— Women constitute a large share of the world's poor and lag behind men in education, income, and health. In the developing countries, women play multiple roles as providers, cultivators and care givers to the family members. They are more concerned about environmental issues because of their close association and have a key role in tackling climate change as consumers, educators and change agents in homes and society. They are also innovators, organizers with good social networking skills, which position them uniquely to minimise the harmful impacts of climate change on their families. They have the potential in terms of experience and a strong body of indigenous knowledge to combat the increased disaster risks and enable their families to cope with climate change. However, socio-cultural barriers and women's traditional roles confine them to home giving them little time to participate in community discussions, leadership and in taking action in their own homes for appropriate adaptation and mitigation strategies (UNDP, 2010). Their perspectives and needs are often not heard in policy formulation. Given the knowledge and skills, women can find sustainable solutions to reduce the vulnerability of their families to climate change. Studies have shown that women cope to environmental stress by spending less time on household work, cutting down on leisure time, taking help of children or other family members. Women report cutting down time on income generating activities. The coping strategies adopted by them involved a considerable amount of risk taking as they interfered not only with the household work but also with their income generating activities, education of girls and other opportunities for skill development. Several coping strategies were not sustainable since they shifted the negative impact to alter time or another target group and were in fact equivalent to maladaptation. The paper highlights the positive role that awareness and knowledge enhancement of women can play in dealing with climate stresses, extremes and disasters in a positive way. It is therefore essential to engage women in initiatives to build adaptive capacity to deal with climate change and enable them to lead more empowered lives.

Keywords: Coping Strategies, Climate Change, Gendered Impact, Women, Adpative Capacity

1. Introduction

Climate change brings with it drought, floods, heat episodes, deforestation and scarcity of natural resources making the lives of poor women in developing countries much harder since they have to struggle much more to fulfill their roles and responsibilities. Women spend large amounts of time in accession and management of prime resources such as food, fodder, fuel-wood and freshwater for their families. Climate change coupled with urbanization, modernization and industrialization is expected to increase the existing shortfalls in water and fuel wood, thus increasing the time taken by women in the accession of these resources. Besides this, climatic stresses and extremes magnify the care giving burdens of women due to increased disease load, thereby diminishing their role in non-traditional activities of income generation further confining women to the home (UNDP, 2009; Nellemann, et al. 2011). Thus there are both direct and indirect impacts of climate change on women and figure 1 summarises the likely impacts of climate change on women.

The direct impacts of climate change constitute increased droughts and accompanied water shortages, increased weather events such as cyclones, floods, heat waves and hurricanes. As a result of these climatic extremes, more women are likely to have injuries and fatalities. This has been shown by a study conducted on disasters in 141 countries during the period 1981-2002 indicating that natural disasters lowered the life expectancy of women more than that of men, especially in lower socio-economic strata of society (Neumayer and Plumper, 2007). The indirect impacts of climate change are increased epidemics, decreased food security due to decreased crop production and loss of species due to decreased biodiversity. The gender based intra-household distribution of food becomes magnified and acute during extreme events or disasters. This has been shown by studies conducted in four flood-affected districts of Bihar and Eastern Uttar Pradesh in India, where women and girls were expected to reduce their food consumption substantially during environmentally stressful periods. The calorie intake of women reduced from 1000 calories in normal times to a mere 300 calories during the period of floods and went up to only 500 calories in the post flood period. During the period of floods, men consumed 50% of the total food available with the family; the children consumed 35%, whereas the women consumed only 15% food (Moench and Dixit, 2004). Another study con-

ducted in the drought prone districts of Andhra Pradesh, India also reported that when food was in short supply

due to drought, more women reported that they ate less. Women ate two meals instead of three, served food first to men, then children and finally to themselves thus exacerbating the gender based inequalities in distribution of food (Lambrou and Nelson, FAO, 2010). Flooding also led to high male out migration leaving the women to deal with the floods. The burden of household work increased due to household repairs, drying and fixing belongings, cleaning of the home and the farm as well as reclaiming fields for planting.

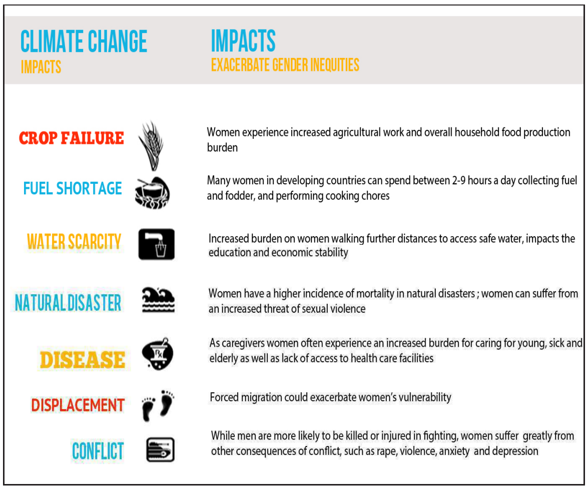

Figure 1: Likely impacts of climate change on women (WEDO, 2012).

The direct impacts of climate change constitute increased droughts and accompanied water shortages, increased weather events such as cyclones, floods, heat waves and hurricanes. As a result of these climatic extremes, more women are likely to have injuries and fatalities. This has been shown by a study conducted on disasters in 141 countries during the period 1981-2002 indicating that natural disasters lowered the life expectancy of women more than that of men, especially in lower socio-economic strata of society (Neumayer and Plumper, 2007). The indirect impacts of climate change are increased epidemics, decreased food security due to decreased crop production and loss of species due to decreased biodiversity. The gender based intra-household distribution of food becomes magnified and acute during extreme events or disasters. This has been shown by studies conducted in four flood-affected districts of Bihar and Eastern Uttar Pradesh in India, where women and girls were expected to reduce their food consumption substantially during environmentally stressful periods. The calorie intake of women reduced from 1000 calories in normal times to a mere 300 calories during the period of floods and went up to only 500 calories in the post flood period. During the period of floods, men consumed 50% of the total food available with the family; the children consumed 35%, whereas the women consumed only 15% food (Moench and Dixit, 2004). Another study conducted in the drought prone districts of Andhra Pradesh, India also reported that when food was in short supply due to drought, more women reported that they ate less. Women ate two meals instead of three, served food first to men, then children and finally to themselves thus exacerbating the gender based inequalities in distribution of food (Lambrou and Nelson, FAO, 2010). Flooding also led to high male out migration leaving the women to deal with the floods. The burden of household work increased due to household repairs, drying and fixing belongings, cleaning of the home and the farm as well as reclaiming fields for planting.

Women are also prone to more stress as a result of climatic extremes (floods, droughts) and disasters since they are the primary care givers to the entire family. There are other factors that compound the negative impacts of climate change on women. These are economic inequalities, low or no education, ascribed socio-economic roles, lack of access to rights and information and strict gendered codes, further limiting the mobility of women. There exists a two-way relationship between gender and climate change. On the one hand, the inbuilt gender inequalities in a society lead women to face disproportionately larger impacts of climate change as compared to the men; on the other hand, climate change tends to magnify existing gender inequalities.

A combination of all these factors, leads to poorer nutritional and overall status of women in the society and continue to be impediments in the nation's ability to achieve its own national as well as the Millennium Development Goals.

2. VULNERABILITY OF WOMEN TO CLIMATE CHANGE

In most parts of the developing world it is women who are responsible for collection of freshwater for their families, a task, which consumes much of their time and energy. Women in many developing countries walk for an average of six kilometers every day to collect water (Johannesburg Summit on Sustainable Development Fact sheet, 2002). Data from 35 developing countries has shown that water collection and management is a deeply gendered task with women bearing as much as 64% of the workload (WHO/UNICEF, 2010). Since women depend much more on resources (fuel, fodder, freshwater) most at risk from climate change, when these become scarce, women have to walk farther and work harder for their accession and management (CCAFS, 2011). Moreover, when water supplies become contaminated, women often have to compromise with the quality of water, which has an impact on the health of the entire family. The female children have to share the responsibility of carrying water, often leading to decreased enrollment rates of girls in schools and very large gender gaps in school attendance in many countries (UNDP, 2006). Almost 50 million girls are missing from primary school in developing countries because they share the burden of water and fuel collection for their homes (UNICEF, 2008). Studies have shown that Indian women born during a drought or a flood year are 19% less likely to ever attend primary school (UNDP, 2007-08). Other problems such as conflicts and eve teasing over water collection are also very common in urban settlements. Further, poor access to water is most often accompanied by poor sanitation facilities. Women have to pay heavy costs for the same due to the lack of appropriate system of disposal of domestic and human wastes. It has been reported that due to lack of privacy for defecation in the day, women often reduce their intake of food and water in order to hold on till darkness sets in, leading to discomfort, urinary tract infections, chronic constipation and mental stress (WHO/UNICEF, 2004).

Climatic changes and extremes exert a lot of pressure on the availability of resources, which are at the core of traditional responsibilities of women and as a result exacerbate their work burdens. As the workloads of women and girls increase, they tend to miss out on opportunities of education, skill development and income generation. This not only leads to disempowerment of women but also has inter-generational implications (UNDP, 2006). The close linkage between availability of water and women empowerment is apparent by Figure 2 showing a linear relationship between availability of water in different countries and their Gender related Development Index.

3. Need to adapt to climate change

Climate change is likely to continue in the near future because of its trade off with economic development and the long life of Green House Gases in the atmosphere. It is therefore important to adapt to bring changes in our lifestyles and methods to minimize the losses due to climate change. Adaptive capacity is the ability of a system to adjust to climate change in order to moderate the potential damages, to take advantage of opportunities, or to cope with the consequences. Some of the adaptive strategies are reactive in response to past or current events; others are anticipatory based on the assessment of future conditions. Adaptive measures can either be undertaken by individuals, groups or communities for themselves or by the Government as well as by public institutions. The eighth Conference of Parties of UNFCCC stated that 'Adaptation is of high priority and requires urgent attention and action on part of all the countries' (Adger, et al. 2005). There is a wide array of potential adaptive responses available to human societies, which are healthy and sustainable. These range from purely technological (e.g., developing new crop varieties, sea defenses), to behavioral (e.g., altered food choices such as vegetarian diets, reducing consumption, conservation of water, energy), to managerial (e.g., altered farm practices, insur ance, occupational shift, seeking credit) and to policy (e.g., planning regulations). These adaptive capacities must be considered for adoption by all sections of society specially the vulnerable groups such as women and children.

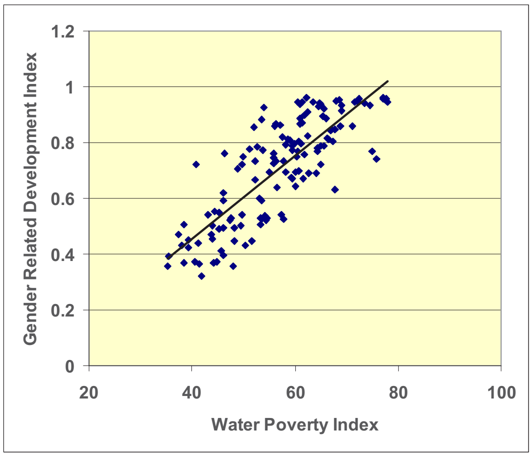

Figure 2: Relationship between Water Poverty Index of different countries and their Gender related Development Index (Source: GDI: UNDP, 2008; WPI: Sullivan, 2002)

The fourth IPCC report notes that there are individuals and groups within all societies that do not have sufficient capacity to adapt to climate change. As an example, gender differences in societies affect the vulnerability and adaptive capacity of women. The international climate negotiators for the first time in 2010 recognised that gender is integral to both mitigation and adaptation and included it in UNFCCC text. The Conference of Parties 16, incorporated women and gender concerns in various aspects of climate change including adaptation.

A small list of some adaptation options in some selected sectors is given below in Table 1

4. Common Coping Strategies of families

Individuals and communities on their own adopt many strategies to tide over difficult periods of disasters, floods, and droughts as well as periods of water scarcity.

A common coping mechanism of families is to withdraw girls from the school to reduce expenditure on education and seek their help in household chores such as fetching water and fuel wood (Eldridge 2002). In a study conducted by World Bank in the drought prone districts of Andhra Pradesh,it was reported that droughts led to disruption of education, higher expenditures on health dislocation of local markets and services (World Bank, 2009). The common coping mechanisms practiced by families were taking credit (68%), occupational shifts (28%) and altered cropping patterns.

Table 1: Selected examples of adaptations in some specific sectors (Adapted from IPCC, 2007)

Sector	**Adaptation option**
Water	Expanded rainwater harvesting; water storage and conservation techniques; water re-use; water purification, desalination; water-use and irrigation efficiency
Agriculture	Adjustment of planting dates and crop variety; crop and livestock relocation; storage of seeds, improved land management, e.g. erosion control and soil protection through tree planting
Infrastructure, settlements	Relocation; seawalls and storm surge barriers; dune reinforcement; protection of existing natural barriers
Human health	Heat-health action plans; emergency medical services; improved disease surveillance and control; safe water and improved sanitation
Energy	Use of renewable sources; energy efficiency ratings, conservation

.The same study was also conducted in the drought prone districts of Maharashtra, where the families reported a variety of coping mechanisms such as borrowing money from formal and informal sources (50%), changed agricultural practices, crop insurance (50%), as well as seasonal migration (World Bank, 2009). The landless households were the worst affected due to decreased food consumption, deterioration in health and disruption in schooling. In the flood prone districts of Orissa, almost 60% families reported increased sickness due to water borne diseases leading to an increase in expenditure on health, which was met by reducing expenditure on food. Another coping mechanism of families was abandoning their homes (48% families). The common coping mechanisms practiced especially by landless and medium farmers were borrowing money most often from private moneylenders (54%), distress sale of cattle and jewelry (15%), and migration to towns for alternative employment (World Bank, 2009). In another study conducted in selected drought prone areas of Andhra Pradesh, the common coping strategies were taking up wage employment (70% women, 57% men), taking loans (33%) as well as migration for income. Almost 33% families reported insufficient food in a low rainfall year and so the families coped up by eating less. In order to provide food for the family for the entire year, women often hid some of the crop from men since it was men who decided on the amount of grain to be kept for consumption and the amount to be sold in the market to generate income (Lambrou and Nelson, 2010).

A study conducted in 20 villages of drought-affected districts of Gujarat, the shortage of food, was reported as the primary concern by families (65%). The coping mechanisms of families were taking up wage labour in non-farm sector (diamond polishing, construction), migration for work, change in cropping pattern, and increased focus on animal husbandry, distress sale of cattle and jewelry and increased involvement of women in the work force. In the drought prone districts of Rajasthan, families responded to reduced level of income during drought year by selling assets, land, jewelry, vehicles, borrowing money from formal and informal sources and lowering the consumption of food, growing a mix of crops, migration and withdrawing children from school for supplementing family income. In the northern and southern parts of Rajasthan, withdrawing girl children from school especially amongst low income group families was common. The common coping strategies of families in flood hit areas of Nepal were borrowing money from relatives/landlords, temporary migration, wage earning by children and adults, building makeshift houses away from rivers as well as sale of land and other assets such as ornaments (Moench and Dixit, 2004).
Despite a whole lot of coping strategies practiced by families, majority of them involved considerable risk taking leading to negative impacts on family members. It is apparent that the negative impacts are borne much more by the poor owing to their limited assets and

knowledge resulting in low adaptive capacity. Within the poor, it is women and female children who are affected the most because of their gender and the associated socially constructed behaviors and practices, limited access to resources, education and training. It is therefore imperative to build human, social and economic capacity of the most vulnerable groups of population including women to enable them to adapt to climate change.

6. Why target women

Since it is the women who are most vulnerable because of their dependence on resources most at risk due to climate change, it is important to engage them in areas of climate change preparedness, risk reduction, adaptation and mitigation and strengthen their capacity to adapt to climate change.

Women are far more concerned about environmental issues because of their close association and have a key role in tackling climate change as consumers, educators and change agents in homes and society. They are also innovators, organizers with good social networking skills, which position them uniquely to minimise the harmful impacts of climate change on their families. They have the potential in terms of experience and a strong body of indigenous knowledge to combat the increased disaster risks and enable their families to cope with climate change. However, socio-cultural barriers and women's traditional roles confine them to the home giving them little time to participate in community discussions, leadership and in taking action in their own homes for appropriate adaptation and mitigation strategies (UNDP, 2010). Their perspectives and needs are often not heard in policy formulation. Given the knowledge and skills, women can find sustainable solutions to reduce the vulnerability of their families to climate change. This is supported by a lot of evidence such as in the case of Honduras in 1998, when Hurricane Mitch struck, a community by the name of *La Masica* reported no casualties. This was because six months earlier, a disaster agency had provided gender sensitive community education on early warning systems and hazard management (GGCA, 2009). Also, an innovative Action Aid- project in Nepal had seen women's empowerment make rapid progress through the use of video discussions about climate change (Khamis, et al. 2009). These clearly indicate, the positive role that awareness and knowledge enhancement of women can play in dealing with climate stresses, extremes and disasters. Access to information, knowledge and skills is one of the principal determinants of adaptive capacity of people to climate change along with institutions, infrastructure, technology, economic wealth and equity among populations (IPCC, 2001). Knowledge is one of the crucial factors for enhancing resilience and adaptive capacity of people to changed socio-ecological system (Folke, et al. 2002). Enhancing knowledge leads to building human capital, which along with economic, social, physical and natural capitals, determine the adaptive capacity of individuals at the household and community levels (Osman Elsha, et al. 2005; Vincent, 2009).

7. Conclusion

Women constitute a large share of the world's poor and lag behind men in education, income, and health. In the developing countries, women play multiple roles as providers, cultivators and care givers to the family members. They are more concerned about environmental issues because of their close association and have a key role in tackling climate change as consumers, educators and change agents in homes and society. They are also innovators, organizers with good social networking skills, which position them uniquely to minimise the harmful impacts of climate change on their families. They have the potential in terms of experience and a strong body of indigenous knowledge to combat the increased disaster risks and enable their families to cope with climate change. However, socio-cultural barriers and women's traditional roles confine them to home giving them little time to participate in community discussions, leadership and in taking action in their own homes for appropriate adaptation and mitigation strategies (UNDP, 2010). Their perspectives and needs are often not heard in policy formulation. Given the knowledge and skills, women can find sustainable solutions to reduce the vulnerability of their families to climate change. Access to information, knowledge and skills is one of the principal determinants of adaptive capacity of people to climate change along with institutions, infrastructure, technology, economic wealth and equity among populations (IPCC, 2001). It is therefore essential to engage women in initiatives to build adaptive capacity to deal with climate change and enable them to lead more empowered lives.

REFERENCES

1. Adger, W.N., Hughes, T.P., Folke, C., Carpenter, S.R. & Rockström. J. (2005). Social Ecological Resilience to Coastal Disasters. Science, 309, 1036-1039.
2. Arnell, N.W., (2004). Climate change and global water resources: SRES emissions and socio economic scenarios. Global Environment Change, 14, 31-52.
3. Asian Development Bank. (2001). Water for All: The Water Policy of the Asian Development Bank. Retrieved from http://www.adb.org/documents/policies/water (Accessed on February 16, 2013).
4. BBC World Service. (2007). Climate Change: Global Poll. Retrieved from: http://news.bbc.co.uk/2/shared/bsp/hi/pdfs/25_09_07climatepoll.pdf (Accessed on March 4, 2010).
5. IPCC, (2001): Impacts, Adaptation & Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken and K. S. White (eds). Cambridge, Cambridge University Press, 1,000 pp.

6. IPCC, (2007a): Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller (eds). Cambridge, Cambridge University Press, 996 pp.
7. IPCC, (2007b): Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.
8. IPCC, (2008): Climate Change and Water. Technical Paper VI. Contribution of Working Group II. B. Bates, Zbigniew W. Kundzewicz, S. Wu and J. Palutikof (eds). Geneva, IPCC Secretariat, 210 pp.
9. MOSPI (2007). Compendium of Environment Statistics India, 2007. Ministry of Statistics & Programme Implementation, Government of India.
10. UNDP (2006). Human Development Report. *Beyond Scarcity: Power, poverty and the global water crisis.* United Nations Development Programme. New York: Macmillan.
11. UNDP. (2007-08). *Human development report 2007: Fighting climate change: Human solidarity in a divided world*. United Nations Development Programme. New York: Macmillan.
12. UNDP. (2011). *Managing natural resources for human development, Developing the non-oil economy to achieve the MDGs.* Timor-Leste Human Development Report 2011. United Nations Development Programme.
13. Venkateswaran S. (1995). *Environment, Development and the Gender Gap*. New Delhi: Sage.
14. WEDO (2008). *Gender, Climate Change and Human Security lessons from Bangladesh, Ghana and Senegal* (ELIAMEP).
15. WEDO. (2012). *Gender, Climate Change and Human Security lessons from Bangladesh, Ghana and Senegal* (ELIAMEP).
16. WHO/UNICEF (2004). *Joint Monitoring Programme for Water Supply and Sanitation; Meeting drinking water and sanitation target: a mid-term assessment of progress*. UNICEF: New York and WHO: Geneva.
17. WHO/UNICEF. (2008). *Joint Monitoring Programme for Water supply and Sanitation. Progress on Drinking Water and Sanitation: Special Focus on Sanitation.* UNICEF: New York and WHO: Geneva.
18. WHO/UNICEF (2010). *Joint Monitoring Programme Report. Progress on sanitation and Drinking water for Water supply and Sanitation*. UNICEF: New York and WHO: Geneva.

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Climate Change: A Threat to Biodiversity

Seema Talwar[1]*, Pamil Tayal[1], Sanjeev Kumar[1], Kiran Bamel[1] and Prabhavathi V[1]

[1]Department of Botany, Shivaji College, University of Delhi, New Delhi 110 027, India

***Corresponding author:** *seematalwar2014@gmail.com*

Abstract— India is endowed with rich flora and fauna and thus ranked among seventeen megabiodiversity countries of the world. The country harbors many economically important plants that are endemic to it or serves as keystone species in the ecosystem. Plant phenology, flower production, seed set, plant-pollination interactions have been largely controlled by a wide range of ecological factors such as temperature, light, wind, humidity and diverse habitat. Increasing anthropogenic activities (deforestation, habitat fragmentation, industrialization, overexploitation of economic species and introduction of exotic plants) have threatened such ecological interactions leading to loss of biodiversity. Nevertheless, rise in temperature and CO_2 concentration have greatly influenced the mutualistic ecological interaction between plants and pollinators; as more than 80% of plants depend on animals for pollination services. Such alterations affected not only the symbiotic association but also the adaptive co-evolution of both the organisms thereby influencing community structure, composition and functioning of the ecosystem. Elevated temperature affects physiology of flowers in terms of flower number and size, pollen development and anthesis, floral scent and nectaries formation. The manipulated floral phenology forced pollinators to adapt themselves towards the changing environment. Similar to flowering plants, pollinators too are susceptible to diverse global changes. They have been affected in a number of ways such as foraging activity, body size, maturation period and life span. However, both the symbiotic partners endeavor hard for their respective growth and reproductive success, but climate change has proved to be an emerging challenge for their survival generation after generation. As a consequence of such physiological changes in flowering plants and their respective pollinators the biodiversity is greatly threatened.

Many authors have addressed the effect of climate change in terms of alterations in plant height, leaf formation, chlorophyll concentration, secondary metabolite concentration and overall plant growth rate. But the information is scarce regarding the physiological responses affecting plant-pollinator interactions. The review summarizes all the possible effects of rise in temperature on flowering plants, their beneficial counterparts (pollinators) and its effect on plant-pollinator association. It will shed light on possible consequences for future generations of flowering plants and pollinators. The work will advance the knowledge on the strategies to be followed by ecological partners towards the changing environment and mechanisms necessitated for the conservation of both plants and pollinators. It is also suggested that the future research should lay emphasis on standardizing the methods for conservation and restoration of threatened and vulnerable plants on priority. The conservation phenomenon should receive urgent attention for reproductive success and regeneration potential of the species for sustainable development.

Keywords: Biodiversity, Climate change, Pollinator, Plant-Pollinator interaction, Reproduction.

1. INTRODUCTION

India is one of the 17 mega biodiversity countries of the world, supporting 7% of the world's biodiversity (Ravindranath et al. 2003). It has a great diversity of natural ecosystems. Cold and high Himalayan regions in the North to the sea coasts in the South ; wet green forests in the North-East to the dry arid deserts in the North-West; with different types of forests, wetlands, islands and the oceans. Therefore, India enjoys the variation in climate and this diversity of climatic conditions has given rise to a rich and varied flora. Around forty six thousand plant species belonging to different groups have been reported from India (Arora and Ahuja, 2006). Biodiversity is a wealth which cannot be valued. It is essential to maintain the various ecological functions, such as water cycle, soil fertility, pollination, protection against soil erosion and stability of food producing and other ecosystems. In a nut shell, we can say that all forms of the living organisms and their survival are completely dependent on conservation of biodiversity. Such an invaluable heritage is getting destroyed at an alarming rate due to various reasons. There are numerous factors that contribute to a species becoming threatened or extinct. Various anthropogenic activities such as increasing pressure of human population, habitat fragmentation, encroachment, industrialization, deforestation have rendered them increasingly vulnerable. Other ecological reasons such as inbreeding depression, high infant mortality, forest fire, scarcity of pollinators and seed dispersal agents are also responsible for reduction of plant species and sometimes it may lead to the extinction also (Whitmore and Sayer 1992; Pimm and Raven 2000). Among the various reasons listed for decrease in number of species, one important aspect which is emerging as a new challenge for the survival of tree species is the climate change. Climate is a key determinant for the phenology, physiology, distribution, interactions and structure of forests (Kirschbaum et al. 1996). The world's recent climate has shown a significant increase in average temperature, due to which major physiological and ecological processes are disturbing in a perceptible way. In recent years, some anomalies have been observed due to the change in temperature. The global mean temperature is going to increase at a rapid rate in the coming decades (Zwiers, 2002) and it is estimated to rise 2-8.6^{0}F by 2100 (IPCC, 2007).

The increasing rate of climate change is significantly going to affect the flora and fauna across the globe. The increased global temperature will alter the growth rates and other physiological functions of the forests (Bugmann, 1999; Fischlin and Gyalistras, 1997). Due to this temperature stress, distribution of forests will also get affected and there will be changes in the patterns of sexual reproduction. Furthermore, some other characters are also likely to alter and a successive reaction of climate sensitive species and ecosystems is expected under changing climatic conditions (Theurillat and Guisan, 2001). The impacts of increased atmospheric carbon-dioxide, elevated temperature, rising water level and increased UV radiations will modify the conditions for growth of both terrestrial as well as aquatic plants (Watson et al. 1996; Craufurd and Wheeler, 2009; Sinha et al. 2011). It is not only the natural vegetation, but also annual crops like winter rye, maize and sugar beet show the variation in response to the elevated temperature (Chmeilewski et al. 2004; Iioh et al. 2014). Climatic conditions may alter the physiology and reproduction of the plants as well as of pollinators (Lieth 1975; Geider et al. 2001).

It is also reported by Woodward (1987) and Prentice et al (1992) that climate change provides unfavourable conditions for composition and distribution of biomes also. Biomes are sensitive towards climate change and any fluctuations in the climatic conditions may cause shifting, shrinkage or expansion. If the anthropogenic activities (industrialization, deforestation, urbanization) continue at the same pace, the negative repercussions of climate change are going to be detrimental (Deshingkar et al. 1997), especially for agricultural food crops in developing countries where people are already facing the food security problems (Iioh et al. 2014).

Climate warming is also expected to alter biological phenomena such as plant growth, phenology, floral biology, foraging activity of pollinators, their life span and size etc. Number of studies report changes in plant and animal life cycle from a wide range of regions. These phenological changes are sensitive and easily evident indicators in response to climate warming (Scaven and Rafferty, 2013). The possible effects of climate change on natural and agricultural terrestrial plant communities have already received considerable attention at national and international level (Mueller-Dombois, 1992; Shah et al. 2011; Sinha et al. 2011; Iioh et al. 2014). Therefore, our aim in this paper is to summarize the effects of elevated temperature on plants, pollinators, their physiology and interaction among plants and pollinators.

2. EFFECT ON PHENOLOGY

Plant phenology is the study of periodicity in the production of vegetative and reproductive plant structures, most notably leafing, flowering and fruiting schedules (Haugaasen and Peres, 2005). As phenology is closely linked to weather conditions, any change in phenology can serve as a natural indicator of climate change (Penuelas and Filella 2001; Fitter and Fitter, 2002). Climate change may cause variation in timing, duration and synchronization of phenological events in tropical forests (Reich, 1995). Significant variation has been observed in onset dates of flowering (Fitter and Fitter, 2002) and fruiting responses (Chapman et al. 2005) as a result of climate change. A change in plant phenology is one of the earliest observations in response to global climate change and it could have the serious consequences both for plants as well as for animals that depend on floral resources (Cleland et al. 2007). Some species in ecosystem are strongly adapted to the climatic conditions that a small change can lead to the vulnerability of such plants (Moza and Bhatnagar, 2005). Global warming has advanced the first flowering date of some plants (Memmott et al. 2007).

In *Arabidopsis thalliana*, at high temperature flowering occurred earlier (Springate and Kover, 2014). Studies conducted by Menzel and Fabian (1999) in Europe, have reported that first flowering date of *Robinia pseudoacacia* (locust tree) has advanced by three-eight days. They also observed that certain plant species in Europe, leaf unfolding in spring has advanced by up to six days, whereas the autumn leaf colouring is delayed by 4–8 days. Abu-Asab et al. (2001) also observed changes in the first-flowering dates of over 100 plant species, representing 44 families of angiosperms for 29 years (1970–99) in Washington DC. They observed that in most of the trees flowering started 3–5 days earlier than they did some years ago. Five studies from temperate regions of the USA and UK, also showed the advancement of first flowering by 2-6 days per 1^{0}C (Sparks et al. 2000**;** Fitter and Fitter 2002). Similar observations has also been reported in *Ranunculus brotherusii* where warming has advanced the flowering time but on the other hand, in *Trollius farreri* and *Aster alpines* warming significantly delayed the onset of flowering (Liu et al. 2012). Early flowering due to the elevated temperature could cause problems for birds, especially for migratory birds. These birds come from thousands of kilometers to feed on the flowering plants and plants also rely on these birds to distribute their pollen. If the birds arrive after flowering has started, they will have less nectar and less pollen grains to feed on and the plants and their reproduction will also get affected (Price and Waser, 1998). Early flowering may lead to smaller flowering plants that may results in decrease in number of seeds per fruit. However, delayed flowering may reduce the time during the growing season for plants to fully develop fruits and seeds and thus resulting in the production of small seeds (Liu et al. 2012).

Phenology of some crop plants have also influenced by elevated temperature. In rice plants, phenological events such as tillering, panicle initiation, flowering and harvesting periods has been found to be reduced when the temperature was increased by 2^0 and 4^0C. Yield of the crop was significantly reduced in both cases, at 2^0C, yield was reduced by 13.3%, whereas in 4^0C, it was reduced to 23% (Rani and Maragatham, 2013; Weerakoon et al. 2008). Similarly, in wheat, production was also declined by 5-8% (Wheeler et al. 1996) and 10% (Mitchell et al. 1993), per 1^0C rise in mean seasonal temperature. Anthesis and grain maturity both were advanced at elevated temperature in wheat. Therefore, duration of growth and yield both were significantly reduced. Therefore, it can be concluded that the most common impact on the crop plants is the shortening of the developmental stages at the higher temperature (Craufurd and Wheeler, 2009).

Differential changes in phenology in response to climate change among interacting species (plants and pollinators) may lead to decoupling in their life cycle events which in turn might lead to change in the species composition of ecosystem, community structure and ecosystem functioning. Synchronized timing of mutualistic partners is critical for efficient pollination of plants as well as the survival of pollinators. Therefore, one of the major concerns related to global warming and pollination interaction is the demographic consequence of mismatch between plants and pollinators.

3. EFFECT ON FLORAL TRAITS

Floral traits have a significant impact on success of effective pollination. Elevated temperature can affect the floral traits such as flower number, flower size and length of corolla tube etc. These morphological floral traits are directly related to agents of pollination, and an analysis of these attributes can help in the prediction of their probable pollinator.

Plants growing at higher temperature usually have less flowers than their counterparts growing in colder conditions (Walch and Van Hasslet, 1991), it may be because low temperature speed up the floral transition by limiting somatic growth (Tromp, 1984). In rice plant, high temperature during flowering caused spikelet sterlility and therefore, reduced the yield of crop (Rani and Maragatham, 2013). In *Dianthus* species after vernalization, number of flowers was increased (Chouard, 1960), similar condition has also been observed in *Brunonia*, *Calandrinia* and *Lavandula angustifolia* (Niu et al. 2002). Higher temperature can delay flowering and reduce the number of flowers in many species (Warner and Erwin, 2006), because they may lower flower formation by eliminating the effects of vernalization (Hideyuki and Takashi, 2003; Inouye et al. 2003). In *Anemone trullifolia* var. *linearis*, warming significantly reduced both the flower number as well as number of fruits per plant for the multi-inflorescence species (Liu et al. 2012). In *Delphinium nuttallianum* (Nuttall's larkspur) growing in arctic area, warming had less number of flowering plants as compared to the control plots (Saavedra et al. 2003). Similarly, no flowering has been observed in Lychee (*Litchi chinensis*) plants when exposed to temperature above 20^0C for 8 or more hours per day (Menzel and Simpson, 1995). Reduced flower production under high temperature decreases the food availability, and therefore directly affects the reproductive output and population density of pollinators (Boggs and Ross, 1993; Minckley et al. 1994; Westphal et al. 2003). In contrast, plants growing in arctic and alpine tundra indicated the increased flower production under elevated temperature (Arft et al. 1999). Similar observations have also been reported in the plants growing in New Zealand (Schauber et al. 2002). Increased flower production may affect the reproductive success of plant species. Increased flowering also increases visitation rates within the same plant and it cause higher selfing rates due to increased geitonogamy (Vrieling et al. 1999) and it may increase the chances of inbreeding depression. In *Terminalia chebula*, where the flower production in the same plant was more as compared to other sites, most of the fruits obtained through selfing drooped early (Talwar and Bhatnagar, 2014). Increased flower numbers may also affect pollinators, as food availability is one of the most important factors which controls the activity and population density of many pollinator species (Steffan-Dewenter et al. 2002; Westphal et al. 2003; Hegland and Boeke 2006; Steffan- Dewenter and Schiele 2008).

In *Cucurbita maxima* when the plants were exposed to 23^0C, smaller diameter of the flowers was produced (Hoover et al. 2012). Small sized flower may reduce the rate of pollinator visitation, thereby increasing pollination limitations. In *Ipomoea trichocarpa* under high temperature, anthesis started 2-3 hours earlier as well as the length of corolla tube also became longer as compared to colder conditions. Early anthesis in *Ipomoea*, would be beneficial for the early active pollinators but it may have the negative consequences of resource availability for the pollinators which get active later in the day (Murcia, 1990). On the other hand, if anthesis occurs later in the day as an effect of high temperature, it would receive less pollinator visit as some of the pollinators avoid high temperature during afternoon (Rao and Raju, 2002). It would result in pollinator limitation and therefore, reduced fruit and seed set (Wilcock and Neiland, 2002).

Temperature also affects the production of pollen grains (male gametophyte) as well as their viability also. In *Glycine max*, 30-50% pollen grains were less produced when plants were exposed at 38^0 C in day and 30^0C in night and the viability of the pollen grains was also low (Koti et al. 2005), and thus affected the reproductive potential of the plant as well as of the pollinators dependent on these pollen grains to rear their offspring

(Muller et al. 2006). Similarly in *Arachis hypogaea* less viable pollen grains were produced under elevated temperature (44^{0}C) (Prasad et al. 2003). In pepper, pollen germination was reduced up to 6% (25% normal at 28^{0}C) and pollen tubes were also shorter when exposed to 32^{0}C (Aloni et al. 2001). There is no as such data which shows, whether non-viable pollen grains are less attractive to pollinators or not. In *Solanum tuberosum*, bumblebees were more attracted towards the flowers having viable pollen grains as compare to those flowers having non-viable pollen grains revealing that viable pollen grains were rich in lipids and proteins (Batra, 1993).

4. EFFECT ON PLANT HEIGHT

Besides affecting the floral traits, warming can also change the other characters of the plants. In *Silene noctiflora* plants grown under high temperature become shorter in height (Qaderi and Reid, 2008). In contrast, *Anemone nemorosa* plants grown under warmer conditions showed increased vegetative growth in terms of height (De Frenne et al. 2011). Height of a plant affects the visitation rate. Some pollinators show height-specific foraging patterns (Levin and Kerster, 1973), and they are generally more attracted towards tall plants (Aarssen, 1995). Therefore, reduction in plant height affects the reproductive potential of the plants as time and energy of most of the pollinators would be waste in locating the floral resources (Aspi et al. 2003; Donnely et al. 1998).

5. EFFECT ON SEED SET AND GERMINATION

Temperature plays an important role in seed germination. During seed germination, when seeds were exposed to high temperature for long duration it may cause delayed germination and reduced dry mass (Wahid et al. 2007). Reduction in grain formation has been reported in rice, when plants were exposed to 34^{0}C (Morita et al. 2004), emergence of rice seeds was also delayed during germination at 40^{0}C (Akman, 2009). Similarly, plant height, number of tillers and total biomass were also reduced in response to high temperature in rice cultivars (Mitra and Bhatia, 2008). Seed yield of canola was decreased by 15% at high temperature (Gan et al. 2004). In wheat, at high temperature (45^{0}C), germination was strictly prohibited (Cheng et al. 2009). Similarly, seeds of maize, rice and sorghum when exposed to high temperature, showed decrease in seed germination rate (Iioh et al. 2014). It is because, when seeds are exposed to high temperature, they have more production of Abscissic acid (ABA) and therefore, inhibits seed germination (Essemine et al. 2010; Toh et al. 2008). So, elevated temperature had a direct and negative effect on seed germination.

Warming also has a significant effect on seed mass and number of seeds. In nine multi-inflorescence species (*Anemone trullifolia var. linearis, Caltha scaposa, Gentiana Formosa, Ranunculus brotherusii, Trollius farreri, Aster alpines, Chamaesium paradoxum, Deschampsia caespitosa* and *Haplosphaera himalayensis*) growing on Tibetan Plateau alpine meadow showed that warming considerably decreased the total number of seeds as well as seed weight. Total seed mass and number decreased by 56.7% and 60.4% on average, respectively (Liu et al. 2012).

6. PHYSIOLOGICAL EFFECT ON POLLINATORS

Pollination is the first step by which genes are exchanged between different plants (cross-pollination) or are recombined with same (self-pollination). It also imparts the potential of plants to adapt to new environmental conditions. Failure of pollination at any step can cause poor seed set and lower the crop yield (Wilcock and Neiland, 2002; Sanchez et al. 2004). If pollination occurs through biotic agents, then the protection and management of these biotic agents are also required for successful reproduction of the plant species. Pollination by insects does not only ensure the maintenance of a population, but also increases genetic diversity. Pollinator loss can affect plants in several ways, with reduced fruit and seed set being the most obvious result. In the absence of pollinators, a higher percentage of seeds are set through self-pollination, which decreases heterozygosity and increases the expression of deleterious traits associated with inbreeding. Therefore, scarcity of pollinators affects breeding system of plant which results in the production of less vigorous offspring. A study conducted on *Rhus aculeatus*, an evergreen shrub, reported that the plant is facing threat of extinction because of unsuccessful pollination. Reduction in the number of pollinators visiting the flowers is found to be the main reason for this plant's vulnerability (Arnonne et al. 2004).

Pollinators are also at risk to the changing environmental conditions. Most of the plants are entomophilous and therefore, insect pollinated plants are more prone than wind pollinated plants. Insects are small and poikilothermic, and therefore temperature plays an important role in their development and activity patterns which is significantly evident in alpine and arctic regions (Totland 1994; Hodkinson et al. 1998). Tropical insects are most likely to experience harmful effects of warming as they show narrow thermal tolerance (Hegland et al. 2009). The activity of insects is strongly influenced by temperature (Bradshaw and Holzapfel, 2007). Honey bees can be considered as a good indicator of climate change as they overwinter in the adult phase, and respond quickly as the temperature increases (Gordo and Sanz, 2006). Nature's Calendar project (http://www.naturescalendar. org.uk) reveal that in bumble bees flight have been advanced by 2 weeks from 2001 to 2007 as an effect of elevated temperature (Sparks and Collinson, 2007). It is because of the termination of queen's winter hibernation at high temperature of the soil (Alford, 1969). Studies conducted by Willmer (1983), observed that *Bombus* spp. like to visit the flowers either early morning or late evening. They do not forage in the afternoon to avoid high temperature. In *Pterocarpus santalinus* no pollinating insects were observed throughout the day because of high temperature, and most of the flowers remain unvisited, resulted in low fruit set and seed set. *Apis dorsata*, a major pollinator, visited the flowers during moonlight and other two pollinators (*A. cerana indica and A. florea*) also restricted their activity during early morning hours. The nocturnal foraging activity of *A. dorsata* was due to avoid excessively high temperature during daytime (Rao and Raju 2002). Flowers of *Albizzia lebbeck* were visited by *A. dorsata* during moonlit nights in May–June when temperature was around 40^0C (Sihag, 1984). Hedegart (1976) also observed that the insect pollinators on *Tectona grandis* were incapable to work at the very high temperatures. Therefore, it can be concluded that the pollinator activity is completely dependent on the temperature and high temperature is one of the major reasons to scarcity of pollinating insects.

Elevated temperature can affect the life-span of the pollinators also. *Colias eurytheme* showed the reduced life-span when exposed at 45^oC, especially males whose lives had decreased nearly 40% (Kingsolver and Watt, 1983). Similarly, *Osmia lignaria* also resulted in shorter life time under long summers (Sgolastra et al. 2011). Reduced life span of certain pollinators can certainly effect the time period of pollen receipt and pollen removal. Such an effect would be disastrous for the plants which are dependent on a particular species of pollinators for their pollen transfer during the short flowering period. The reduced period of pollinator availability is responsible for the results that are similar to those of reduced phenological overlap. The reduction in the life span of pollinators affects negatively even those individual species that flower outside this window of phenological overlap (Hegland et al., 2009; Rafferty and Ives, 2012).

In solitary bees, when exposed to high temperature, less weight of larvae or pupae developed and ultimately resulted in the formation of smaller sized adults (Kingsolver and Huey, 2008; Radmacher and Strohm 2010, 2011). Similarly, in *Manduca sexta* (tobacco hornworn) when exposed to different temperatures (20, 25 and 30^oC) body size showed the variation. In tobacco hornworm, body range is inversely proportional to the increasing temperature. As we increase the temperature, size of the hornworm decreases and it transforms into smaller adult hawkmoths (Davidowitz et al 2004; Kingsolver et al. 2012). Body size is directly related to the efficiency of pollinators regarding the pollen carrying capacity. It may be reduced or it may be improved and thus it can affect the seed set also. Therefore, temperature induced changes can lead to the smaller adult pollinators and affect their reproductive potential (Sahli and Conner 2007; Scaven and Rafferty 2013). Habitat loss due to the climate change may cause the extinction of other pollinators such as birds. In tropical area, most of the plants are pollinated by birds, thus reduction in pollination services in tropics would be a detrimental effect in ornithophilous plants (Sekercioglu et al. 2012; Thakur and Bhatnagar, 2013).

7. PLANT-POLLINATOR INTERACTION

Climate change has the potential to desynchronize the phenologies of interdependent species, with a major impact on mutualistic populations. One of such mutualistic interaction is plant-pollinator interaction (Gilman et al. 2011).Plant-pollinator mutualistic interaction plays a vital role in the maintenance of stability of a community and thereby creating a balance in the ecosystem (Bawa, 1990). Interaction among flowering plants and their pollinators play an important role ecologically as well as economically. Angiospermic plants rely heavily on pollinators for cross-pollination. Approximately 88% of angiosperms are dependent on pollinators for pollination services (Ollerton et al. 2011). Around $220 billion annually is provided by the pollinators as a result of the pollination (Gallai et al. 2009). The mutualistic plant-pollinator populations have majorly been effected due to climate change. Plant and pollinators both are at the risk of extinction from climate change i.e. disruption in seasonal timing (phenology) of flower production and foraging activity of pollinators and therefore alters the plant-pollinator interaction (Harrison 2000; Wall et al. 2003). Plants pollinated by insects are more prone to climate change than wind pollinated plant. Scarcity of pollinators can affect plant in several ways. Reduced seed set, less vigorous offspring and decreased heterozygosity are some of the obvious results. Usually insect pollinated plants relying on one type of pollinator (specialized) are severely affected due to climate change.

Plant-pollinator interactions can be disrupted in two ways; either temporal (phenological) or spatial (distributional). Availability of mutualistic partners is disturbed due to the change in climatic conditions. Also, reduced sharing of habitat in time as well as space contributes towards complete trophic decoupling (Stenseth and Mysterud 2002; Visser and Both 2005). Decoupling phenomenon resulted in reduction of pollen deposition through less visits by pollinators and limits the reproduction in flowering plants. Limitation of reproduction due to insufficient pollination is common among the plant species (Ashman et al. 2004). Less food availability (pollen and nectar) consequently resulted in low reproductive success to pollinators causing their population to be decline (Boggs and Ross, 1993). The effects of mismatch on pollinator population may be more severe than the plants, because pollinators are more dependent on pollen and nectar than flowering plant species depending for the transfer of pollen grains. For example, the reproductive success of hummingbirds may be determined by the degree of matching (both timing and peak abundance) with its main flower resources (Waser, 1976). Specialized pollinators are most likely to occur with significant reduction in food, as they are dependent on particular plants for their food (nectar and pollen) but generalized pollinators could also experience in food reduction following phenological shifts (Hegland et al, 2009). Therefore, it can be concluded that specialized pollinators are more vulnerable to extinction than generalized pollinators.

Due to this global climate change, many plants may shift towards the higher latitudes/altitudes (Breshears et al 2008; Kelly and Goulden 2008; Frei et al. 2010; Chen et al. 2011) but the diversity and activity of pollinators decline at higher elevations (Totland and Sottocornola 2001; Hoiss et al. 2012). Reduction in the number of pollinators can promote self-pollination and therefore, increases inbreeding depression. Gordo and Sanz (2005) observed the phenological responses of both plants and pollinators in relation to the increasing temperature on the Iberian Peninsula. They found that *Apis mellifera* and *Pieris rapae* advanced their activity period resulting in the temporal mismatch with some of their main plant resources. This result reveal that insect phenologies has been advanced more than plant phenologies (Visser and Both 2005, Sparks and Collinson 2007) and insects also respond to the climate change in relation to the food availability. Kudo et al. (2004) observed that early flowering plants in Japan advanced their flowering during a warm spring, but on the other hand bumble bee queen had no effect by spring temperature and thus resulting in a decreased seed-set in bumble bee-pollinated plants. Therefore, it can be concluded that incidence of mismatch between plant and pollinators may vary among species and regions (Hegland et al. 2009).

8. CONCLUSIONS

Evidences from analysis of a wide literature indicate that an anomalous climatic condition has significantly affected species physiology, the range of distribution of species and physiology of organisms (plants and pollinators). In contrast, little emphasis has been given to the plant-pollinator interaction which is one of the major ecological processes. There is a need to overcome the data limitations by initiating studies to develop database on systematic study of plant, pollinators and interaction among them. The findings on the effect of climate change on plant and animal phenology and their physiology would be helpful in developing the models in order to estimate the impact of climate change on plant and pollinator development in different parts of world. The detailed survey and methodological research in this area is much needed as limited studies have been devoted to understand the effect of climate change on biodiversity. Indian economy is dependent on agriculture. As all crops are dependent on physical conditions, out of which temperature plays a key role in their growth and development, therefore, fluctuations in the temperature may lead to the problem of food scarcity and can disturb the economic growth. The consequences of climate change on flowering, fruiting, and seed dispersal in the geographically restricted plant species will be more serious. Hence, there is a need to carry out exhaustive methodical studies on life-history (phenology, floral biology, breeding system, pollination, fruit and seed set, dispersal mechanisms and seed germination) of plant species. The detailed data possibly will offer valuable clues about the effect of predictable climate changes. Thus, future research should include not only direct effects of temperature on plant, pollinators and their interactions, but also indirect and correlated effects of climate change. In addition to this, there is an urgent need to develop some new crop varieties and cropping patterns to meet the imminent changed climatic conditions.

REFERENCES

1. Aarssen, L.W., 1995. Hypotheses for the evolution of apical dominance in plants: implications for the interpretation of overcompensation. Oikos 74, 149–156.
2. Abu-Asab M., Peterson, S., Stanwyn, P.M., Shelter, G., Sylvia, S. 2001. Earlier plant flowering in spring as a response to global warming in the Washington, DC, area. Biodiversity Conserv. 10, 597–612.
3. Akman, Z., 2009. Comparison of high temperature tolerance in maize, rice and sorghum seeds by plant growth regulators. J. Anim. Vet. Adv. 8, 358–361.
4. Alford, D.V., 1969. A study of hibernation of bumblebees (Hymenoptera-Bombidae) in Southern England. J. Anim. Ecol. 38, 149–170.
5. Aloni, B., Peet, M.M., Pharr, M., Karni, L., 2001. The effect of high temperature and high atmospheric CO2 on carbohydrate changes in bell pepper (Capsicum annum) pollen in relation to its germination. Physiol. Plant. 112, 505–512.
6. Arft, A.M., Walker, M.D., Gurevitch, J., Alatalo, J.M., Bret-Harte, M.S., 1999. Responses of tundra plants to experimental warming: Meta-analysis of the international tundra experiment. Ecol. Monogr. 69, 491–511.
7. Arnonne, G., Micco De, V., Scala, M., 2004. Plant reproductive ecology for conservation of endangered mediterranean species. The Bot. 54, 23–29.
8. Arora, S., Ahuja. V., 2006. Biodiversity conservation in megadiverse countries: a profile. in: Perspectives on Biodiversity. A Vision for Megadiverse Countries. Verma, D.D., Arora, S. and Rai, R.K. (Eds.), Ministry of Environment and Forests, Government of India, pp 21-39.
9. Ashman, T.L., Knight, T.M., Steets, J.A., Amarasekare, P., Burd, M., Campbell, D.R., 2004. Pollen limitation of plant reproduction: ecological and evolutionary causes and consequences. Ecol. 85, 2408–2421.
10. Aspi, J., Jäkäläniemi, A., Tuomi, J., Siikamäki, P., 2003. Multilevel phenotypic selection on

morphological characters in a metapopulation of *Silene tatarica*. Evol. 57, 509–517.

11. Batra, S.W.T., 1993. Male-fertile potato flowers are selectively buzz-pollinated only by *Bombus terricola* Kirby in upstate New York. J. Kansas Entomol. Soc. 66, 252–254.
12. Bawa, K.S., 1990. Plant-pollinator interactions in tropical rain forests. Ann. Rev. Ecol. Syst. 21, 399–422.
13. Boggs, C.L., Ross, C.L., 1993. The effect of adult food limitation on life history traits in *Speyeria mormonia* (Lepidoptera: Nymphalidae). Ecol. 74, 433–441.
14. Bradshaw, W.E., Holzapfel, C.M., 2007. Evolution of animal photoperiodism. Ann. Rev. Ecol. Evol. Syst. 38, 1–25.
15. Breshears, D.D., Huxman, T.E., Adams. H.D., Zou, C.B., Davison, J.E., 2008. Vegetation synchronously leans upslope as climate warms. PNAS 105, 11591–11592.
16. Bugmann, H. 1999. Anthropogene Klimaveränderung, Sukzessionsprozesse und forstwirtschaftliche Optionen', *Schweiz. Z. Forstwesen* 150, 275–287.
17. Chapman, C.A., Chapman, L.J., Struhsaker, T.T., Zanne, A.E., Clarke, C.J., Poulson, J.R., 2005. A long-term evaluation of fruiting phenology: importance of climate change. J. Trop. Ecol. 21, 31–45.
18. Chen, I.C., Hill. J.K., Ohlemuller. R., Roy, D.B., Thomas, C.D., 2011. Rapid range shifts of species associated with high levels of climate warming. Science 333, 1024–1026.
19. Cheng, L., Zou, Y., Ding, S., Zhang, J., Yu, X., Cao, J., Lu, G., 2009. Polyamine accumulation in transgenic tomato enhances the tolerance to high temperature stress. J. Integr. Biol. 51, 489–499.
20. Chmielewski, F.-M.; Müller, A., Bruns, E. 2004. Climate changes and trends in phenology of fruit trees and fields crops in Germany, 1961-2000. Agri. Forest Meter. 121, 69–78
21. Chouard, P., 1960. Vernalization and its relations to dormancy. Ann. Rev. Pl. Physiol. 11, 191–238.
22. Cleland, E.E., Chuine, I., Menzel, A., Mooney, H.A., Schwartz, M.D., 2007. Shifting plant phenology in response to global change. Tr. Eco. Evol. 22 (7), 357–365.
23. Craufurd, P.Q., Wheeler, T.R., 2009. Climate change and the flowering time of annual crops. J. Exp. Bot. 60(9), 2529–2539.
24. Davidowitz, G., D'Amico, L.J., Nijhout, H.F., 2004. The effects of environmental variation on a mechanism that controls insect body size. Evol. Ecol. Res. 6, 49–62.
25. De Frenne, P., Brunet. J., Shevtsova, A., Kolb, A., Graae, B.J., 2011. Temperature effects on forest herbs assessed by warming and transplant experiments along a latitudinal gradient. Glob. Change Biol. 17, 3240–3253.
26. Deshingkar, P., Bradley, P.N., Chadwick, M.J., Leach, G., 1997. Adopting to climate change in a forest based land use system. A case study of Himachal Pradesh, India. Report submitted to the SEI.
27. Donnelly, S.E, Lortie, C.J., Aarssen, L.W., 1998. Pollination in *Verbascum thapsus* (Scrophulariaceae): The advantage of being tall. Am. J. Bot. 85, 1618–1625.
28. Essemine, J., Ammar, S., Bouzid, S., 2010. Impact of heat stress on germination and growth in higher plants: Physiological, biochemical, and molecular repercussions and mechanisms of defence. J. Biol. Sc. 10, 565–572.
29. Fischlin, A., Gyalistras, D., 1997. Assessing impacts of climatic change on Forest in the Alps. Global Ecol. Biogeogr. Lett. 6, 19–37.
30. Fitter, A.H., Fitter, R.S.R., 2002. Rapid changes in flowering time in British plants. Science 296, 1689–1691.
31. Frei, E., Bodin, J., Walther, G.R., 2010. Plant species range shifts in mountainous areas-all uphill from here? Bot. Helv. 120, 117–128.
32. Gallai, N., Salles, J-M, Settele. J., Vaissiere, B.E., 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecol. Econ. 68, 810–821.
33. Gan, Y., Angad, S.V., Cutforth, H.W., Potts, D., Angadi, V.V., Mc-Donald, C.L., 2004. Canola and mustard response to short period of high temperature and water stress at different developmental stages. Can. J. Plant Sci. 84, 697–704.
34. Geider, R.J., Delucia, E.H., Falkowski, P.G., Finzi, A., Grime, J.P., Grace, J., Kana, T.M., Laroche, J., Long, S.P., Osbome, B.A., Platt, T., Prentice, I.C., Raven, J.A., Schlesinger, W.H., Smetacek, V., Stuart, V., Sathyendranath, S.; Thomas, R.B.; Vogelmann, T.C.; Williams, P.; Woodward, F.I. 2001. Primary productivity of planet Earth: Biological determinants and physical constraints in terrestrial and aquatic habitats. Global Change Biol. 7 (8), 849–882.
35. Gilman, R.T., Fabina, N.S., Abott, K.C., Rafferty N.E., 2011. Evolution of plant–pollinator mutualisms in response to climate change. Evol. Appl. 5, 2–16.
36. Gordo, O., Sanz, J.J., 2005. Phenology and climate change: a long-term study in a Mediterranean locality. Oecol. 146, 484–495.
37. Gordo, O., Sanz, J.J., 2006. Temporal trends in phenology of the honey bee *Apis mellifera* (L.) and the small white *Pieris rapae* (L.) in the Iberian peninsula (1952–2004). Ecol. Entomol. 31, 261–268.
38. Harrison, R.D., 2000. Repercussions of El Nin˜o: drought causes extinction and the breakdown of mutualism in Borneo. Proc. R. Soc. Lond. B, 267, 911–915
39. Haugaasen, T., Peres, C.A., 2005. Tree phenology in adjacent Amazonian flooded and unflooded forests. Biotropica 37(4), 620–630.

40. Hedegart, R., 1976. Breeding systems, variation and genetic improvement of teak (*Tectona grandis* L.f.) in: Burley, J., Styles, B.T. (Eds.), Tropical trees: variation breeding and conservation. p. 109-121. Linn. Soc. Symp. Ser. No. 2, London: Academic Press.
41. Hegland, S.J., Boeke, L. 2006. Relationships between the density and diversity of floral resources and flower visitor activity in a temperate grassland community. Ecol. Entomol. 31, 532–538.
42. Hegland, S.J., Nielsen, A., Lazaro, A., Bjerknes, A-L., Totland, Ø., 2009. How does climate warming affect plant-pollinator interactions? Ecol. Lett. 12, 184–195.
43. Hideyuki, S., Takashi, S., 2003. Effects of high temperature interruption during vernalization on the inflorescence formation in turnip plants. J. Japanese Soc. Horti. Sci. 72, 329–334.
44. Hodkinson, I.D., Webb, N.R., Bale, J.S., Coulson, S.J., Strathdee, A.T., 1998. Global change and Arctic ecosystems: conclusions and predictions from experiments with terrestrial invertebrates on Spitsbergen. Arct. Antarct. Alp. Res. 30, 306–313.
45. Hoiss, B., Gaviria, j., Leingartner, A., Krauss, J., Steffan-Dewenter, I., 2012. Combined effects of climate and management on plant diversity and pollination type in alpine grasslands. Diversity distrib. 1–10. (DOI: 10.1111/j.1472-4642.2012.00941.x).
46. Hoover, S.E.R., Ladley, J.J., Shchepetkina, A.A., Tisch, M., Gieseg, S.P., 2012. Warming, CO2, and nitrogen deposition interactively affect a plant-pollinator mutualism. Ecol. Lett. 15, 227–234.
47. Iioh, A.C., Omatta, G., Ogbadu, G.H., Onyenekwe, P.C., 2014. Effects of elevated temperature on seed germination and seedling growth on three cereal crops in Nigeria. Acad. J. 9(18), 806–813.
48. Inouye, D.W., Saavedra, F., Lee-Yang, W., 2003. Environmental influences on the phenology and abundance of flowering by Androsace septentrionalis (Primulaceae). Am. J. Bot. 90, 905–910.
49. IPCC (2007) Climate change 2007: Working Group II Report: Impacts, adaptation and vulnerability. WMO and UNEP, Geneva.
50. Kelly, A.E., Goulden, M.L., 2008. Rapid shifts in plant distribution with recent climate change. Proc. Natl Acad. Sci. USA, 105, 11823–11826.
51. Kingsolver, J.G., Diamond, S.E., Seiter, S.A., Higgins, J.K., 2012. Direct and indirect phenotypic selection on developmental trajectories in *Manduca sexta*. Funct. Ecol. 26, 598–607.
52. Kingsolver, J.G., Huey, R.B., 2008. Size, temperature, and fitness: Three rules. Evol. Ecol. Res. 10, 251–268.
53. Kingsolver, J.G., Watt, W.B., 1983. Thermoregulatory strategies in *Colias* butterflies: Thermal stress and the limits to adaptation in temporally varying environments. Am. Nat. 121, 32–55.
54. Kirschbaum, M.U.F., Cannell, M.G.R., Cruz, R.V.O., Galinski, W., Cramer, W.P., 1996. Climate change impacts on forests. in: Watson, R.T., Zinyowera, M.C., Moss, R.H., Dokken, D.J., (Eds.), Climate change 1995. Impacts, adaptation and mitigation of climate change: Scietific-technical analyses. Cambridge University Press, Cambridge
55. Koti, S., Reddy, K. R., Reddy, V.R., Kakani, V.G., Zhao, D., 2005. Interactive effects of carbon dioxide, temperature, and ultraviolet-B radiation on soybean (*Glycine max* L.) flower and pollen morphology, pollen production, germination, and tube lengths. J. Exp. Bot. 56, 725–736.
56. Kudo, G., Nishikawa, Y., Kasagi, T., Kosuge, S., 2004. Does seed production of spring ephemerals decrease when spring comes early? Ecol. Res. 19, 255–259.
57. Leith, C., 1975. Climate response and fluctuation dissipation. J. Atmos. Sci. 32, 2022–2026.
58. Levin, D.A., Kerster, H.W., 1973. Assortative pollination for stature in *Lythrum salicaria*. Evol. 27, 144–152.
59. Liu, Y., Mu, J., Niklas, K.J., Li, G., Sun, S., 2012. Global warming reduces plant reproductive output for temperate multi-inflorescence species on the Tibetan plateau. New Phytol. 195, 427–436.
60. Memmott, J., Craze, P.G., Waser, N.M., Price, M.V., 2007. Global warming and the disruption of plant-pollinator interactions. Ecol. Lett. 10, 710–717.
61. Menzel, A., Fabian, P., 1999. Growing season extended in Europe. Nature 397, 659–661.
62. Menzel, C.M., Simpson, D.R., 1995. Temperatures above 20^0C reduce flowering in lychee (*Litchi chinensis* Sonn.). J. Hortic. Sci. 70, 981–987.
63. Minckley, R.L., Wcislo, W.T., Yanega, D., Buchmann, S.L., 1994. Behavior and phenology of a specialist bee (*Dieunomia*) and sunflower (*Helianthus*) pollen availability. Ecol. 75, 1406–1419.
64. Mitchell, R.A.C., Mitchell, V., Driscioll, S.P., Franklin, J., Lawlor, D.W. 1993. Effects of increased CO2 concentration and temperature on growth and yield of winter wheat at two levels of nitrogen application. Plant Cell Environ. 16, 521–529.
65. Mitra, R., Bhatia, C.R., 2004. Bioenergetic cost of heat tolerance in wheat crop. Curr. Sc. 94, 1049–1053.
66. Morita, S., Shiratsuchi, H., Takahashi, J., Fujita, K., 2004. Effect of high temperature on ripening in rice plants: Analysis of the effects of high night and high day temperatures applied to the panicle and other parts of the plant. Japan. J. Crop Sci. 73: 77–83.
67. Moza, M., Bhatnagar, A.K., 2005. Phenology and climate change. Curr. Sci. 89(2), 243–244.
68. Mueller-Dombois, D., 1972. Potential effects of the increase in carbon-dioxide and climate change in the dynamics of vegetation. Water, Air and Soil Poll. 64, 61–79

69. Muller, A., Diener, S., Schnyder, S., Stutz, K., Sedivy, C., 2006. Quantitative pollen requirements of solitary bees: Implications for bee conservation and the evolution of bee-flower relationships. Biol. Conserv. 130, 604–615.
70. Murcia, C., 1990. Effect of floral morphology and temperature on pollen receipt and removal in *Ipomoea trichocarpa*. Ecol. 71, 1098–1109.
71. Niu, G., Heins, R., Cameron, A., Carlson, W., 2002. Prevernalization daily light integral and vernalization temperature influence flowering of herbaceous perennials. Horti. Sci. 37, 1028–1031.
72. Ollerton, J., Winfree, R., Tarrant, S., 2011. How many flowering plants are pollinated by animals. Oikos 120, 321–326.
73. Penuelas, J. Filella, I. 2001. Responses to a warming world. Science 294, 793–795.
74. Pimm, S.L., Raven, P., 2000. Extinction by numbers. Nature 403, 843–845.
75. Prasad, P.V.V., Boote, K.J., Allen Jr., L.H., Thomas, J.M.G. 2003. Super-optimal temperatures are detrimental to peanut (*Arachis hypogaea* L.) reproductive processes and yield at both ambient and elevated carbon dioxide. Global Change Biol. 9: 1775–1787.
76. Prentice, I.C., Cramer, W., Harrison, S.P., Leemans, R., Monserud, R.A., Solomon, A.M., 1992. A global biome model based on plant physiology and dominance, soil properties and climate. J. Biogeogr. 19, 117–134.
77. Price, M.V., Waser, N.M., 1998. Effects of experimental warming on plantreproductive phenology in a subalpine meadow. Ecol 79, 1261–1271
78. Qaderi, M.M., Reid, D.M., 2008. Combined effects of temperature and carbon dioxide on plant growth and subsequent seed germinability of *Silene noctiflora*. Int. J. Plant Sci. 169, 1200–1209.
79. Radmacher, S., Strohm, E., 2010. Factors affecting offspring body size in the solitary bee *Osmia bicornis* (Hymenoptera, Megachilidae). Apidologie 41, 169–177.
80. Radmacher, S., Strohm, E., 2011. Effects of constant and fluctuating temperatures on the development of the solitary bee *Osmia bicornis* (Hymenoptera: Megachilidae). Apidologie 42, 711–720.
81. Rafferty, N.E., Ives, A.R., 2012. Pollinator effectiveness varies with experimental shifts in flowering time. Ecol. 93, 803–814.
82. Rani B.A., Maragatham, N., 2013. Effect of elevated temperature on rice phenology and yield. Ind. J. Sc. Tech. 6 (8), 5095–5097.
83. Rao, S.P., Solomon, A.J.R., 2002. Pollination ecology of Red Sanders *Pterocarpus santalinus* (Fabaceae), an endemic and endangered tree species. Curr. Sci. 83, 1144–1148.
84. Ravindranath, N.H., Joshi, N.V., Sukumar, R., Murthy, I.K., Suresh, H.S. 2003. Vulnerability and adaptation to climate change in the forest sector. in: Climate Change and India-Vulnerability Assessment and Adaptation. Shukla, P.R., Sharma, S.K., Ravindranath, N.H., Garg, A. Bhattacharya, S. (Eds.), University Press Pvt Ltd, Hyderabad, India, pp 227–265.
85. Reich, P.B., 1995. Phenology of tropical forests: pattern, causes and consequences. Can. J. Bot. 73, 164–174.
86. Saavedra, F., Inouye, D.W., Price, M.V., Harte, J., 2003. Changes in flowering and abundance of *Delphinium nuttallianum* (Ranunculaceae) in response to a subalpine climate warming experiment. Glob. Change Biol. 9, 885–894.
87. Sahli, H.F., Conner, J.K., 2007. Visitation, effectiveness, and efficiency of 15 genera of visitors to wild radish *Raphanus raphanistrum* (Brassicaceae). Am. J. Bot. 94, 203–209.
88. Sanchez, A.M., Bosch, M., Bots M., Nieuwland, J., Feron, R., Mariani, C., 2004. Pistil factors controlling pollination. The Plant Cell 16, 98–106.
89. Scaven, V.L., Rafferty N.E., 2013. Physiological effects of climate warming on flowering plants and insect pollinators and potential consequences for their interactions. Curr. Zool. 59(3), 418–426.
90. Schauber, E.M., Kelly, D., Turchin, P., Simon, C., Lee, W.G., 2002. Masting by eighteen New Zealand plant species: The role of temperature as a synchronizing cue. Ecol. 83, 1214–1225.
91. Sekercioglu, C.H., Primack, R.B., Wormworth, J., 2012. The effects of climate change on tropical birds. Biol. Conserv. 148, 1–18
92. Sgolastra, F., Kemp, W.P., Buckner, J.S., Pitts-Singer, T.L., Maini, S., 2011. The long summer: Pre-wintering temperatures affect metabolic expenditure and winter survival in a solitary bee. J. Insect Physiol. 57, 1651–1659.
93. Shah, F., J. Huangi, J., Cui, K., Nie, L., Shah, T., Chen, C., Wang, K., 2011. Impact of high-temperature stress on rice plant and its traits related to tolerance. J. Agri. Sc., 1–12.
94. Sihag, R. C., 1984. Influence of environmental factors on pollination activity of bees. Environ. Ecol. 2, 149–152.
95. Sinha, P.G., Saradhi, P.P., Uprety, D.C., Bhatnagar, A.K., 2011. Effect of elevated CO2 concentration on photosynthesis and flowering in three wheat species belonging to different ploidies. Agri. Eco. Envir. 142, 432–436.
96. Sparks, T., Collinson, N. 2007. Review of Spring 2007, Nature's Calendar project. Available at: [WWW document]. http:// www.naturescalendar.org.uk/NR/rdonlyres/E58D7E9E-0C9B- 4ACD-AB54-14203125C5A3/0/report_spring_2007.pdf. Last accessed on 21 November 2008.
97. Sparks, T.H., Jeffree, E.P., Jeffree, C.E., 2000. An examination of the relationship between flowering times and temperature at the national scale using long-term phenological records from the UK. Int. J.

Biometeorol. 44, 82–87. (doi:10.1007/s004840000049)

98. Springate, D.A., Kover, P.X., 2014. Plant responses to elevated temperatures: a field study on phenological sensitivity and fitness responses to simulated climate warming. Global Change Biol. 20, 456–465.

99. Steffan-Dewenter, I., Munzenberg, U., Burger, C., Thies, C., Tscharntke, T. 2002. Scale-dependent effects of landscape context on three pollinator guilds. Ecol. 83, 1421–1432.

100. Steffan-Dewenter, I., Schiele, S. 2008. Do resources or natural enemies drive bee population dynamics in fragmented habitats. Ecol. 89, 1375–1387.

101. Stenseth, N.C., Mysterud, A. 2002. Climate, changing phenology, and other life history and traits: nonlinearity and matchmismatch to the environment. Proc. Natl Acad. Sci. USA, 99, 13379–13381.

102. Talwar, S., Bhatnagar, A.K., 2014. Pollination biology of *Terminalia chebula* Retz. in Delhi and Western Ghats. Int. J. Pl. Repro. Biol. 6(2), 181–194.

103. Thakur, P., Bhatnagar, A.K., 2013. Pollination constraints in flowering plants - Human actions undoing over hundred million years of co-evolution and posing an unprecedented threat to biodiversity. Int. J. Pl. Repro. Biol. 5(1), 29–74

104. Theurillat, J-P., Guisan, A., 2001. Potential impact of climate change on vegetation in the European Alps: A review. *Climatic change* 50, 77–109.

105. Toh, S., Imamura, A., Watanabe, A., Okamot, A., Jikumaru, Y., Hanada, A., Aso, Y., Ishiyama, K., Tamura, N., Iuchi, S., 2008. High temperature induced abscissic acid biosynthesis and its role in the inhibition of gibberellin action in *Arabidopsis* seeds. Plant Physio. 146, 1368–1385.

106. Totland, Ø., 1994. Influence of climate, time of day and season, and flower density on insect flower visitation in alpine Norway. Arct. Antarct. Alp. Res. 26, 66–71.

107. Totland, O., Sottocornola, M., 2001. Pollen limitation of reproductive success in two sympatric alpine willows (Salicaceae) with contrasting pollination strategies. Am. J. Bot. 88, 1011–1015.

108. Tromp, J., 1984. Floral-bud formation in apple as affected by air and root temperature, air humidity, light intensity, and day length. Acta Horti.149, 39–47.

109. Visser, M.E., Both, C. 2005. Shifts in phenology due to global climate change: the need for a yardstick. Proc. R. Soc. B-Biol. Sci., 272, 2561–2569.

110. Vrieling, K., Saumitou-Laprade, P., Cuguen, J., van Dijk, H., de Jong, T.J., Klinkhamer, P.G.L. 1999. Direct and indirect estimates of the selfing rate in small and large individuals of the bumblebee pollinated *Cynoglossum officinale* L. (Boraginaceae). Ecol. Lett. 2, 331–337.

111. Wahid, A., Gelani, S., Ashraf, M., Foolad, M.R., 2007. Heat tolerance in plants: An overview. Environ. Exp. Bot. 61, 199–223.

112. Walch. K., Van Hasslet, P.R., 1991. The influence of low temperature on the membrane lipid composition and flowering capacity of tulip bulbs. Acta Horti. 298, 345–353.

113. Wall, M.A., Timmerman-Erskine, M., Boyd, R.S., 2003. Conservation impact of climatic variability on pollination of the Federally endangered plant, *Clematis socialis* (Ranunculaceae) Southeast. Nature 2, 11–24.

114. Warner, R.M., Erwin, J.E., 2006. Prolonged high-temperature exposure differentially reduces growth and flowering of 12 Viola ・ wittrockiana Gams. cvs. Scientia Horticulturae 108, 295–302.

115. Waser, N.M., 1976. Food-supply and nest timing of broad-tailed hummingbirds in Rocky mountains. Condor. 78, 133–135.

116. Watson, R.T., Zinyoera, M.C., Moss, R.H. 1996. Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analysis. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

117. Weerakoon, W.M.W., Maruyama, A., Ohba, K., 2008. Impact of humidity on temperature-induced grain sterility in rice (*Oryza sativa* L). J. Agro. Crop Sc. 194, 135–140.

118. Westphal, C., Steffan-Dewenter, I., Tscharntke, T., 2003. Mass flowering crops enhance pollinator densities at a landscape scale. Ecol. Lett. 6, 961–965.

119. Wheeler, T.R., Batts, G.R., Ellis, R.H., Hadley, P., Morison, J.I.L., 1996. Growth and yield of winter wheat (*Triticum aestivum*) crops in response to CO2 and temperature. J. of Agri. Sci. 127, 37–48.

120. Whitmore, T.C., Sayer. J.A. 1992. Deforestation and species extinction in tropical moist forests. in: Tropical Deforestation and Species Extinction. Whitmore, T.C., Sayer, J.A., (Eds.), Chapman and Hall, London, pp 1–14.

121. Wilcock, C., Neiland, R., 2002. Pollination failure in plants: Why it happens and when it matters. Trends Plant Sci. 7, 270–277.

122. Willmer, P.G., 1983. Thermal constraints on activity patterns in nectar-feeding insects. Ecol. Entomol. 8, 455–469.

123. Woodward, F.I., 1987. Stomatal numbers are sensitive to increases in CO_2 from pre-industrial levels. Nature 327, 617–618

124. Zwiers, F.W., 2002. Climate Change. The 20-Year Forecast. Nature 416, 690–691

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Potential impact of climate change on soil degradation and related issues: A review

Seema[1], J. Behari[2] and Paulraj R[1]*
[1]School of Environmental Sciences, Jawaharlal Nehru University, New Delhi-110067, India
[2]Amity University, Noida, Uttar Pradesh-201303, India
***Corresponding author:** *paulrajr@yahoo.com*

Abstract— Human activities are aggravating changes in global environment at unprecedented rates with potential severe consequences on various spheres of environment. Soils are closely linked to atmospheric system through different cycles such as carbon (C), nitrogen (N) and hydrological cycles. Climate change both in terms of temperature and precipitation is recognized as one of the major factors responsible for land degradation resulting in significant alterations in soil functions and processes such as soil organic matter (SOM), soil aggregate stability, soil available water, bulk density, microbial flora and fauna diversity, C and N nutrient cycling in environment. Land degradation is a complex process which deteriorates several soil features and reduces the land potential to produce benefits from a particular land use. Soils are crucial to food security and adverse changes in temperature and precipitation are likely to intensify degradation of soil and water resources which limits crop yields. Global food security threatened by climate change through changes in soil properties and processes is one of the most important challenges in the 21st century to supply food for the increasing population. Climate change will most likely result in depletion and altered distribution of natural resources which in turn will decrease crop yields and may heighten human conflicts. Hence this paper addresses land degradation as one of the most important factors assumed to be strongly influenced by global climate change.

Keywords: Climate change, land degradation, food security, soil processes, human conflict

1. INTRODUCTION

In the last 150-200 years considerable changes have taken place in the gaseous composition of atmosphere because of natural processes and human activities (Varallay, 2010). Anthropogenic activities like industrialization, increasing energy consumption, intensive agriculture, urban and rural development have aggravated the changes in the global climate at virtually unprecedented rates (Varallyay, 2010; Varallyay, 2007). Concentration of main greenhouse gases (carbon dioxide, methane, NO_x and carbohalogenides) has increased significantly in the last century especially CO_2 which showed a tremendous increase of 25-30% in the last 100-120 years (Varallyay, 2007). Increased greenhouse gases will lead to increase in global average temperature, precipitation and rainfall intensity in future as predicted by all general circulation models (GSMs) (Zang, 2005). The recent report of intergovernmental panel on climate change (IPCC) indicates that as compared to 1980-1999 temperature, the average global temperature will most probably rise between 1.1 and 6.4° C by 2090-2099 with the most likely rise between 1.8 and 40° C (Brevik, 2013).

Climate change both in terms of temperature and precipitation results in significant modification in soil conditions as depicted in Fig.1 although long term global soil change prognosis is rather difficult and far from satisfactory (Varallyay, 2012; Varallyay, 2007). United Nations Conventions to Combat Desertification (UNCCD) recognized climatic variations as one of the major contributing factors to land degradation (Javed et al., 2012) and is likely to be intensified by adverse changes in temperature and precipitation regimes (IPCC, 2001). According to 2007 impact assessments of climate change by IPCC, degradation of croplands is one of the three major procesess that are expected to follow climate change (Raleigh and Urdal, 2007). Land degradation is a complex process in which several soil features deteriorate and reduces the land potential to produce benefits from a particular landuse under a specified form of land management (Kumar and Das, 2014; Varallyay, 2007). As shown in Fig.1, soil degradation encompasses changes in physical, chemical and biological properties of soil (Kumar and Das, 2014; Javed et al., 2012) which may lead to the loss of soil; limitations in normal soil functions; decrease in productive capacity and soil fertility (Varallyay, 2007). Soils are crucial to food security and global food security threatened by climate change through changes in soil properties and processes is one of the most important challenges to supply food for the increasing population in the 21st century (Kang et al., 2009; Brevik, 2013). Hence this paper addresses land degradation as one of the most important factors assumed to be strongly influenced by global climate change and various processes associated with it.

2. LAND DEGRADATION PROCESSES

Land degradation may be the result of natural or /and human activities and climate change may have stronger or weaker, favourable or unfavourable, permanent or periodical, harmful (sometimes catastrophic), primary or secondary impact on soil processes (Varallyay, 2010).

Main soil degradation processes are:

2.1 Soil erosion

The rate, type and extension of soil erosion depend on combined influence of climate (quantity and intensity of rainfall), relief, vegetation and erodability characteristics

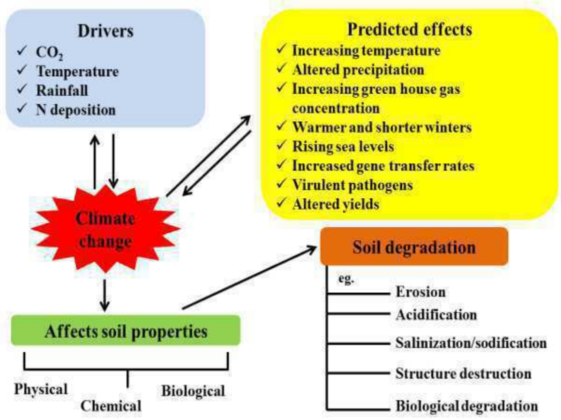

Figure 1. Schematic representation of the potential link between climate change, effect on soil properties and soil degradation.

of soil. There are no linear relationships observed between mean annual precipitation, surface run-off and rate of erosion but the main influence of climate change on erosion could be one of the followings (Varallyay, 2010; Varallyay, 2007):

a) Precipitation → Higher → Higher erosion
Precipitation → Lower → Lower erosion

b) Lower precipitation or higher temperature → Intensify wind erosion

Several researchers have examined effect of climate change on erosion rates. Favis-Mortlock and Boardman (1995) found that a 7% increase in precipitation could lead to 26% increase in erosion in UK. Lee et al. (1996) observed that 20% precipitation increase gave 37% increase in erosion. Similarly, Pruski and Nearing (2002) studied the effect of storm frequency and/or intensity on erosion and found that change in precipitation amount and intensity has much greater effect on soil erosion and run-off generation than change in storm frequency. Other studies conducted in US also indicated that in every case where precipitation was predicted to increase significantly, erosion also increased significantly.

2.2 Acidification

Acidification is a natural process that usually occurs as a result of nitrate leaching in high rainfall areas, on older more weathered soils and/or in association with lighter textured soils with low acid-buffering capacity (Fenton and Helyar, 2007). Most surprisingly, it is one of the main constraints to crop production in humid parts of the world and in tropical regions, the productivity of up to half of arable lands is limited by acidification (Brady and Weil, 2007). Acidification is regulated by climate through temperature and precipitation. Increase in precipitation increases downward filtration and leaching which may consequently increase acidification whereas decline in rainfall decreases leaching and reduces acidification extent (Kumar and Das, 2014). Climate indirectly influences this process by determining the dominant vegetation types, their productivity, the chemical character and decomposition of their litter deposits (Varallyay, 2010; Varallyay, 2007).

2.3 Salinization/ Sodification

One of the well-marked consequences of climate change is rise in eustatic sea level and IPCC has estimated a rise of 1-2 mm in sea level globally (MOSPI, 2013). Because of rising sea levels and increased risks of flooding, climate change is expected to contribute to further extensions of salt affected territories under the direct effect of temporal sea water inundations or due to rise of sea level connected water tables of saline or brackish ground waters. Besides that, higher precipitation reduces whereas lower precipitation and higher temperature intensifies salinization or sodification processes (Varallyay, 2007). pH and EC are important soil chemical properties used to characterize salinity and sodicity of soil. Smith et al. (2002) found that in a semi-arid environment, climate change scenario of decreasing precipitation and increasing temperature resulted in decrease in EC whereas increase in pH suggesting the tendency towards formation of salt-affected soils.

2.4 Structure destruction

Soil structure is one of the important properties of soil since it helps in maintaining important ecosystem functions in soil such as organic carbon accumulation, movement and storage of water, infiltration capacity and root and microbial community activity (Allen et al., 2011). Climate change deteriorates soil structure though quantification of changes in soil structure is hard to determine because of influence of land use and management (Kumar and Das, 2014). However, the most important direct impact of climate change is destruction of soil aggregates by raindrops, surface run-off and filtrating water while the indirect influences act through vegetation pattern and land use practices (Varallyay, 2007).

2.5 Biological degradation

Climate change consequences such as precipitation, temperature and vegetation alteration influence biological processes of soil considerably but only limited data is available on these consequences (Varallyay, 2007). Key biological processes like soil organic matter, soil carbon, labile soil organic carbon, soil respiration and biomass are known to be affected by global warming. Response of soil organic matter (SOM) to elevated temperature is controversial and without scientific consensus. Generally, increase in temperature enhances SOM decomposition thus reducing its availability but climate change drivers such as increase in temperature and precipitation, carbon dioxide fertilisation and atmospheric nitrogen decomposition may support plant productivity and consequently increases SOM (Allen et al., 2011). Lal et al (2007) predicted that soil organic carbon declines with increase in mean global temperature and thus adversely affect the important soil functions and processes.

Similarly, Davidson and Janssen (2006) and Knorr et al (2005) found that temperature rise rapidly depletes labile soil organic carbon. Recent studies have also shown that both soil respiration and biomass are responsive to changes in seasonal timing of rainfall (Chou et al., 2008) and short term environmental changes (Haynes, 2008) respectively.

3. Climate change impact on food security and human conflict

Climate change is likely to influence global food security and is considered among important challenges of 21st century (Kang et al., 2009). Reduction in crop yields may be experienced in some areas while other areas are likely to be benefitted. Temperature plays an important role in governing crop productions. In temperate areas, a rise of few degrees is projected to generally increase crop yields while greater warming may reduce agricultural outputs whereas in tropical areas, even minimal temperature increases may be detrimental to food production (Raleigh and Urdal, 2007). Adverse changes in temperature and precipitation are likely to intensify degradation of soil and water resources which also limits crop yields. In India, studies carried out showed that food production is sensitive to climate change like variations in monsoon rainfall and temperature. It is predicted that wheat production will decrease by 4-5 million tons for every 1°C increase in temperature and a loss of 10-40% in production may occur by 2100 (MOSPI, 2013). According to IPCC (2014) report, there could be a decrease of about 50% in food production in the most favourable and high-yielding areas of wheat in Indo-Gangetic plains as a result of heat stress at 2 times carbon dioxide. Changing climate is also projected to reduce monsoon sorghum grain yield in India by 2 to 14% by the year 2020, with worsening yields by 2050 and 2080 (Hijioka et al., 2014). For every 1 degree increase in temperature, yields of wheat, soyabean, groundnut, potato and mustard are expected to reduce by 3-7% (Agarwal, 2009). Similarly, paddy production may decline by 6% for every 1 degree increase in temperature (Saseendran et al., 2000). Moreover, with rising temperatures, the countrywide agricultural loss in India is estimated to be more than US$ 7 billion in 2030 which will severely affect the income of about 10% of the population (Hijioka et al., 2014).

Not only those, climate change leads to environmentally induced migration of people that can heighten the pressures on resources of destination resulting in resource competition and subsequently increases the risk of human conflict, particularly in less developed areas with limited mitigation capabilities. Ware (2005) and Byers and Dragojlovic (2004) found that global climate change has been contributing in communal tensions and conflicts in Melanesian countries and Darfur. Therefore, under certain conditions, climate change may increase the risk of some forms of violent conflicts.

4. Conclusions

Earth's climate is changing both in terms of temperature and precipitation because of increasing levels of greenhouse gases in the atmosphere. Changes in average temperature and precipitation affects various soil functions and processes such as soil aggregate stability, soil organic matter, microbial flora and fauna diversity, C and N nutrient cycling in environment. There are enormous evidences which points towards the impact of climate change on land degradation by different processes such as erosion, soil acidification, salinization, sodification, structure destruction or biological degradation. With increasing temperature and precipitation anomalies, depletion and altered distribution of natural resources will most likely occur which in turn will decrease crop yields and may heighten human conflicts. Therefore, detailed integrated multidisciplinary studies are required to quantify existing facts and processes in different spheres of environment for more actual prediction of consequences of climate change on environment, ecology, economy and even society which will ensure better preparedness of rational control of Earth processes under various climate scenarios.

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References

1. Agarwal, P. K., 2009. Global climate change and Indian agriculture: Case studies from ICAR network project. Indian Council of Agricultural Research, pp. 148.
2. Allen, D. E., Singh, B. P., Dalal, R. C., 2011. Soil health indicators under climate change: A review of current knowledge, in: Singh, B. P., Cowie, A. L., Chan, K. Y. (Eds.), Soil Health and Climate Change. Soil Biology, 29, Springer-Verlag Berlin Heidelberg.
3. Brady, N. C., Weil, R. R., 2007. The nature and properties of soils. Prentice Hall, New Delhi, India, pp. 380.
4. Brevick, E. C., 2013. The potential impact of climate change on soil properties and processes and corresponding influence on food security. Agriculture, 3, 398-417.
5. Byers, M., Dragojlovic, N., 2004. Darfur: a climate change-induced humanitarian crisis? Human Security Bulletin. October.
6. Chou, W. W., Silver, W. L., Jackson, R. D., Thompson, A. W., Allen-Diaz, B., 2008. The sensitivity of annual grassland carbon cycling to the quantity and timing of rainfall. Glob. Chang. Biol., 14, 1382–1394.
7. Davidson, E. A., Janssens, I. A., 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature, 440, 165–173.

8. Favis-Mortlock, D. T., Boardman, J., 1995. Nonlinear responses of soil erosion to climate change: a modelling study on the UK South Downs. Catena, 25, 365–387.
9. Fenton, G., Helyar, K., 2007. Soil acidification, in: Charman, P. E. V., Murphy, B. W. (Eds.), Soils: Their properties and management. 3rd Edition, Oxford University Press, Melbourne.
10. Haynes, R. J., 2008. Soil organic matter quality and the size and activity of the microbial biomass: their significance to the quality of agricultural soils, in: Huang, Q., Huang, P.M. Violante, A. (Eds.), Soil mineral-microbe-organic interactions: theories and applications. Springer, Berlin, pp. 201–230.
11. Hijioka, Y., Lin, E., Pereira, J. J., Corlett, R. T., Cui, X., Insarov, G. E., Lasco, R. D., Lindgren, E., Surjan, A., 2014, in: Barros, V. R., Field, C. B., Dokken, D. J., Mastrandrea, M. D., Mach, K. J., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B. E., Kissel, E. S., Levy, A. N., MacCraken, S., Mastrandea, P. R., White, L. L. (Eds.), Climate change 2014: Impacts, Adaptation and Vulnerability. Part B: Regional aspects-Asia. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University press, Cambridge, UK and New York, USA, pp. 1327-1370.
12. IPCC, 2001. Climate change 2001: Impacts, adaptations and vulnerability.Intergovernmental panel on climate change. <http://www.grida.no/climate/ipcc_tar/wg2/index.htm>
13. Javed, A., Jamal, S., Khandey, M. Y., 2012. Climate change induced land degradation and socio-economic deterioration: A remote sensing and GIS based case study from Rajasthan, India. Journal of Geographic Information System, 4, 219-228.
14. Kang, Y., Khan, S., Ma, X., 2009. Climate change impacts on crop yield, crop water productivity and food security: A review. Progress in Natural Science, 19, 1665–1674.
15. Knorr, W., Prentice, I. C., House, J. I., Holland, E. A., 2005. Long-term sensitivity of soil organic carbon turnover to warming. Nature, 433, 298–301.
16. Kumar, R., Das, A. J., 2014. Climate change and its impact on land degradation: Imperative need to focus. J. Climatol. Weather Forecasting, 2, 108, doi:10.4172/2332-2594.1000108.
17. Lal, R., Follett, R. F., Stewart, B. A., Kimble, J. M., 2007. Soil carbon sequestration to mitigate climate change and advance food security. Soil Sci., 172, 943–956.
18. Lee, J. L., Phillips, D. L., Dodson, R. F., 1996. Sensitivity of the US Corn Belt to climate change and elevated CO_2: II. Soil erosion and organic carbon. Agricultural Systems, 52, 503–521.
19. MOSPI, 2013. Statistics related to climate change-India. Ministry of Statistics and Programme Implementation, Government of India, New Delhi.
20. Pruski, F. F., Nearing, M. A. 2002. Runoff and soil-loss responses to changes in precipitation: a computer simulation study. Journal of Soil and Water Conservation, 57 (1), 7 – 16.
21. Raleigh, C., Urdal, H., 2007. Climate change, environmental degradation and armed conflict. Political geography, 26, 674–694.
22. Saseendran, A. S. K., Singh, K. K., Rathore, L. S., Singh, S. V., Sinha, S. K., 2000. Effects of climate change on rice production in the tropical humid climate of Kerala, India. Climate Change, 44, 495-514.
23. Smith, J. L., Halvoson, J. J., Bolton, H. Jr., 2002. Soil properties and microbial activity across a 500 m elevation gradient in a semi-arid environment. Soil Biol. Biochem., 34, 1749–1757.
24. Varallyay, G., 2010. The impacts of climate changes on soils and on their water management. Agron. Res. 8(2), 385-396.
25. Varallyay, G., 2007. Potential impacts of climate change of Agro-ecosystems: A review. Agriculturae Conspectus Scientificus, Vol. 72(1), 1-8.
26. Ware, H., 2005. Demography, migration and conflict in the Pacific. Journal of Peace Research, 42(4), 435-54.
27. X.C. Zhang., Nearing, M. A., 2005. Impact of climate change on soil erosion, runoff and wheat productivity in central Oklahoma. Catena, 61, 185-195.

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Climate Change: A Threat to Agriculture in India

Anjana Singha Naorem[1*] and Bijaya Thongatabam[1]
[1]Department of Zoology, Miranda House, University of Delhi, Delhi-110007
***Corresponding author:** *anjanasingha@gmail.com*

Abstract— The heat of climate change has been felt globally touching every sphere of life. Agriculture sector also had to bear the brunt of this change which is manifold. Nearly 18% Gross Domestic Product (GDP) of the Indian economy is generated by agriculture alone and any threat to its productivity can have dwindling effect on the food security and eventually to the country's economy. Besides the direct impact on the crop yield, its effect on the pest population, their distribution, behaviour, etc. has indirectly resulted in decline in crop productivity. Fluctuations in agricultural productivity owing to these factors affect the food security. Food security has become a prime concern more so in developing nations like India owing to lack of resources to mitigate the adverse effect of climate change on agriculture; and greater (~50%) dependence of the population on agriculture for livelihood. This paper examines some of the threats associated with the increasing global temperature on the agriculture sector and some mitigation strategies by different stakeholders in India.

Keywords: Climate Change, Agriculture, Temperature, Productivity and Crop Yield.

1. Introduction

Our planet earth has been experiencing a gradual increase in the average temperature every year. This increase is largely anthropogenic. Owing to the non-judicious use of fossil fuels, industrialization, clearing of forests to meet the demands of the ever-increasing population and blind race towards development of the nation, high concentration of green house gases (GHG) has been released resulting in global warming, a major factor leading to climate change. This heat of climate change has been experienced globally and has affected all forms of life on earth in many ways (Kumar and Parikh, 2001; Bale *et al.*, 2002; FAO, 2008; Datta, 2013).

India, a developing nation and primarily an agricultural based country has also felt the impact of climate change in the recent years. Developing countries are more vulnerable to such climate change owing to factors like less technological advancement, lack of resources to mitigate the adversities on agriculture, etc. Moreover, a greater dependence on agriculture for livelihood of larger proportion of population can further aggravate the situation (Nath and Behera, 2011).

Intergovernmental Panel on Climate Change (IPCC, 2014) has indicated that adverse impact of climate change due to rising temperatures and extreme weather events on food production system could impact agricultural growth which will be more so in countries near thermal optimum as a relatively minor increase during the growing season of 1 or 2 degrees Celsius can decrease the grain harvest (Sheehy, 2002, Lester, 2008). Any factor that results in the fluctuation of the yield would surely affect the economy of the country. The economic impact of climate change on agriculture, a major sector in India, is thus of paramount importance. This study broadly examines the ways by which the heat of climate change is going to affect the agrarian economy of India.

2. Impact on Agriculture

Indian agriculture system largely relies on the weather and climatic conditions. Some of the climate change factors that affect agriculture include change in the amount and pattern of monsoon, precipitation, temperature, carbondioxide, heat waves, droughts, etc. Any change in these physical conditions will influence crop productivity both directly and indirectly. Direct effect includes the physical factors like impact of changing temperature, rainfall and carbon dioxide whereas the indirect effect includes largely the biological factors and few physical factors like fluctuations in the population of insect pests, their distribution, disease transmission, soil fertility, sea level rise, etc.

2.1 Direct effect on some of the crop production

India ranks second in the production of wheat, rice and sorghum among cereals (FAO, 2014). It is also the largest producer of banana, mango and papaya among fruits and some of the vegetables like chickpeas, ginger etc (FAO, 2014). But unfortunately, the rising temperature has had an adverse impact on these agricultural products. International Rice Research Institute forecasts 20% reduction in yields in India per degree celsius rise of temperature. At temperatures above 35 degrees for more than one hour during flowering, results in rice becoming sterile and hence producing no grain (Senapati *et al.*, 2013). Such yield loss has been reported for wheat production too. Geographers at the University of Southampton reported that recent warmer temperatures in the country's major wheat belt are having a negative effect on crop yield especially during the crop ripening period. More specifically, they found a rise in night temperatures had a severe impact on wheat productivity (Duncan *et al.*, 2014).

Higher temperatures though has negative impact on agricultural produce but one of the important factor of climate change- the high levels of atmospheric CO_2 is having a positive impact on crop yield. The balance between these two parameters along with other factors like water availability, precipitation, soil nutrition, pest abundance etc. ultimately is the deciding factor in agricultural yield. Increase in carbondioxide concentration is known to have an increase in photosynthetic activity hence higher yield of the crop which is known as carbon fertilization effect. For the majority of the crops, the detrimental effect of higher temperatures on yields overrides the CO_2 fertilization effect. Kumar and Parikh (2001) assessed the impact of rise in temperature on wheat and rice yield in North India and found that 2 degree rise in temperature resulted in reduced yield.Wheat yield declined from 37% to 58%. When they combined the negative effects of higher temperature with the positive effects of CO_2 fertilization, the decline in yields ranged from 8% to 38%. In the mustard crop similar findings were observed. Increase in CO_2 from 369 to 550 ppm with no change in temperature resulted in 15.8–31% increase in yield of irrigated mustard while increasing temperature reduced mustard grain yield. The positive effect of increase in CO_2 concentration was nullified by temperature rise. Rise in temperature coupled with rise in CO_2 to 450 and 550 ppm decreased yield reduction to 82.4 and 79.4% respectively (Boomiraj *et al.,* 2010)

Impact on horticultural crops is also very evident due to the climate change. It is predicted that reduction in the winter regime (chilling duration) may affect pollination in some plants owing to early and frequent flower and fruit drop; anthocyanin production may be affected in apples and capsicum, tuber initiation process in vegetables like potato may be delayed, tip burn and blossom end rot may result in decreased tomato production,etc. (Datta, 2013). Sunburn and cracking in apples, apricot, cherries and litchi have been reported owing to high temperature and moisture stress (Kumar and Kumar, 2007). Such morphological, physiological and phenological changes like malformations in plant structures, sterility, yield reduction, delay or advancement in maturity affecting the reproductive phase of the plant, increase in vegetative growth, etc. have been reported due to the variable climatic conditions experienced by the crop plants.

One of the other impacts of climate change is on the availability of water resource. Climate change has resulted in extreme events like inter and intra-seasonal droughts and floods, low soil organic matter, soil erosion, less availability of energy, coastal floods, etc. affecting livelihood and food security. It has been realised that farmers dependent on rain-fed agriculture would not only face water scarcity but would have adverse impact of it on agriculture (Pachauri, 2010). Low water use efficiency, poor maintenance of irrigation systems and poor recovery of water charges are some of the major problems associated with the water resource management in the country which along with irregularities in rain owing to climate change have impacted heavily on several of the crop plants. Excessive rains and extreme variation in temperature has been reported to adversely affect the productivity of jowar crop in Karnataka (Kaul and Ram, 2009). Srivastava *et al.* (2010) reported that with a reduced monsoon, sorghum productivity may decline up to 14% in central India and up to 2% in south central India by 2020. In India, under the projected surface warming and shift in rainfall the crop yield may decrease by 30% by the mid-21stcentury. This may result in reduction in arable land and hence pressure on agriculture production (Kapur *et al.*, 2009).

2.2 Indirect effect of climate change

IPCC (2007) have reported that with increase in frequency of warmer days and nights and reduction in winter season, the insect outbreak may result which will affect the agriculture, forestry and health sectors. Shorter winters are favourable for the breeding of large number of insect pests, their range expansion, disruption of synchrony between pests and natural enemies (Bale *et al.,* 2002, Parmesan 2007). Generally, it is predicted that with the increase in global temperatures, the insect species will shift their geographical ranges closer to the northern pole or to higher elevations, and result in increase in their population size (Samways, 2005).

Rise in temperature along with reduction in precipitation could cause reduction in availability of irrigation water leading to increase in soil salinity. Sea level increase has also resulted significantly to soil salinity. Increase in soil salinity particularly in irrigated croplands which provide 40% of the world's food has resulted in threat in vegetable production (Datta, 2013). Soil salinity results in decreased water uptake due to high osmotic potential of the soil solution, so the plant has to invest more energy for the absorption of water. This may result in toxicity to the plants often showing the symptoms of stunted plant growth, small leaves, and marginal necrosis of leaves or fruit distortions. Sometimes it may also result in interference with uptake of essential nutrients. Soil temperature also affects yield by affecting the fertility of the soil. At high temperatures, the nutrient availability of the soil increases due to high rates of organic matter decomposition but it is only short-term; in the long-run organic matter content will diminish, resulting in a decline in soil fertility (Pathak, 2012).

3. Threat to Food Security- An Economic Impact

Agriculture occupies a prominent position in Indian policy-making not only because of its contribution to GDP but also because of the dependence of large proportion of the population on this sector for its livelihood. Despite the declining input of the agriculture, it is still the biggest contributor contributing nearly 18% GDP to Indian economy. It supports the livelihood of over 80% of the rural population and employs nearly 50% of the labour force (Tyagi, 2012, NAEP, 2012). There are four major components of food security - availability, accessibility, stability and utilization of food (ADB, 2012).Threat to agriculture production will affect the food demand by affecting these four key components of food security. Climate change has adversely affected the food security in all countries through agriculture production (Kaul and Ram, 2009, Pathak, 2012, Datta, 2013).

Currently in India 213 million people are food insecure and over 100 million are reliant on the national food welfare system (Duncan *et al*., 2014).The rising temperatures will adversely affect the world's food production and India would be the hardest hit in the area of production of wheat, rice, soy and maize, according to the analysis by the Universal Ecological Fund (FEU-US) (Senapati *et al.,* 2013). Availability of food is directly affected by climate change through its impact on agricultural production. Indirect impact of climate change is on economic growth, income distribution and agricultural demand (Schmidhuber and Tubiello, 2007). It is estimated that due to climtate change, the GDP may decrease up to 6.2% and agriculture production may decrease up to 24% by 2080 in India (Zhai and Zhuang, 2009, Zhai *et al.,* 2009). Food security is a global challenge but in Indian condition it is more critical as by 2050, India's population is projected to grow to 1.6 billion (Misra and Dave, 2013). Therefore, in future more crop production will be required to satisfy the food demand against all the challenges faced by agriculture sector.

Global warming has resulted in huge loss of Himalayan glaciers in the form of water which is estimated to be 174 gigatonnes of water between 2003-2009 and has contributed to catastrophic floods of the Indus, Ganges and Brahmaputra rivers (Gardner *et al.,* 2013). The UN second working report predicted huge coastal erosion by rising sea levels (about 40 cm) resulting from faster melting glaciers in the Himalaya-Hindukushranges (Mahapatra, 2009). UNFCCC has identified India as one of the hotspots for forced migration due to climate change, with people displaced by drought, floods and a rising sea. The estimated high impact on Bangladesh's coasts means more refugees from that country to India. This migration has lead to internal displacement resulting in dramatic increase in environmental refugees and adding huge economic burden to the nation (Mahapatra, 2010, Sangma and Rana, 2010)

4. Mitigation Strategies

Climate change has diverse impacts which include population growth, poverty, economic development, sustainable development and resource management globally. So the mitigation solutions should come from all disciplines and fields of research and development (UNFCCC, 2014). IPCC (2007) predicts that due to climate change, 40 to 170 million people will be undernourished all over the world. Some stringent action needs to be developed to mitigate against and adapt to climate change to address to serious issues of food security. Such serious issues at both national and global level need to be resolved by the participation of the people from all spheres to meet the challenges and lessen the impact to almost nil.

4.1 Local mitigation strategies

Farmers in some wheat growing areas have been changing their growing season slightly in order to align the most sensitive point of the crop growth cycle- the reproductive and grain ripening phase, with a cooler period. But these solutions are temporary which will not be able to overcome the crop loss if the average temperature rise continues as predicted for the future (Duncan *et al*., 2014).To address to the issues of food security, large scale agricultural research, cropping system developed so far, needs to be well promoted among farmers. New cultivars that are resistant to drought, pests, diseases, heat and salt can be promoted to be used by farmers against the traditional varieties (Pachauri, 2010). Judicious use of land resources should be one of the strategies to meet these challenges (Datta, 2013). Apart from this, strict afforestation measures, adoption of efficient use of water for irrigation, organic farming and promotion of use of renewable sources of energy could mitigate the problem to a large extent.

4.2 Government strategies for mitigation

National Mission for Sustainable Agriculture (NMSA) under National Action Plan on Climate Change (NAPCC) addresses issues on '*Sustainable Agriculture*' in the context of risks associated with climate change (NMSA, 2010). It stresses on devising appropriate adaptation and mitigation strategies to transform Indian agriculture into a climate resilient production system to ensure food security, enhancing livelihood opportunities and contributing to economic stability at National Level. NMSA has indentified 10 key dimensions for promoting suitable agricultural practices, which will be realized by implementing a Programme of Action (PoA) that covers both adaptation and mitigation measures through four functional areas, namely, Research and Development, Technologies, Products and Practices, Infrastructure and Capacity building. The emphasis of these action plans are on:

- Developing mainstream research and development activities
- Developing and adopting improved technology and best agricultural practices
- Creation of physical and financial infrastructure and institutional frame work to facilitate access to information and promoting capacity building
- Developing suitable drought and pest resistant crop varieties to promote dryland agriculture
- Coverage of rain fed areas for integrating farming systems with livestock and fisheries to increase the agricultural production

5. Conclusion

Impact of climate change on agricultural productivity is multidimensional as several factors regulate the crop yield and these factors in turn are under the influence of climate change. This has serious implication as understanding the overall effect of climate change on the food supply can be difficult. Such climatic fluctuations could adversely affect agricultural sustainability resulting in unforeseen situational shortages. If the temperature continues to rise, large scale agricultural research for developing climate tolerant varieties of crop and advancement in agricultural practices to adapt to the changing climate may probably prevent temperature-induced yield losses. Stringent government plans and actions along with educating the farmers regarding the use of eco-friendly and organic techniques with the efficient use of the natural resources like water, land, will alleviate the threat to a certain extent.

The most important and challenging task in tackling the threats to climate change is the need for effective and adequate mitigation measures worldwide by which reduction in the emission of greenhouse gases can be achieved to overcome the various threats associated with it.

References

1. Asian Development Bank (ADB), 2012. Food security and poverty in Asia and the Pacific: Key challenge and policy issues. Mandaluyong City, Philippines. Pp. 33.
2. Bale, J.S.B., Masters, G.J., Hodkinson, I.D., Awmack, C., Bezemer, T.M., Brown, V.K., Butterfield, J., Buse, A., Coulson, J.C., Farrar, J., Good, J.E.G., Harrington, R., Hartley, S., Jones, T.H., Lindroth, R.L., Press, M.C., Symrnioudis, I., Watt, A.D., Whittaker, J.B., 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Glob. Change Biol. 8, 1-16.
3. Boomiraj, K., Chakrabarti, B., Aggarwal, P.K., Choudharya, R.,Chander, S., 2010. Assessing the vulnerability of Indian mustard to climate change. Agric. Ecosyst. Environ. 138, 265-273.
4. Datta, S., 2013.Impact of climate change in Indian horticulture- a review. Int. J. Sci. Environ. Technol. 2(4), 661- 671.
5. Duncan, J.M.A., Dash, J., Atkinson, P.M., 2014. Elucidating the impact of temperature variability and extremes on cereal croplands through remote sensing. Glob. Change Biol. doi: 10.1111/gcb.12660.
6. Food and Agriculture Organization of the United Nations (FAO), 2008. Climate change and food security: a framework document. Rome, Italy.
7. Food and Agriculture Organization of the United Nations (FAO), 2014. http://faostat3.fao.org/home/E. Retrived on 25 June 2015
8. Gardner, A.S., Moholdt,G., Cogley, J.G., Wouters, B., Arendt, A.A., Wahr, J. Berthier, E., Hock, R., Pfeffer, W.T., Kaser, G., Ligtenberg, S.R.M., Bolch, T., Sharp, M.J., Hagen, J.O., van den Broeke, M.R., Paul, F. 2013. A Reconciled estimate of glacier contributions to sea level rise: 2003 to 2009. Science, 340, 852-857.
9. IPCC, 2007. Climate Change- Impacts, Adaptation and Vulnerability. in: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E.(eds.) Cambridge University Press, Cambridge, UK, pp. 976.
10. IPCC, 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. in: Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.
11. Kapur, D., Khosla, R., Mehta,P.B., 2009. Climate change: India's options. Economic and Political Weekly 36(31).
12. Kaul, S., Ram G., 2009. Impact of global warming on production of jowar in India (special issue: sustainable agriculture in the context of climate change). Agric. Situa. India 66(5), 253-256.
13. Kumar, K.S.K., Parikh, J., 2001. Socio-Economic Impacts of Climate Change on Indian Agriculture. Int. Rev. Environ. Strategies 2(2), 277-93;
14. Kumar, R., Kumar, K.K., 2007. Managing physiological disorders in litchi.Indian Horticulture. 52(1), 22-24.
15. Lester, R. B. 2008. Rising temperatures and rising seas: the crop yield effect. in: plan b 3.0: mobilizing to save civilization. earth policy institute.
16. Mahapatra, R. 2009. Sea change coming. Infochange news and features. http://infochangeindia.org/environment/coastal-nightmares/sea-change-coming.html. Retrieved on April1, 2015.
17. Mahapatra, R, 2010. Coastal refugees. Infochange Agenda. http://infochangeindia.org/agenda/coastal-communities/coastal-refugees.html. accessed on 28/02/2015.
18. Misra, A.K., Dave, N., 2013. Impact of soil salinity and erosion and its overall impact on India. International Journal of Innovative Research in Engineering & Science, 2(3), 12-17.
19. NAEP, 2012. Detailed Project Report of the National Agricultural Education Project. Indian Council of Agricultural Research Department of Agricultural Research & Education.
20. Nath, P.K., Behera, B., 2011. A critical review of impact and adaptation to climate change in developed and developing countries. Environ. Dev. Sustain. 13, 141-162.
21. NMSA (National Mission for Sustainable Agriculture. 2010. Strategies for meeting the challenges of climate change. Department of Agriculture and Cooperation, Ministry of Agriculture. New Delhi.
22. Pachauri, R.K. 2010. Climate change and its implications for India's fragile ecosystems. in: Sugathan, R., Seath, F., Deka, K. (eds) Policy notes for Parlimentarians. The human impact of climate change in India advancing political leadership. Pp. 1-4
23. Parmesan, C., 2007. Influences of species, latitudes and methodologies on estimates of phenological response to global warming.Global Change Biology. 13, 1860-1872.
24. Pathak, H, 2012. Climate change and agriculture. in: Pathak, H., Aggarwal, P.K. Singh, S.D.(eds.), Climate Change Impact, Adaptation and Mitigation in Agricultur: Methodology for Assessment and Application. Indian Agricultural Research Institute, New Delhi. pp 302
25. Samways, M.J., 2005. Global climate change and synergistic effects. In: Insect Diversity Conservation. Cambridge University Press. Pp. 342.
26. Sangma, T., Rana, T. 2010. Climate change: Threat to the abode of clouds. The human impact of climate change in India advancing political leadership. Pp. 11-

16.
27. Schmidhuber, J., Tubiello, F.N., 2007. Global food security under climate change', Proc.Natl. Acad. Sci. U.S.A. 104(50), 581-596.
28. Senapati, M.R., Behera, B., Mishra, S.R., 2013. Impact of climate change on Indian agriculture and its mitigating priorities. American Journal of Environmental Protection. 1(4), 109-111.
29. Srivastava, A., Kumar, S.N., Aggarwal, P.K., 2010. Assessment on vulnerability of sorghum to climate changes in India. Agric. Ecosyt. Environ.138, 160-169.
30. Sheehy, J.E. 2002. International Rice Research Institute, Earth Policy Institute, 1 October 2002; Pedro Sanchez, "The Climate Change-Soil Fertility-Food Security Nexus," speech, Sustainable Food Security for All by 2020, Bonn, Germany, 4–6 September 2002; USDA.
31. Tyagi, V, 2012. India's agriculture: Challenges for growth & development in present scenario. International Journal of Physical and Social Sciences. 2(5), 116-128.
32. United Nations Framework Convention on Climate Change, 2014. Background on the UNFCCC: The international response to climate change.
33. Zhai, F., Lin, T., Byambadori, E., 2009. A general equilibrium analysis of the impact of climate change on agriculture in the people's republic of China', Asian Devel. Rev. 26(1), 206-225.
34. Zhai, F., Zhuang, J., 2009. Agriculture impact of climate change: A general equilibrium analysis with special reference to Southeast Asia. ADBI Working Paper Series 131.

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Impact of Climate Change on Crops and Adaptation Strategies in India

Neha Singh[1*], Hema Singh[1] and R. K. Mall[2]
[1]Department of Botany, Banaras Hindu University, Varanasi
[2]Institute of Environment and Sustainable Development, Banaras Hindu University, Varanasi
***Corresponding author:** *nnssingh68@gmail.com*

Abstract— In India, several studies shows that there is increasing trend in surface temperature i.e. 0.5 to 0.7^o C during 1901-2013, the recent period 1971-2013 has seen a relatively accelerated warming of 0.22^{o}C/decade, no significant trend in rainfall and/or decreasing/increasing trends in rainfall and sharp decrease in rainy days. Fifth assessment report of Inter-Governmental Panel on Climate change for India projected an increase in temperature by 1.5^{o}C to 4.3^{o}C and increase in rainfall by 6-14% for all Representative Concentration Pathway (RCP) scenarios by 2080, compared with baseline 1961-1990. Different simulation studies also showed mean warming in India is likely to be in the range 1.7-2^{o}C by 2030s 1.9-2.4^{o}C by 2060s and 1.9-4.8^{o}C by 2080s relative to pre-industrial period. This would result in increase in extreme weather events like floods, drought, cyclones, heat and cold waves, which will be detrimental to agriculture and thus threatens food security. Now a days crop simulation models are being used, which are less time consuming to study the effects of climate change on crops. After gathering the information about impact we can develop adaptation strategies like change in planting dates and varieties, climate-change tolerant genotypes etc. In this study, an attempt has been made to present the current status of the climate change impact on agriculture and adaptation strategies in India.

Keywords: Climate Change, Crop Simulation Models, Adaptation Strategies.

1. Introduction

The surface air temperature over the past century across India shows a significant warming of 0.51^{o}C/100 years caused mainly by the warming in post-monsoon and winter seasons by increase in temperature contributed by rise in maximum as well as minimum temperature (Krishna Kumar et al. 2011). Simulation study using PRECIS (Providing Regional Climate for Impact Studies)- a Regional Climate Model (RCM) for future projections indicate an increase in an all-round warming over the Indian sub-continent due to increase in greenhouse gases and positive change in rainfall by increasing rain intensity especially during the monsoon months (Kumar et al. 2011, Kumar et al. 2006). Further study using PRECIS estimated 20% rise in all India summer monsoon rainfall in future scenarios as compared to present with maximum effect on western Ghats, west central India and northwestern Peninsular India (Kumar et al. 2006) and higher warming in the northern part of the country compared to the southern part of the country and large increase in night temperatures than the day temperatures (Rupa Kumar et al. 2006,Chaturvedi et al. 2012). Future study on climate change for 2030 scenarios shows projected increase in maximum and minimum temperature and rainfall at Western Ghats, coastal regions and north-east regions at different rates with some exceptions like east coast and kharif season at north east showing decreasing trends in rainfall (Naresh Kumar et al. 2011). Many studies have confirmed decrease in monsoon rainfall and increase in post-monsoon rainfall in different parts of the country (Kothyari et al.1996, Krishna Kumar et al. 2009, Choudhury et al. 2012), however, Patle and Libang (2014) found decrease in post monsoon rainfall in north-east regions of the country.

Similar results were found by the latest study of Intergovernmental Panel on Climate Change (IPCC), fifth Assessment Report (AR5) using Representative Concentration Pathways (RCPs) scenarios under the coupled Model Inter-comparison Project 5 (CMIP5). The CMIP5 ensemble that mean climate is closer to observed climate than any individual model. The RCPs represent pathways of radiative forcing with maximum radiative forcing of 2.6 W/m^2 and maximum of 8.5W/m^2.The variance in precipitation and temperature rise increases rapidly from the RCP2.6 to RCP 8.5 and the precipitation changes are large for each subsequent period i.e. short, medium and large (Chaturvedi et al. 2012).Table 1 shows gradual increase in annual average temperature and rainfall for the 2080s relative to 1961-1990 baselines. Similar result has been observed for short, medium and long-term scenarios compared to the pre-industrial base line in table 2.

Global warming may also threaten India's food security if there is a negative effect on agriculture. Although, the effect of increasing CO_2 concentrations will increase the net primary productivity of plants, but climate changes, and the changes in disturbance regimes associated with them, may lead either to increased or decreased net ecosystem productivity. In many tropical and subtropical regions, potential yields are projected to decrease for most projected increases in temperature. Indirectly, there may be considerable effects on land use due to snow melt, spatial and temporal rainfall variability, availability of irrigation, frequency and intensity of inter- and intra-seasonal droughts and floods, soil organic matter transformations, soil erosion, change in pest profiles, decline in arable areas due to submergence of coastal lands, and availability of energy. All these can have tremendous impact on agricultural production and hence, food security of any region (Aggarwal, 2003, 2008, Mall et al., 2011). The rising temperatures and carbon dioxide and uncertainties in rainfall associated with global warming may or may not have serious direct and indirect consequences on crop production.

Table1: All-India average annual temperature and rainfall change projections for 2080s relative to the 1961–1990 baseline (Chaturvedi et al. 2012).

RCP scenarios	Change in temperature (°C)	Change in rainfall
RCP 2.6	1.5	6%
RCP 4.5	2.4	10%
RCP 6.0	2.8	9%
RCP 8.5	4.3	14%

Table 2: CMIP5 model ensemble based temperature change projections for short- (2030s), medium (2060s) and long-term (2080s) scenarios compared to the pre-industrial base line (1880s) for all RCP scenarios (Chaturvedi et al. 2012).

Scenarios based on time duration	Change in temperature(°C)	Change in rainfall
2030s	1.7-2.02	1.2-2.4%
2060s	1.92-2.37	2.7-6.6%
2080s	1.95-4.78	3.5-11.3%

It is, therefore, important to have an assessment of the direct and indirect consequences of global warming on different crops especially on cereals contributing to the food security (Gadgil et al., 1995, 1999a,b). Mechanistic crop growth models are now routinely used for assessing the impacts of climate change. There are several crop simulation models now available for the same crop that can be employed for impact assessment of climate change (Saxena et al., 2002; Mall and Aggarwal, 2002, Mall et al., 2006). Crop weather models, in general, integrate current knowledge from various disciplines including agrometeorology, soil physics, soil chemistry, crop physiology, plant breeding, and agronomy, into a set of mathematical equations to predict growth, development and yield of a crop (Aggarwal and Kalra 1994; Hoogenboom, 2000; Sivakumar and Motha, 2007).

2. IMPACT OF CLIMATE CHANGE ON AGRICULTURE

A number of studies on climate change shows increase in temperature and variability in rainfall pattern will likely to affect agriculture through their direct and indirect effects on crops, soils, livestock and pests. The increase in atmospheric carbon dioxide promotes growth and productivity of plants by carbon fertilization but increase in temperature, above optimum level reduces crop duration, increase crop respiration rates, affect the survival and distribution of pest populations, and hasten nutrient mineralization in soils, decrease fertilizer-use efficiencies and increase evapo-transpiration. Recent IPCC report and several other studies indicate a probability of 10-40% loss in crop production in India and other South Asian countries with increases in temperature by 2080-2100 and decrease in irrigation water. India could lose 4-5 million tons wheat production with every rise of 1^0C temperature throughout the growing period even after considering carbon fertilization (but no adaptation benefits). Rise in temperature cancels the beneficial effect of CO_2 due to reduced crop duration resulting into lower accumulation of photosynthates dry matter and hence lower crop yield (Ainsworth et al. 2005, Naresh Kumar et al. 2011). The study shows an increase in CO2 by 550ppm would raise yield of wheat and rice by 10%, soybean by 15% and negligibly for sorghum and maize, which are C4 crops. Further studies in Rajasthan, a 2°C rise in temperature were estimated to reduce production of pearl millet by 10-15 per cent. An increase in CO_2concentration would increase the soybean yield by 50 percent when the concentration of carbon dioxide is doubled. However, if the increase in carbon dioxide is accompanied by an increase in temperature then soybean yields could actually decrease when the maximum and minimum temperatures go up by 1°C and 1.5°Crespectively, the gain in yield comes down to 35 percent(Samui and Kamle, 2008).The yield of C4 crops are projected to decline in the future due to increase in temperature and rainfall but may be benefitted through leaf water balance (Ghannoum et al.,2000) It is estimated that by 2020, food grains requirement would be almost 30-50%more than the current demand (Paroda and Kumar, 2000). Uncertainty in precipitation causes droughts and floods which would change land use pattern, availability of rain for irrigation, soil organic matter transformations, soil erosion, decline in arable areas(due to submergence of coastal lands), and availability of energy. The losses in crop yield will be lower for monsoon season crops but decrease heavily due to decrease in irrigation in the future. Droughts in the year 2002 led to reduction in area covered of more than 15 m ha of the rainy-season crops in India and resulted in loss of more than 10% of food production (Samra and Singh, 2002). Several important socio-economic determinants of food supply, such as government policies, capital availability, prices and returns, infrastructure, land reforms, and inter- and intra-national trade are also influenced by environmental change. Mall et al. (2004) used the CROPGRO-soybean model to simulate the impact of climate change on soybean production in India. Climate change scenarios for the selected regions of the Indian subcontinent were developed using three GCMs namely, Goddard Institute of Space Studies Model (GISS - 2, Russell and Rind, 1999), Geophysical Fluid Dynamics Laboratory Model

(GFDL - R30, Knutson et al., 1999) and United Kingdom Meteorological Office – Hadley Climate Prediction Centre Model (UKMO – HadCM3, Mitchell et al., 1998). For the crop growth model used in this study, the probable changes in surface air temperature during the growing season were estimated at the selected sites in the region following standard rationalization techniques suggested by IPCC (Carter et al., 1999; Mearn et al., 2001). Probable changes in precipitation, cloudiness and solar radiation under the climate changes scenarios were not taken into consideration in this analysis in view of the significant uncertainties associated with non-linear, abrupt and threshold rainfall events projected by GCMs over the Indian subcontinent. In this study, all the GCM projected climate change scenarios (at the time of doubling of CO2 concentrations) predicted decreased yields for almost all locations. Mean decline in yields across different scenarios ranged from 14% in Pune (West India) to 23% in Gwalior (Central India). Decline in soybean yield is found to be less in west and south India as compared to other parts of the country. The mean yield was found to be significantly affected under UKMO model generated climate scenarios for both current and doubled CO2 atmosphere. These environmental changes are likely to further increase the pressure on Indian agriculture, in addition to the on-going stresses of yield stagnation, land use, competition for land, water and other resources and globalization.

3. MODELS TO STUDY CLIMATE CHANGE EFFECT ON AGRICULTURE

The predominant tool for assessing the impacts of climate change on agricultural productivity is the crop growth simulation model (Hertel and Rosch, 2010). The crop models were developed to simulate crop responses to environmental conditions at the plot and field level. They perform this by computing crop dynamics based on deterministic (cause and effect) equations and simulation of underlying processes at time scales of minutes to days (Tubiello and Ewert ,2002). Many impact studies in India have employed crop simulation models to project the impacts of climate change on crops at regional scale (Sheeshy et al.,2006; Amgain et al., 2006; Subash and Ram Mohan, 2012; Vashisht et al., 2013; Mishra et al.,2013; Patel et al.,2013). One of the immediate challenges of using process-based models for projecting crop response to climate change is they do not directly provide information on climate impacts at larger scale (Roudier et al., 2011). But climate models typically operate at large scale so therefore they are needed to be downscaled to the scale of a crop model or a crop model matched to the scale of climate model output (Challinor et al., 2007). The spatial differences posed another uncertainty in crop response projections. Process- based models are also limited by the bio-physical processes like radiation-use efficiency (RUE), whilst others are based on water-use or nitrogen-use efficiency, which are all determined by the aims for which the models are developed (Challinor et al.,2009).

4. ADAPTATION STRATEGIES

Agriculture is the main occupation of developing countries which is inhabited by large fraction of the resource poor population. Any perturbation in agriculturecan considerably affect the food system. It is thus needed to provide strategies to different categories and different sections of producers to global climate change depending on background of changing demand to globalization and population increase as well as the socio-economic and environmental consequences of possible adaptation strategies (Aggarwal et al. 2004). It is difficult to modify the climate according to our requirement as it varies spatially and temporally. Therefore, it is important to develop adaptation strategies at each and every level- farmers, village, society, district and national level. Changes in climate can be expected to have significant impacts upon crop yields through changes in both temperature and moisture by changes in the distribution of plant diseases and pests. Agriculture proved to be one of the most adaptable human activities to varied climate conditions (Mendelsohn et al., 2001) by adopting proper measures in terms of adaptation and mitigation. The purpose of mitigation and adaptation measures is meant for gradual lowering of the adverse effects caused due to climate change and sustains development even with these losses.

Mitigation and adaptation are the terms which are closely related but differ in temporal and spatial scales on which they are effective. The activities performed in mitigation will be evident after a long time on a large scale because of long residence time of greenhouse gases in the atmosphere, whereas the effects of adaptation measures are effective immediately or in the near future on a local or regional scale (Kumar and Parikh,2001). Adaptation measures take account of establishing disaster risk management plans and risk transfer mechanisms, such as crop insurance and diversified livelihood systems (Reilly and John, 1996). Mitigation steps include carbon sequestration in agriculture and forestry which is large and global responsibility.

5. ADAPTATION BY CHANGE IN MANAGEMENT PRACTICES

Climate change effect can be mitigated to certain extend using alternate cultivars and farming practices (such as mixed cropping, crop-livestock), change in date of sowing, spacing, seed population and input management. Integrated Nutrient Management (INM) and Site-Specific Nutrient Management (SSNM) also have the potential to mitigate effects of climate change which has resulted in increased rice yields and thereby increased net CO_2 assimilation, 30-40% increase in nitrogen use efficiency which offers important prospect for decreasing greenhouse gas emissions. This technique of increasing greenhouse gases will be beneficial for those areas where temperature is not reaching critical values.

Table 3: Study of climate change effect on wheat and rice using models

Crop	Climate model	Crop model	Weather parameter	Effect on crop	Reference
Wheat	PRECIS	DSSAT	Temperature	Decrease in crop yield (4-61%),crop water productivity (40-76%)	Vashisht et al. 2013.
	REMO,HadRM3	DSSAT	Temperature,Rainfall, solar radiation	Decrease in yield in upper and middle IGB increase in yield in lower IGB	Mishra et al.2013
		DSSAT	Temperature, Rainfall, solar radiation	Decrease in yield	Subash and Ram Mohan 2012.
	PRECIS	InfoCrop	Temperature, Rainfall	Decrease in yield in north east	
		CERES-Wheat	Temperature	Decrease in biomass, yield on increase in temperature and vice-versa	Kumar et al. 2011
		CSM-CERES-Wheat	CO_2, temperature, rainfall	Decrease in yield due to rise in temperature but increases with rise in CO_2 and rainfall	Patel et al. 2008
			Temperature, Rainfall, solar radiation		Amgain et al. 2006
Rice	PRECIS	DSSAT	Temperature,rainfall,solar radiation	Yield increase with late sowing	
	REMO,HadRM3	DSSAT	Temperature,rainfall,solar radiation	decrease in yield in upper and middle IGBincrease in yield in lower IGB	Verma et al. 2014
				Decrease in yield	Mishra et al.2013
		DSSAT	Temperature,rainfall,solar radiation	Decrease in yield	
	Monte Carlo		Rainfall variability	Decrease in yield	Subash and Ram Mohan 2012.
	PRECIS		Temperature	Decrease in yield	Auffhammer et al. 2012
		ORYZA2000	Temperature	Decrease in yield due to rise in temperature but increases with rise in CO_2 and rainfall	Chaudhari et al. 2008
		CSM-CERES-Rice	CO_2, temperature, rainfall		Sheeshy et al. 2006
					Amgain et al. 2006

Judicious fertilizer application, a principal component of SSNM approach has two fold benefits-reducing GHG emissions and improving yields under high CO2 levels. One of the key emerging technologies to reduce GHG emissions from paddy fields is the use of zymogenic bacteria, acetic acid and hydrogen-producers, methanogens, CH4 oxidizers, and nitrifiers and denitrifiers in rice paddies which help to maintain the soil redox potential in a range where both $N_2O$and CH_4emissions are low. The application of urease inhibitor, hydroquinone (HQ), and a nitrification inhibitor, dicyandiamide (DCD) together with urea also is an effective technology for reducing N_2O and $CH_4$from paddy fields. Use of neem-coated urea is another simple and cost effective technology which can be practiced in the entire South Asia by small farmers. Promotion of integrated farming systems for marginal and small farmers will also be a viable and effective alternative in combating climate change. Multiple enterprise agriculture wherein crop, livestock, poultry, fish farming and trees ina single unit of land will minimize risk.

6. ADAPTATION OF SCIENTIFIC TECHNOLOGIES

Agricultural biodiversity and crop germplasm like seed, plants and plant parts exploration can be utilized to tolerate temperature, water and other atmospheric stresses caused by climate change. This is performed by evaluation of all the wild relatives, land races, extant varieties, modern varieties and breeding stocks that could help in unraveling previously unknown or ignored traits. Genetic resources could well be used as basic raw material which will allow agriculture to adapt to climate change (Birthal et al. 2014). In India, at CRIDA, Hyderabad has come out with a transformed *Sorghum bicolor* L. Moench cv. SPV462 with the mtlD gene encoding for mannitol -1- phosphate dehydrogenase from *E.coli* with an aim to enhance tolerance to water deficit and NaCl stresses (Maheswari et al.,2006).

Germination potential of these transgenic seeds was several folds higher when challenged with salt and water stresses and they have remarkably robust root system in terms of root biomass and length. Similarly strategies for genetic enhancement of heat tolerant genotypes especially in pulses by identifying and validating markers for high temperature tolerance coupled with yield potential is one of the key technological advances that can prove to be a significant strategy for adapting to climate change. In case of rabi cropping system an additional characteristics of early flowering (photo- and temperature-insensitivity, but development related onset of flowering) and early maturity and high produce.

Other improved and novel management practices like changing the cropping calendar , adjustment of planting dates, planned grazing processes, intercropping, crop rotation, establishment of seed banks, differential plant germination strategies to minimize the effect of high temperature increase-induced spikelet sterility can be used to reduce yield instability, by avoiding flowering to coincide with the hottest period (Gadgil,1995). Example like grain-legume intercrops have many potential benefits such as stable yields, better use of resources, weeds, pest and disease reductions, increased protein content of cereals, reduced N leaching as compared to sole cropping systems. are of crucial importance in highly variable and unpredictable environments. These facilities will provide a practical means to re-establish crops obliterated by major disasters and extreme climate events. This will also help in plant community dynamics, as to buffer against inter-annual variability in growing conditions.

Agro-forestry forms a buffer against climate variability, and reduces atmospheric loads of greenhouse gases by sequestering carbon and produces a range of economic, environmental, and socio-economic benefits by improving soil fertility through control of erosion, maintenance of soil organic matter and physical properties, increased N accretion, extraction of nutrients from deep soil horizons, and promotion of more closed nutrient cycling.

Technologies are now being tried to convert theC3 plants to C4 plants to overcome the ill effect of climate change by efficient use of conventional breeding and molecular/ mutation breeding, marker assisted selection, whole genome expression analysis and its subsequent elucidation and gene finding by bioinformatics like development of varieties with changed duration that can overwinter the transient effects of change, release of varieties for high temperature, drought and submergence tolerance, evolving varieties which respond positively in growth and yield to high CO_2. Besides varieties with high fertilizer and radiation use efficiency and also novel crops and varieties that can tolerate coastal salinity and salt water inundation are needed.

7. ADAPTATION BY ADOPTING NEW POLICIES AND CROP INSURANCE

Development plans are the need of the time to adapt the changing climate using crop insurance, subsidies, pricing policies and change in land use. Steps like financial compensation/incentive for enriching soil carbon, and introduction of new credit instruments with deferred repayment, liabilities during extreme weather events, and weather insurance as a major vehicle to transfer risk,increasing the efficiency of irrigation water use through drip and sprinkler methods could encourage farmers to improve soil health, manage with less water, and assist in overall sustainable development. Changing land use by increasing area under bio-fuels, agro-forestry reduces the emission of GHGs. Governmental should prioritize adaptation options inkey sectors, viz. storm warning systems, water storage and diversion, health planning and infrastructure needs. Efforts to integrate national development policies and neologies for sustainable development framework, provisions for financial aid for the farmers should be made by government and other agencies like SHGs, banks and agricultural credit societies, banking, micro-credit/insurance services before, during and after a disaster event should be promoted. Private sectors should come up with new and advanced technologies and better policies. Communication and information initiatives should be made apparent for all. Above all, there should be political will to implement economic diversification in spreading diverse livelihood strategies, migrations and financial mechanisms (Schneider et al.,2007).

8. RESOURCE CONSERVATION BASED TECHNOLOGIES

The key resource conservation-based technologies are *in situ* moisture conservation, rainwater harvesting and recycling, efficient use of irrigation water, fertilizer, conservation agriculture like organic manures, minimal tillage and residue management to increase the soil carbon and use of nitrification inhibitor such as neem coated urea and fertilizer placement practices to prevent GHGs emission, energy efficiency in crop production and irrigation and use of poor quality water to combat rain uncertainty. The above strategies are performed by GIS and remote sensing, integrated watershed development; developing strategies for improving rainwater use efficiency through rainwater harvesting, storage, and reuse; contingency crop planning to minimize loss of production during drought/flood years (Kapoor 2006). Recent success of zero tillage (ZT) has effectively reduced the demand for water in rice-wheat cropping systems in more than 1 million ha of area in the Indo-Gangetic Plains by realizing higher yields andreducing production costs converting the greenhouse gases like CO2into O2 in the atmosphere and carbon, and enriches soil organic matter (Ojha et al. 2014). Another conservation methodology adopted in IGP is bed-planting which increases water use efficiency, reduced water logging, better access forinter-row cultivation, weed control and banding of fertilizers, better stand establishment, less crop lodging and reduced seed rates.

In coastal salinity, a technology named *Doruvu/ Kottai*is performed for managing seawater intrusion in coastal areas was practiced effectively in Andhra Pradesh and Tamil Nadu in India which involves digging of deep (upto 6 m) open wells, which allows horizontal flow of underground water enabled in to the well through pipes. This technology helps in increased fresh water storage in comparatively lesser area giving more water to pump and irrigate crops.

System of Rice Intensification (SRI) is performed by keeping the rice fields moist rather than continuously saturated with water, thereby minimizing anaerobic conditions, and improving root growth and diversity of aerobic soil organisms; rice plants are spaced optimally to permit more growth of roots and canopy which prevents lodging caused by wind and/or rain and to keep all leaves photo synthetically active; and rice seedlings are transplanted when young with two leaves, quickly, shallow and carefully, to avoid trauma to roots and to minimize transplant shock. SRI offers a potential strategy to counter

Climate related risk because it uses less water. SRI method reduces the agronomic and economic risks that farmers face with the advent of climate change by using less amount of water.

Agriculture accounts for about 60% of all nitrous oxide, mainly from fertilizer use and about 50% of methane mainly from natural and cultivated wetlands and enteric fermentation. Methane and nitrous oxide emissions are projected to further increase from 35 to 60% by 2030.The agriculture contribution to GDP has been reduced but a large population depends on it. It has increased the GHGs emission of methane and N_2O due to flooded rice fields and anaerobic animal waste processing. It has also led to land fragmentation and decline in the size of land holdings leading to inefficiency in agriculture. Steps are needed to ensure cooperative and contract farming that can bring small and marginal farmers together for increasing production and marketing efficiencies.

9. CONCLUSION

At this juncture, based on the different reports it can be concluded that the agricultural impacts of climate change in India are uncertain. The total average impact may be positive or negative depending on the climate scenarios (temperature rising in 2◦C, 3◦C, 4◦C, increase in CO2 and interaction of increase in temperature and CO2). Impacts also vary both quantitatively and qualitatively by crop, level of agronomic management, region and season. The climatic change and increasing climatic variability are likely to exert pressure on agricultural systems and may constraint attainment of future food production targets. The change in temperature posed serious threat to crops especially increase in temperature. It is therefore necessary to take adaptive steps like capacity building, development activities and change in policies, which would otherwise result into large economic losses. It is necessary to carry out extensive research on development of adverse climate tolerant genotypes, and land use systems to ensure adequate food production. Various risk management services like reliable weather forecast; establishment of early warning systems should be made available to farmers. At the same time, financial aids in the form of financial incentives for resource conservation and efficient use and increased minimum support price, investment in aquifer recharge, drip and sprinklers could be necessary steps. Lastly, national and international steps are needed to make food security and poverty alleviation central in climate change.

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REFERENCES

1. Aggarwal, P. K, 2003.Impact of climate change on Indian agriculture.J. Plant Biology.30(2), 189-198.
2. Aggarwal, P.K., 2008. Global climate change and Indian agriculture: impacts, adaptation and mitigation. Indian J Agr Sci. 78, 911-919.

3. Aggarwal, P.K., 2007. Global climate change and Indian agriculture: impacts, adaptation and mitigation. Indian J Agr Sci. 78(10),911-919.
4. Aggarwal, P.K., Joshi, P.K., Ingram, J.S., Gupta, R.K., 2004. Adapting food systems of the Indo-Gangetic Plains to global environmental change: Key information needs to improve policy formulation. Environ Sci Policy.7,487-498.
5. Aggarwal, P.K. and Kalra, N.,1994. Simulating the effect of climatic factors, genotype and management
6. on productivity of wheat in India, Indian Agricultural Research Institute Publication, New Delhi,
7. India, pp. 156
8. Ainsworth, E. A. and Long, S. P., 2005.What have we learned from 15 years of free-air CO2 enrichment (FACE)? A meta-analytic review of the response of photosynthesis, canopy properties and plant production to rising CO2. New Phytol.165, 351–372.
9. Amgain, L.P., Devkota, N.R., Timsina, J., Singh, B.,2006. Effect of climate change and co2 concentration on growth and yield of rice and wheat in Punjab: simulations using CSM-Ceres-Rice and CSM-Ceres-Wheat models J. Inst. Agric. Anim. Sci. 27,103-110.
10. Auffhammer, M., Ramanathan, V.,Vincent, J.R., 2012. Climate change, the monsoon, and rice yields in India. Climatic Change.111,411-424. DOI 10.1007/s10584-011-0208-4.
11. Birthal, P.S., Khan, Md. T., Negi, D.S., Agarwal, S., 2014. Impact of Climate Change on Yields of Major Food Crops in India: Implications for Food Security. AgrEconRes Rev. 27(2), 145-155.
12. Challinor, A., Wheeler, T., Garforth, C., Craufurd,P.,Kassam,A.,2007. Assessing the vulnerability of food crop systems in Africa to climate change. Climatic Change.83, 381–399.
13. Challinor, A.J., Ewert, F., Arnold, S., Simelton, E., Fraser, E., 2009. Crops and climate change: progress, trends, and challenges in simulating impacts and informing adaptation. J Exp Bot. 60, 2775–2789.
14. Chaturvedi, R.K.; Joshi, J.; Jayaraman, M., Bala, G., Ravindranath, N.H., 2012.Multi-model climate change projections for India under representative concentration pathways. Curr Sci. 103(7),1-12.
15. Chaudhari, K.N., Oza,M.P., Ray, S.S.,2008. Impact of climate change on yields of major food crops in India.ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture.
16. Choudhury, B. U., Das, A., Ngachan S. V., Slong, A., Bordoloi, L. J. ,Chowdhury, P. ,2012. Trend analysis of long term weather variables in mid altitude Meghalaya, North-East India. J Agr Phys. 12 (1), 12-22.
17. Gadgil, D.,1995. Climate change and agriculture: An Indian perspective. Curr Sci. 69(8): 649– 659.
18. Gadgil, S., Abrol, Y.P., and Rao, Seshagiri, P.R.: 1999a, 'On growth and fluctuation of Indian food grain production', *Current Science*, **76** (4), 548-556.
19. Gadgil, S., Rao, Seshagiri, P.R. and Sridhar, P.R.: 1999b, 'Modeling impact of climate variability on rainfed groundnut', *Current Science*, **76 (4)**, 557-569.
20. Gadgil, S.: 1995, 'Climate change and Agriculture – An Indian Perspective', *Current Science*, **69** (8), 649-659.
21. Ghannoum, O., Von Caemmerer, S., Ziska, L. H. and Conroy, J. P., 2000. The growth response of C4 plants to rising atmospheric CO2 partial pressure: a reassessment. Plant Cell Environ.23, 931–942.
22. Hertel, T.W., Rosch, S.D. ,2010. Climate change, agriculture, and poverty.Appl Econ Perspect Policy. 32 (3), 355–385.
23. Hoogenboom, G.: 2000, 'Contribution of agrometeorology to the simulation of crop production and its applications', *Agric. Forest Meteorology*, **103**, 137-157.
24. Kapoor, A.,2006.Mitigating natural disasters through preparedness measures. Proceedings of the International Conference on Adaptation to Climate Variability and Change, 5-7 January 2006, New Delhi, organized by Institute for Social and Environmental.
25. Kothyari, U. C., Singh, V. P., 1996. Rainfall and temperature trends in India.Hydrol Process. 10, 357–372.
26. Krishna Kumar, K., Patwardhan, S.K., Kulkarni, A., Kamala, K., Rao, K.K., Jones, R.,2011. Simulated projections for summer monsoon climate over India by a high-resolution regional climate model (PRECIS).Curr Sci. 101(3), 312-326.
27. Krishnakumar, K. N., PrasadaRao, G. S. L. H. V., Gopakumar, C. S.,2009. Rainfall trends in twentieth century over Kerala, India. AtmosEnviron.43(11), 1940- 1944.
28. Kumar, K.S.K. and Parikh, J.,2001. Indian agriculture and climate sensitivity .Global Environ Chang. 11(2), 147–154.
29. Kumar, S.N., Aggarwal, P.K., Rani, S., Jain, S., Saxena, R., Chauhan, N., 2011. Impact of climate change on crop productivity in Western Ghats, coastal and northeastern regions of India.Currsci.101(3).
30. Maheswari, M., Varalaxmi, Y., Vijayalashmi, A., Yadav, S.K., Sharmila P., Venkateswarlu, B., PardhaSaradhi, P. 2006. 'Metabolic engineering for abiotic stress tolerance in soghum using mtlD gene'. Paper presented in the International Symposium on Frontiers in Genetics and Biotechnology- Retrospect and Prospect at Osmania University, Hyderabad, January 8-9 2006.
31. Mall, R.K., Kumar,R., Bhatla, R , 2011.Climate Change and Disasters in India, Journal of South Asia Disaster Studies, New Delhi, vol. 3 no. 2. Pp1-32.

32. Mall, R. K., Attri, S.D., Kumar, S., 2011. Extreme Weather Events and Climate Change Policy in India, Journal of South Asia Disaster Studies, vol. 4 no. 2, pp 27-76
33. Mall, R.K., Singh, R, Gupta A, Srinivasan,G., Rathore, L.S., 2006. 'Impact of climate change on Indian agriculture: a review'. Clim Chang. 78:445–478
34. Mall, R. K, Singh, R., Gupta, A., Singh R S, Rathore, L. S., 2006, 'Water Resources and Climate Change: An Indian perspective. Curr Sci. 90 (12), 1610-1626.
35. Mall, R.K. and Aggarwal, P.K., 2002 . Climate change and rice yields in diverse agro-environments of India. I. Evaluation of impact assessment models. Clim Chang. 52(3), 315-331.
36. Mall, R.K., Lal, M., Bhatia, V.S., Rathore, L.S., Singh, R.,, 2004. Mitigating climate change impact on Soybean productivity in India: A simulation study. Agr Forest Meteorol. 121 (1-2), 113-125.
37. Mendelsohn, Robert., Dinar, A.., Sanghi, A., 2001. The Effect of Development on the Climate Sensitivity of Agriculture. Environ Dev Econ.6, 85–101.
38. Mishra, A., Singh, R., Raghuwanshi, N.S., Chatterjee, C., Froebrich, J., 2013. Spatial variability of climate change impacts on yield of rice and wheat in the Indian Ganga Basin. Sci Total Environ. 468–469,S132–S138.
39. Ojha, H.R., Sulaiman V, R., Sultana, P., Dahal, K., Thapa, D., Mittal, N., Thompson, P., Bhatta, G.D., Ghimire, L., Aggarwal, P., 2014. Is South Asian Agriculture Adapting to Climate Change? Evidence from the Indo-Gangetic Plains. Agroecolsust food syst .38, 505-531.
40. Paroda, R.S. and Kumar, P., 2000. Food production and demand in South Asia. Agri. Econ Res Rev. 13(1),1-24.
41. Patel, H.R.; Lunagaria, M.M.; Karande, B.I.; Pandey, V., Yadav, S.B., Shah, A.V.; Rao, V.U.M.; Nareshkumar, S.,2013. Impact of projected climate change on groundnut in Gujarat. J Agrometeorol. 15 (Special Issue-I),1-4.
42. Patel, S.R., Sastri, A.S.R.A.S., Singh, R., Naidu, D.,2008. Impact of climate change on yields of major food crops in India.ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture.
43. Patle, G.T. and Libang, A, 2014. Trend analysis of annual and seasonal rainfall to climate variability in North-East region of India. J Appl Nat Sci. 6(2),480-483.
44. Reilly, Y. and John., 1996. Agriculture in a Changing Climate: Impacts and (Eds.) Adaptations" in Watson, Robert, ManufuZinyowera, Richard Moss, and David Dokken. Climate Change: Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses Cambridge University Press: Cambridge, pp.427–468.
45. Roudier, P., Sultan, B., Quirion, P., Alexis, Berg A., 2011. The impact of future climate change on West African crop yields: what does the recent literature say? Global Environ Chall.21,1073–1083.
46. Rupa Kumar, K., Sahai, A.K., Krishna Kumar, K., Patwardhan, S.K., Mishra, P.K., Revadekar, J.V., Kamala, K., Pant, G.B., 2011.High-resolution climate change scenarios for India for the 21st century. Curr Sci. 90(3), 334-345.
47. Samra, J. S. and Singh, G., 2002. Drought Management Strategies, Indian Council of Agricultural Research, New Delhi. p. 68.
48. Samui, R.P., Kamble, M.V. 2008.Indian agriculture under climate change scenario. ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture.
49. Saxana Rani, Bharadwaj and Kalra N., 2006 'Simulation of wheat yield using WTGROWS in northern India'. Jr of Agrometeorology, 8 (1), 87-90.
50. Schneider, S.H., Semenov, S., Patwardhan, A., Burton, I., Magadza, C.H.D., Oppenheimer, M., Pittock, A.B., Rahman, A., Smith, J.B., Suarez, A. and Yamin, F., 2007.Assessing key vulnerabilities and the risk from climate change. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.). In: Climate Change: 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 and New York, pp. 779–810.
51. Sheeshy, J.E., Mitchell, P.L., Ferrer, A.B., 2006. Decline in rice grain yields with temperature: Models and correlations can give different estimates. Field Crop Res.98,151–156.
52. SivakumarM.V.K. and Motha, R.P. 2007. Managing weather and climate risks in agriculture: Summary and Recommendations. Pages 477-491 In (MannavaV.K. Sivakumar and Raymond P.Motha eds.) Managing Weather and Climate Risks in Agriculture. Springer, Berlin
53. Subash, N. and Ram Mohan, H.S., 2012. Evaluation of the impact of climatic trends and variability in rice–wheat system productivity using Cropping System Model DSSAT over the Indo-Gangetic Plains of India. Agr Forest Meteorol.164,71– 81.
54. Tubiello, F.N., Ewert, F., 2002. Modeling the effect of elevated CO2 on crop growth and yield: a review. Eur J Agron.18,57–74.
55. Vashisht, B.B., Mulla, D.J., Jalota, S.K., Kaur, S., Kaur, H., Singh, S., 2013. Productivity of rainfed wheat as affected by climate change scenario in northeastern Punjab, India. Reg Environ Chang.3, 989–998.
56. Verma, P.K., Patel, S.R., Rao, A.V.M. Subba., 2014. Estimating future yield of wet season rice in Chhattisgarh using crop simulation model. Oryza. 51(1), 43-47.

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Exploration of the Role of Brassinosteroids on *Brassica oleracea* L. *Var. botrytis* and *var. italica* under thermal stress

Spall Kaur Nirmal K[1*] Sirhindi Geetika[1] and Sandeep Kumar[2]
[1]Department of Botany, Punjabi University, Patiala-147002
[2]DDU College (University of Delhi), Karampura, New Delhi-110015
***Corresponding author**: *nirmalgoyal83@yahoo.com*

Abstract— Transitory and constantly extreme temperature fluctuations due to climate change cause an array of morphological, physiological and biochemical changes in plants affecting metabolic activity, growth and photosynthesis. The present investigation has been undertaken to explore the role of exogenous applications of 24-epibrassinolide (24-Ebl) and 28-homobrassinolide (28-Hbl) on the photosynthetic pigments, carbohydrate and protein content under the influence of temperature stress in *Brassica oleracea* var. *botrytis* and var. *italica*. Priming seed treatments with various micro molar concentrations of 24-Ebl and 28-Hbl were studied. It was observed that 24-Ebl and 28-Hbl treatments enhanced the protein content at 35^0C in nano-molar concentrations. Brassinosteroids help in remodulating the thermotolerance by ameliorating the photosynthetic pigments, chlorophyll *a*, chlorophyll *b* and carotenoids which otherwise showed inhibition in its level with variation of temperature from the optimum (25^0C). 24-Ebl was significant in mitigating the accumulation of carbohydrates, reducing sugars and non-reducing sugars in nano molar concentrations. The present study indicates the role of brassinosteroids for protection of the plants from thermal stress thereby exhibiting anti-stress property in *Brassica oleracea* var. *botrytis* and var. *italica*.

Keywords: Temperature Stress, 24-Ebl, 28-Hbl, *Brassica* oleracea var. *botrytis*, var. *italica*, Proteins, Carbohydrates.

1. Introduction

Temperature is a major factor of abiotic stresses and is a key determinant of crop productivity. Environmental stress frequently reduced plant growth through over production of ROS which damage various macromolecules and cellular structures (Apel and Hirt, 2004) and lead to the death of cells (Liu *et al.,*2010, Gond & Kachole, 2011). ROS in low concentration acts as signalling molecule mediating a variety of physiological responses including stomatal movement and gene expression (Suzuki *et al.*, 2012). To mitigate the effect of abiotic stress and develop thermotolerance in plants by exogenous application of brassinosteroid the use of plant growth regulators (PGRs) in agriculture to promote plant growth, production and quality is becoming increasingly more common as commented (Tuna., *et al.,* 2007; He & Zhu, 2008; Sirhindi *et al.,* 2011).Role of 24-Ebl and 28-Hbl in *Brassica juncea* seedlings exposed to thermal shocks (35^0C, 40^0C & 45^0C) was studied by (Sirhindi *et al.*, 2009, Kumar *et al.*, 2011) and a significant increase in plant fresh weight, germination rate and growth in seedlings was observed. They also showed the role of antioxidant enzymes in building thermotolerance in such seedlings exposed to low and high temperature. Under abiotic stress, exogenous application of PGRs either by seed priming or foliar spray to the aerial parts of plant may lead to mitigate the inhibitory effects caused by stress (Ashraf *et al.,* 2008; Kumar *et al.,* 2010; Sirhindi *et al.,* 2011). High temperature stress resulted in decrease of chlorophyll content in leaves of *Phaseolus aureus* (Kumar *et al.*, 2011). Essemine *et al.,* (2010) studied behavior in two wheat cultivars of *Triticum durum* (karim and salamb) under temperature stress and found that at photosynthetic level, heat stress generated reactive oxygen species (ROS) damaging both PSI and PSII. Kumar *et al.,*(2011) associated the decrease in shoot growth of *Phaseolus aureus* with increase in electrolyte leakage under high temperature stress. The experimental evidences (Divi *et al*., 2010) indicate interactions of BR with auxin, gibberellic acid, abscisic acid, ethylene and jasmonic acid into various growth and physiological activities along with BR-mediated stress tolerance. Shahid *et al*., (2011) showed enhanced growth and alleviation of deleterious effects induced by salt stress in *Pisum sativum* L. by brassinosteroids. *Brassica oleracea* belongs to family Brassicacea, is a rabi crop in tropical region of India. Heat stress is very harmful and reduces seed germination enhancing seedling mortality. Plant growth regulators play a vital role in response to stress (Sirhindi *et al*., 2009, 2011). BRs potential as anti-stressor compound is well documented for various crops under number of stresses including drought, salinity nutrient deficiency toxicity and extreme temperatures (Krishna, 2003; Upreti and Murti, 2004; Sirhindi *et al.*, 2009 and 2011). *Brassica oleracea*. being a cold seasoned crop is frequently exposed to dynamic fluctuations of seasonal temperature imposing shocking stress resulting into loss of crop productivity. BRs are natural and eco-friendly, due to their anti-stress and immunomodulatory properties have made itself a successful candidate for third generation chemicals.

2. Material and Method

Seeds of *Brassica oleracea* cultivars *botrytis* (cauliflower) *and italica (*broccoli*)* were procured from Indian Agricultural Research Institute, New Delhi. Seeds were surface sterilized with hypochlorite and rinsed 5-6 times with DDW and primed for 8 hours in DW as control and with 24-Ebl and 28-Hbl concentration (0, 10^{-6}, 10^{-9}, 10^{-12} M). Primed seeds were allowed to germinate under control conditions of light (200 PAR m^{-2}, s^{-1}), humidity (80 ± 2%), photoperiod (16 hr light and 8 hr dark) and temperature (25^0C) for 7 days. To 7 day old seedlings temperature treatment of 35^0C was given for five hours daily upto three consecutive days. On ninth day seedlings were left for 24 hour recovery period.

Samples of the both varieties were collected on tenth day of each treatment to determine physiological parameters by estimating photosynthetic pigments, carbohydrates, sugars and proteins in primed and unprimed seedlings.

2.1 Biochemical analysis :

Estimation of total chlorophyll, chlorophyll a and b was done using Witham *et al*. (1971) method. Total carotenoids was done by method of Lichenthaler *et al.* (1982). Determination of total carbohydrates was done according to Dubios *et al.* (1956). Estimation of total soluble sugars and reducing sugars was done following the method of Miller (1972). Estimation of non-reducing sugars was done according to Loewus (1952). Whereas proteins were estimated following the method of Lowery *et al*. (1951).

2.2 Statistical analysis :

Statistically significant differences between means were compared at p ≤ 0.05 using Duncan's multiple range tests.

3. Results and Discussion

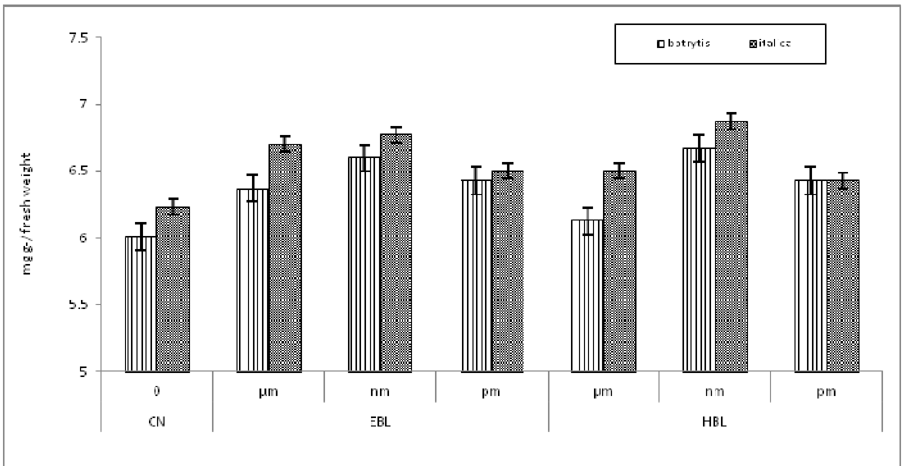
The investigation on treating seedlings of *Brassica oleracea* cultivar *botrytis* (cauliflower)*, italica* (broccoli*)* with various concentrations of 24-Ebl and 28 Hbl revealed that total soluble sugars were better in *B. botrytis* having maximum content in nm treatment of brassinosteroids. However reducing and non-reducing sugars out of total soluble sugars were found to be at better level in *B. italica*. Overall nm Hbl treatment was most effective and enhanced the level of sugars in both the varieties at 35^0C temperature. Application of both analogs of BRs increased the carbohydrate content at 35^0C. Ebl showing better performance in *B. italica* in nm concentration whereas Hbl ameliorated the carbohydrate content in µm concentration in *B. botrytis*. On estimating the photosynthetic pigments significant increase of chlorophyll a and b was seen in primed seedlings with Hbl as compared to unprimed seeds. Chlorophyll a content was significant in Hbl (µm) in *B. italica* whereas levels of chlorophyll a were elevated in *B. botrytis* in Hbl (nm) treatment also. Similar result was found in amelioration of chlorophyll b. Carotenoid content increased on priming seeds with Hbl and Ebl in nano molar concentration in both the varieties.

A great diversity exists in effects of BRs on pigments and photosynthesis. Their influence on chlorophyll content depends to some extent on the mode of application of BRs and the relationship between exogenously applied BRs and the basal chlorophyll content in various crop species. In addition to this, BRs have the ability to confer resistance to plants against various biotic and abiotic stresses, such as salinity (Hayat *et al*. 2010), water stress (Fariduddin *et al*. 2009), temperature extremes (Fariduddin *et al*. 2011, Gomes 2011). Photosynthetic pigments chlorophyll a and b ameliorated in presence of 28-Hbl in both the varieties which otherwise showed inhibition in its level with increase of temperature from the normal. It has been observed that presence of the two isomeric forms of brassinosteroid help in inducing the carotenoid content to a higher level but in very dose dependent manner in both the isomeric forms of BR used. However, BRs have the ability to improve yield quantity and quality of various crop species, and also to protect plants against various kinds of stresses. Several attempts to resolve the actual relationship between these phytohormones and functioning of various parts of the photosynthetic apparatus have been made (Fariduddin *et al*. 2014). Total carbohydrates, total soluble sugars, reducing sugars and non-reducing sugars deviate in temperature from its normal (25^0C) to higher level (35^0C) and presence of BRs either Hbl (*B. botrytis*) or Ebl (*B. italica*) intensified the accumulation of carbohydrates. However, the increase in various parameters reveals that BRs ameliorate the physiological content and the response is dose dependent (Gomes, 2011). Protein content was found to increase in 10^9 mm concentration thereby mitigating the effect of temperature stress. 24-epibrassinolide and 28-homobrassinolide helped in ameliorating chlorophyll a and b, carotenoids, carbohydrates and proteins. In all these attributes overall nano molar concentration gave the best result among primed/unprimed seeds. Total sugars, reducing and non-reducing increased in treated seeds as 24-Epibrassinolide ameliorated the content and here pico concentration of brassinolide is found to be most effective Micromolar dose proved to increase the carbohydrate content.

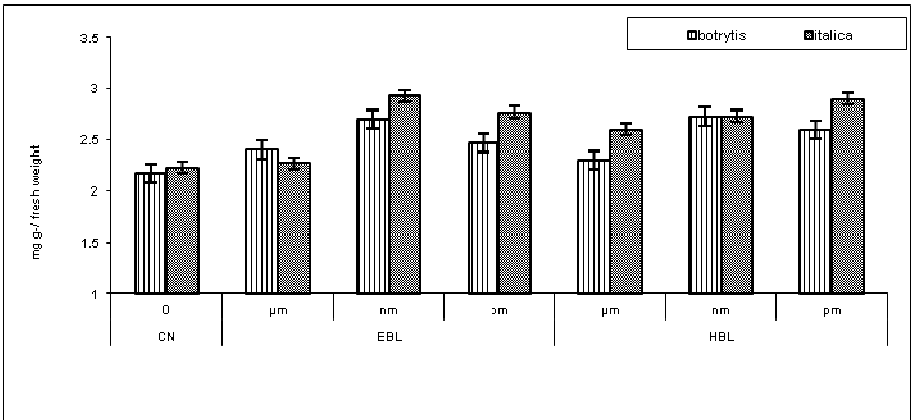
4. Conclusion

The present study reveals that the exogenous application of various micromolar doses of BRs under thermal stress help the plant in ameliorating various physiological parameters. However, the increase in various parameters reveals the response of brs is dose dependent in both the varieties of *brassica oleracea l.* var. *botrytis* and var.

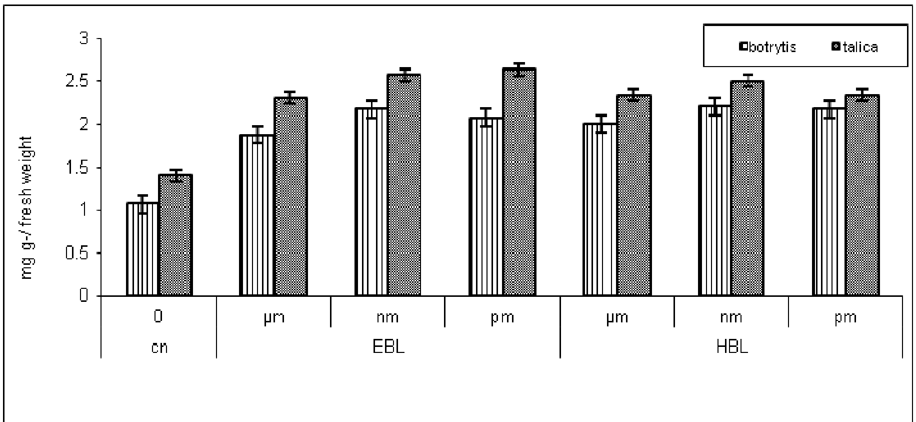
italica. The knowledge of the physical and chemical properties of these steroids allures us to consider them as



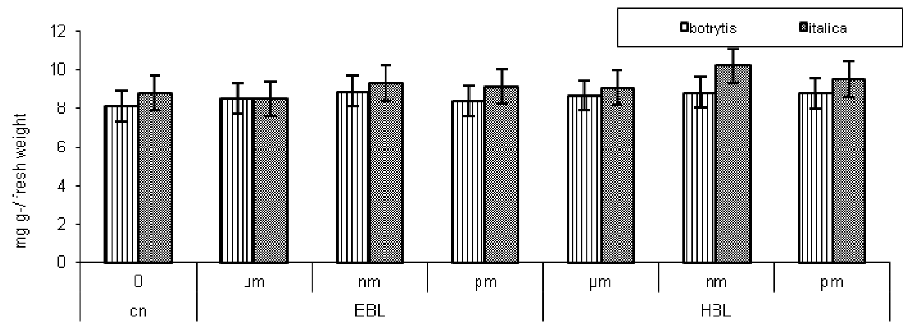
Effect of priming treatement on total soluble sugars in varieities of *B.oleracea* at 35ºC



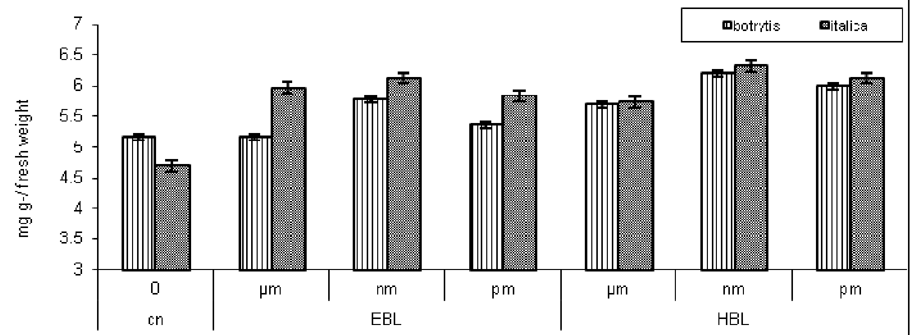
Effect of priming treatement on total reducing sugars in varieities of *B.oleracea* at 35ºC



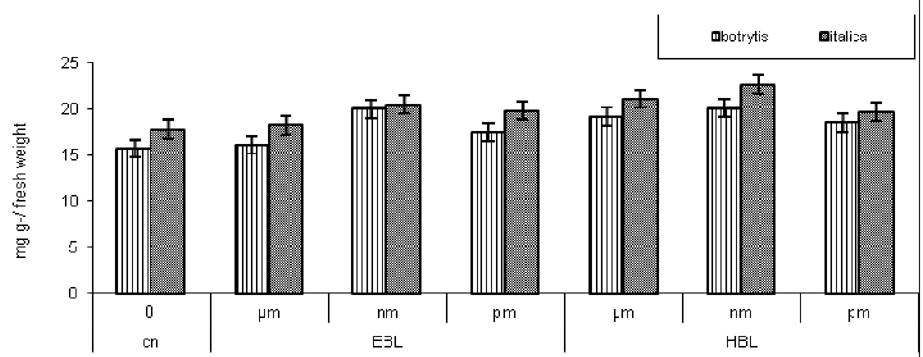
Effect of priming treatement on non reducing sugars in varieities of *B.oleracea* at 35ºC



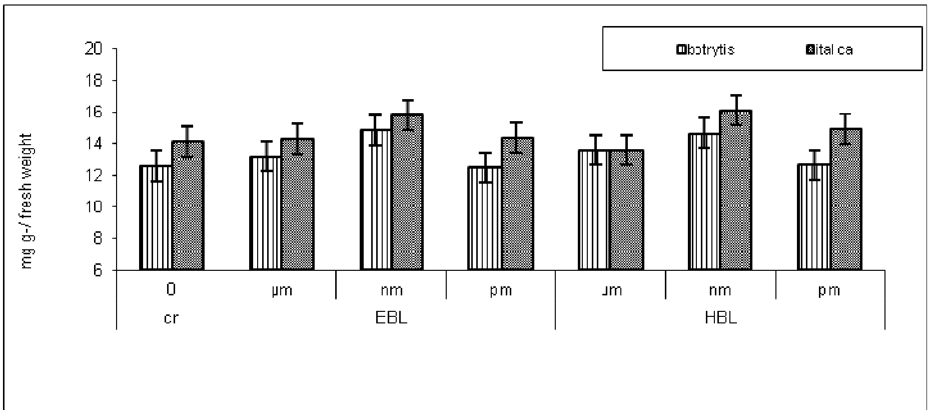
Effect of priming treatement on total protein content in varieities of *B.oleracea* at 35ºC



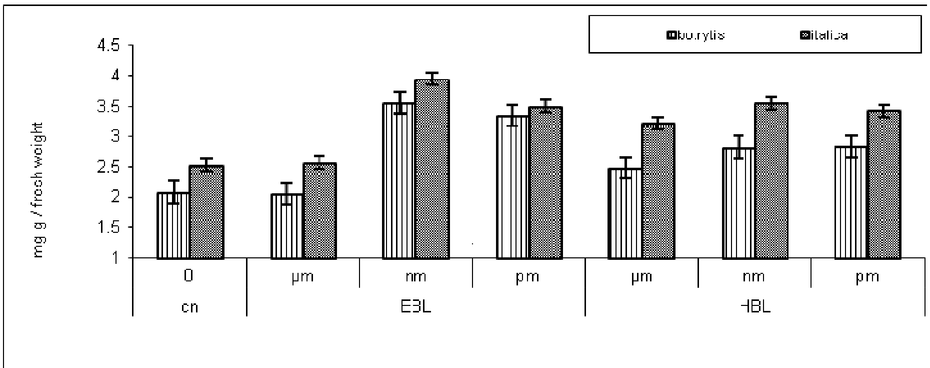
Effect of priming treatement on total carbohydrate content in varieities of *B.oleracea* at 35ºC



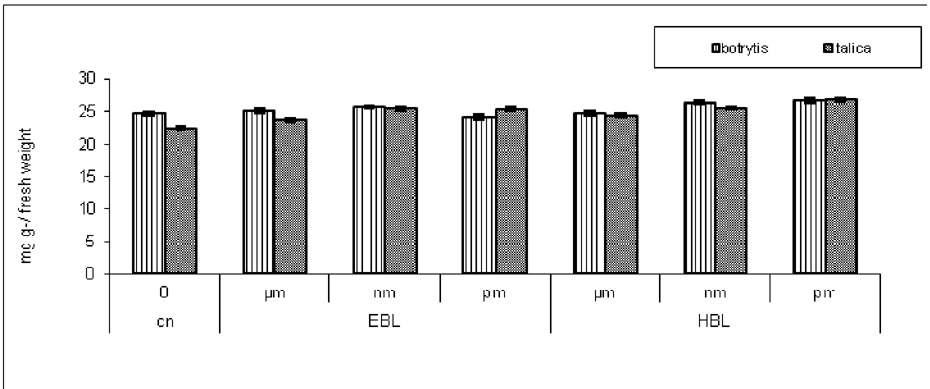
Effect of priming treatement on chlorophyll a in varieties of *B.oleracea* at 35ºC



Effect of priming treatement on chlcrophyll b in varieities of *B.cleracea* at 35⁰C



Effect of priming treatement on carotenoids in varieities of *B.cleracea* at 35⁰C



Effect of priming treatement on total chlorophyll in varieities of *B.cleracea* at 35⁰C a highly promising and environmental friendly promoter of agricultural productivity and a potent stress alleviator in various micro molar doses

REFERENCES

1. Apel, K., Hirt, H., 2004. Reactive oxygen species metabolism, oxidative stress and signal transductions. Ann. Rev. Plant Biol. 55, 373–399.
2. Ashraf, M., Rahmatullah, A.M., Ahmed, R., Mujeeb, F., Sarwar, A., Ali, L., 2010. Alleviation of detrimental effects of NaCl by silicon nutrition in salt sensitive and salt tolerant genotypes of sugarcane (*Saccharum officinarum* L.). Plant Soil. 326 (1), 381-391.
3. Divi, U.K., Rahman, T., Krishna, P., 2010. Brassionsteriod-mediated stress tolerance in *Arabidopsis* shows interaction with abscisic acid,ethylene and salicylic acid pathways. BMC Plant Biology.
4. Dubois, M., Gilles, K.A., Hamiton, J.K., Rebers, P.A., Smith, F., 1956. Anal Chem. 28, 350-356.
5. Essemine, J., Ammar, S., Bouzid, S., 2010. Impact of heat stress on germination and growth in higher plant physiological biochemical and molecular repercussions and mechanism of defence. J Biol Sci. 10, 565-572.
6. Fariduddin, Q., Khanam, S., Hasan, S.A., Ali, B., Ali B., Hayat, S., Ahamad, A., 2009. Effect of 28–homobrassinolide on drought stress induced changes in photosynthesis and antioxidant system of *Brassica juncea* L. Acta Physiol. Plant. 31, 889–897.
7. Farriduddin, Q., Yusuf, M., Chalkoo, S., Ahmad, I., Ahmad, A., 2011. 28 homobrassinolide improves growth and photosynthesis in *Cucumis* sativus L. through an enhanced antioxidant system in the presence of chilling stress. Photosynthetica. 49, 55-64.
8. Farriduddin, Q., Yusuf, M., Ahmad, I., Ahmad, A., 2014. Brassinosteroids and their role in response of plants to abiotic stresses. Biologia Plantarum. 58(1), 9–17.
9. Gomes, M.M.A., 2011. Physiological effects related to brassinosteroid application in plants. Brassinosteroids : a Class of Plant Hormones In: Hayat, S., Ahmad, A. (ed.). Springer, Dordrecht–Heidelberg – London – New York.
10. Gond, P.B., Kachole, M.S., 2011. Effect of exogenous hydrogen peroxide on peroxidase and polyphenol oxidase activities in *Cajanus cajan* (L.). Inter. J. of Current Res. 3, 61–65.
11. Hayat, S., Hasan, S.A., Yusuf, M., Hayat, Q., Ahmad, A., 2010. Effect of 28–homobrassinolide on photosynthesis, fluorescence and antioxidant system in the presence or absence of salinity and temperature in *Vigna radiata*. Environ. exp. Bot. 69, 105–112.
12. Hopkins, W.J., 1995. Physiology of plants under stress. Introduction to Plant Physiology. third ed. John Wiley & Sons, New York.
13. Krishna, P., 2003. Brassinosteroids-Mediated Stress Responses. J Plant Growth Regul. 22**,** 289-297.
14. Kumar, M., Sirhindi, G., Bhardwaj, R., Kumar, S., Jain, G., 2010. Effect of exogenous H_2O_2 on antioxidant enzymes of *Brassica juncea* L. seedlings in relation to 24-epibrassinolide under chilling stress. Indian Journal of Biochemistry and Biophysics. 343(1-2), 217-22.
15. Kumar, S., Kaur, R., Kaur, N., Bhandhari, K., Kaushal, N., Gupta, K., Bains, T.S., Nayyar, H., 2011. Heat-stress induced inhibition in growth and chlorosis in mungbean (*Phaesolus aureus*) is partly mitigated by ascorbic acid application and is related to reduction in oxidative stress. Acta Physiol Plant. 33, 2091-2101.
16. Lichtenthaler, H.K., Bukhardt, G., Kuhn, G., Prenzel, U., 1981. Light induced accumulation and stability of chlorophyll and protein during chloroplast development in radish seedlings. Z Naturforsch. 36, 421-430.
17. Liu, Z.J., Guo, Y.K., Bai, J.G., 2010. Exogenous hydrogen peroxide changes antioxidant enzyme activity and protects ultrastructure in leaves of two cucumber ecotypes under osmotic stress. J. Plant Growth Regul. 29, 171–183.
18. Loewus, F.A., 1952. Improvement in Anthrone method for determination of carbohydrates. Anal Chem. 24, 219.
19. Lowery, O.H., Rosenbergh, N.J., Farr, A.L., Randall, R.J., 1951. Protein measurement with folin-phenol reagent. The Journal of Biological Chemistry. 193, 265-275.
20. Miller, G.L., 1972. Use of DNS reagent for the determination of glucose. Anal Chem. 31, 426-428.
21. Miura, K., Tada, Y.Y., 2014. Regulation of water, salinity and cold stress responses by salicylic acid. Frontiers in Plant Physiology. 5, 1–12.
22. Shahid, M.A., Pervez, M.A., Balal. R.M., Mattson, N.S., Rashid, A., Ahmad, R., Ayyub, C.M., Abbas, T., 2011. Brassinosteroid (24-epibrassinolide) enhances growth and alleviates deleterious effects induced by salt stress in pea (*Pisum sativum L.*) Aust. J Crop Sci. 5(5), 500-510.
23. Sirhindi, G., Kumar, M., Bhardwaj, R., Kumar, S., Pradhan, S.K., 2011. Effects of 24-epibrassinolide on dynamics of growth total proteins and antioxidant defence system in leaf tissues of *Brassica juncea* L. in relation to H_2O_2. Indian J Plant Physiol. 16(1), 68-71.
24. Sirhindi, G., Kumar, S., Bhardwaj, R., Kumar, M., 2009. Effects of 24-epibrassinolide and 28-homobrassinolide on the growth and antioxidant enzymes activities in the seedlings of *Brassica juncea* L. Physiol Mol Biol Plants. 15(4), 335-341.
25. Suzuki, N., Koussevitzky, S., Mittler, R., Miller, G., 2012. ROS and redox signaling in the response of plants to abiotic stress. Plant Cell and Environment. 35, 259–270.
26. Tuna, A.L., Kaya, C., Ashraf, M., Altunlu, H., Yokas, I., Yagmur, B., 2007. The effects of calcium sulphate on growth, membrane stability and nutrient uptake of tomato plants grown under salt stress. Environ and Experiment Bot. 59, 173-178.

27. Upreti, K.K., Murti, G.S.R., 2004. Effects of brassinosteroids on growth, nodulation, phytochrome content and nitrogenase activity in French bean under water stress. Biologia Plantarum. 48(3), 407-411.
28. Witham, F.H., Blaydes, D.F., Devlin, R.M., 1971. Experiments in plant physiology. Van Nostrand New York.

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Comparative Study on Effects of Heavy Metals/Metalloids Present in Fly Ash from Coal Fired Thermal Power Plant on Photosynthetic Parameters of *Ficus bengalensis* and *Plumeria rubra*

Santosh Kumar Prajapati[1*] and Neelima Meravi[1]
[1]Department of Botany, School of Life Sciences,
Guru Ghasidas Vishwavidyalaya, Chattisgarh., (India) - 495009
***Corresponding author:** *sntshprjpt@rediffmail.com*

Abstract— In the present work heavy metals/metalloids present in the fly ash emitted from a coal fired thermal power plant were estimated. The effects of heavy metals/metalloids present in the ash on various photosynthetic parameters (fluorescence, Fv/Fm, fluorescence quenching coefficients, relative electron transport rate, photosynthetic active radiation, ETR-Factor absorptance of photons by photosynthetic pigments etc.) were estimated using JUNIOR-PAM, Chlorophyll Fluorometer, Heinz Walz GmbH, Germany. Heavy metals/metalloids were estimated using atomic absorption spectrophotometer (AAS, 7000 Shimadzu) for Fe, Zn, Pb, Cd, Mo, Cu, Cr, Co and Ni and the standard solution was prepared using standard metal solution of Inorganic Ventures. The observed value of Fv/Fm (indication of the maximum and effective photochemical quantum yield of PS II) for *Ficus bengalensis* and *Plumeria rubra* were 0.775 and 0.689 respectively. The heavy metals/metalloids present in the fly have negative effects on *Plumeria rubra* as compared to *Ficus bengalensis* because for a healthy plant Fv/Fm should not be less than 0.75. Similarly other parameters were also adversely affected by the presence of heavy metals/metalloids present in the fly ash that were deposited on the plants leaves. The reduction in yield of PS II will ultimately lead to overall reduction in the plant productivity and ultimately ecosystem productivity. Therefore, the issue of fly ash emitted from thermal power plants need to be addressed in a proper way

Keywords: Heavy Metals; Fluorescence; ETR-Factor; Fv/Fm.

1. Introduction

Environmental pollution in recent years has increases manifolds due to rapid growth of industries and anthropogenic pressure worldwide. Heavy metal pollution due to thermal power plant, mining and other industries is of serious concern to the environmentalists since they persist in the environment for generations and may have cause serious problems to the biotic world. There are various sources of heavy metal coming in the environment such as mining industries, electroplating industries, thermal power plants, textile, and leather and tanning industries etc. Out of these industries fly ash coming from thermal power plants is an important source of heavy metals to the environment. Huge amount of fly ash is generated in India from the coal fired thermal power plants leading to environmental pollution (TERI, 2000). The fly ash contains several heavy metals/metalloids such as As, Mo, Se, Cd and Zn (el-Mogazi et al., 1988). Presence of these metals/metalloids and other components may make the fly ash toxic which may have adverse impacts on flora and fauna of the ecosystems particularly in the surroundings of power plants. Environmentally released metals are mainly deposited in soils and are mobilized either by leaching or by uptake into plants (Prajapati et al., 2012 & 2014).

There are various literatures which have established that there is a clear cut relationship between the exposure of heavy metals/metalloids and the physiological responses in plants (such as changes in chlorophyll content and photosynthesis activities). Usually metals/metalloids exposure of low levels does not lead to any visible effects on the plants, but it is only after a threshold limit of metals/metalloids (Rodríguez et al., 2007). Fly ash originating from thermal power plants is contaminated by metals/metalloids and causes stress that limit plant growth and development (Liphadzi & Kirkham, 2006). Studies have shown that plant species growing in polluted environments may be stressed in various ways such as bioaccumulation of metals in toxic concentrations may disturb normal physiological processes of plants (Dahmani-Muller et al., 2000; Monni et al., 2001; Plekhanov & Chemeris, 2003; Liphadzi & Kirkham, 2006). For example, studies have shown that growth and photosynthetic activities are adversely affected by cadmium (Nagel et al., 1996). However, metal pollution of plants growing in the polluted environments may exhibit toxicity simultaneously and interactively at different levels (Walker et al., 2003; Vάzquez et al., 2006; Rodríguez et al., 2007).

2. MATERIAL AND METHODS

Present experiments were performed in the vicinity of a super thermal power plant (NTPC, Sipat, Chhattisgarh, India) located at 22°07' N and 82°16' 43 E with an installed capacity of 2980 MW. *Ficus bengalensis* and

Plumeria rubra growing in the area were selected for the present study. The fly ash deposited on the leaves of these two plants was taken for the analysis of heavy metals/metalloids. Analysis of fly ash for heavy metals/metalloids (Fe, Zn, Pb, Cd, Mo, Cu, Cr, Co and Ni) were performed with the help of atomic absorption spectrophotometer (AAS) model: AA 7000, SHIMADZU and the standards were prepared using standard metal solution of Inorganic Ventures. Various photosynthetic parameters (fluorescence, Fv/Fm, fluorescence quenching coefficients, relative electron transport rate, photosynthetic active radiation, ETR-Factor absorptance of photons by photosynthetic pigments etc.) were measured using JUNIOR-PAM, Chlorophyll Fluorometer, Heinz Walz GmbH, Germany.

3. Results and Discussions

The dust deposited on plant leaves in the surroundings of coal fired thermal power plant comes mainly because of two reasons. First, due to fly emissions directly from the power plant and second from the re-suspension of fly ash present in the fly ash dykes because of wind and other atmospheric conditions. The dust deposited on the plant leaves were analysed for heavy metals/metalloids by AAS. The analysis of dust deposited on plant leaves showed the presence of various heavy metals/metalloids and in varied concentration as shown in table 1. It is clear from the table that Fe was present in maximum amount followed by Mo>Zn>Cr>Co>Ni>Cd. Lead and copper were absent in the dust deposited on plant leaves. Presence of these metals/metalloids in dust deposited on leaves may have adverse impacts on the various physiological and biochemical processes of plants including the photosynthetic parameters. The dust also closes the stomata leading to reduced rate of gaseous exchange between plant and atmosphere. These contaminants are also harmful for the general public, terrestrial flora and fauna and as well aquatic flora and fauna of the area.

Table 1: Heavy metals/metalloids concentration (μg g^{-1} dry wt. of dust) present in dust deposited on leaves of *Ficus bengalensis* and *Plumeria rubra*

Metal/metalloids	Fe	Zn	Pb	Cd	Mo	Cu	Cr	Co	Ni
Concentration	33.02	1.402	0.00	0.082	4.49	0.00	0.213	0.176	0.127

Dust deposited on plant leaf surfaces may inetrfere with gas diffusion between the leaf and atmosphere. Sedimentation of dust particles affects the upper surfaces of leaves more (Thompson et al., 1984; Kim et al., 2000) while finer particles affects lower surfaces (Ricks and Williams 1974; Krajickova and Mejstrik, 1984; Fowler et al., 1989; Beckett at al. 2000). The adverse effects of dust contaminated by heavy metals/metalloids on the various photosynthetic parameters of *Ficus bengalensis* and *Plumeria rubra* have been shown in the appendix 2 and 3 respectively. The Fv/Fm values which is an indication of the maximum and effective photochemical quantum yield of PS II is below 0.75 for *Plumeria rubra* and above 0.75 for *Ficus benghalensis*. It is clear from the observed value of Fv/Fm for *Plumeria rubra* which is below 0.75 (0.689, 0.691 and 0.686) that the plant is under stress condition while the *Ficus benghalensis* under the same environmental condition is not observing similar stress as indicated by its Fv/Fm value (0.775, 0.767 and 0.763). Accordingly other photosynthetic parameters are also more adversely affected for *Plumeria rubra* as compared to *Ficus benghalensis*.

Dust deposition affects the light available for photosynthesis and blocks the stomatal pore for diffusion of air and thus put stress on plant metabolism (Eller, 1977; Hope et al., 1991; Keller and Lamprecht, 1995; Anthony, 2001).The ETR-F values correspond to the ratio of photons absorbed by photo-synthetic pigments to incident photons which is 0.84 in present case. The PAR value in present case is 429 (in μmoles/(m^2·s) and the relative electron transport rate (ETR) varies during the experiments which is provided in the appendix 2 and 3. Variation of other photosynthetic parameters can also be observed from the given table. Yields of non-photochemical quenching is higher for *Ficus benghalensis* as compared to *Plumeria rubra.*

4. Conclusions

The present study was conducted in the vicinity of a super thermal power plant. In order to ensure whether the fly ash emitted from the thermal power plants have any adverse effects on the flora of the surrounding areas the present experiments were performed. The analysis of fly ash dust deposited on the plant leaves of *Ficus bengalensis* and *Plumeria rubra* that were present in the area for heavy metals/metalloids was performed. The analysis showed that dust present on plant leaves were contaminated by the presence of several metals/metalloids. At the same time, the adverse impacts of these contaminants on the various photosynthetic parameters of the plant leaves were also studied. The study clearly indicated that presence of heavy metals/metalloids is causing stress on the plant. The adverse effects of heavy metals/metalloids on photosynthetic parameters of *Plumeria rubra* is more as compared to *Ficus benghalensis.* This is due to more APTI (air pollution tolerance index) of *Ficus bengalensis* than *Plumeria rubra.* The negative effects of fly ash on plants will ultimately lead to reduction in the net productivity of the plants and ultimately the entire ecosystem. Henceforth, the issues of fly ash emitted from coal fired thermal power plants needs to be properly addressed using modern day emission control technologies and controlling the re-suspension of fly ash dust from dykes by planting the ruderals plant species.

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REFERENCES

1. Anthony, P., 2001. Dust from walking tracks: Impacts on rainforest leaves and epiphylls. Cooperative Research Centre for Tropical Rainforest Ecology and Management, Australia. Available at http://www.rainforest-crc.jcu.edu.au (verified 7 Jan. 2008).
2. Beckett, K.P., P.H. Freer-Smith, and G. Taylor. 2000. Particulate pollution capture by urban trees: Effect of species and wind speed. Glob. Change Biol. 6:995–1003.
3. Dahmani-Muller, H., Van Oort, F., Gelie, B., & Balabane, M., 2000. Strategies of heavy metal uptake by three plant species growing near a metal smelter. Environmental Pollution, 109, 231-238.
4. Eller, B.M., 1977. Road dust induced increase of leaf temperature. Environmental Pollution. 137:99–107.
5. el-Mogazi, D., Lisk, D. J., & Weinstein, L. H., 1988. A review of physical, chemical, and biological properties of fly ash and effects on agricultural ecosystems. The Science of the Total Environment, 74, 1–37.
6. Fowler D, Cape JN, Unsworth MH. 1989. Deposition of atmospheric pollutants on forests. Philosophical Transactions of the Royal Society of London, 324: 247-265
7. Hope, A.S., J.B. Fleming, D.A. Stow, and E. Aguado., 1991. Tussock tundra albedos on the north slope of Alaska: Eff ects of illumination, vegetation composition, and dust deposition. J. Appl. Meteorol. 30:1200–1206.
8. Keller, J., and R. Lamprecht. 1995. Road dust as an indicator for air pollution transport and deposition: An application of SPOT imagery. Remote Sens. Environ. 54:1–12.
9. Kim E, Kalman D, Larson T. 2000. Dry deposition of large, airborne particles onto a surrogate surface. Atmospheric Environment, 34: 2387-2397
10. Krajickova A, Mejstrik V. 1984. The effect of flyash particles on the plugging of stomata. Environmental Pollution Series, 36: 83-93
11. Liphadzi, M. S., & Kirkham, M. B., 2006. Heavy-metal displacement in chelate -treated soil with sludge during phytoremediation. Journal of Plant Nutrition and Soil Science, 169(6), 737-744.
12. Monni, S., Uhlig, C., Hansen, E., & Magel, E., 2001. Ecophysiological responses of *Empetrum nigrum* to heavy metal pollution. Environmental Pollution, 112, 121-129.
13. Nagel, K., Adelmeier, U., & Voigt, J., 1996. Sub cellular distribution of cadmium in the unicellular green alga *Chlamydomonas reinhardtii.* Journal of Plant Physiology, 149, 86-90.
14. Plekhanov, S. E,, Chemeris, Y. K., 2003. Early toxic effects of zinc, cobalt, and cadmium on photosynthetic activity of the Green alga *Chlorella pyrenoidosa* Chick S-39. Biology Bulletin, 30(5), 506-511.
15. Prajapati S K., 2012. Biomonitoring and speciation of road dust for heavy metals using *Calotropis procera* and *Delbergia sissoo.* Environmental Skeptics and Critics, 1(4): 61-64.
16. Meravi, N., Prajapati, S.K., 2014. Effects of Heavy Metals/Metalloids Present in Fly Ash from Coal Fired Thermal Power Plant on Photosynthetic Parameters of *Mangifera indica.* Environmental Skeptics and Critics, 2014, 3(4): 88-92.
17. Ricks GR, Williams RJH. 1974. Effects of atmospheric pollution on deciduous woodland. Part 2: Effects of particulate matter upon stomatal diffusion resistance in leaves of *Quercus petraea* (Mattuschka) Leibl. Environmental Pollution, 6: 87-109
18. Rodríguez, M. C., Barsanti, Passarelli, Evangelista, V., Conforti, V., & Gualtieri, P., 2007. Effects of chromium on photosynthesis and photoreceptive apparatus of the alga *Clamydomonas reinhardtii*. Environment Research, 105, 234-239.
19. TERI (Tata Energy Research Institute)., 2000. Reclaiming ash ponds and immobilizing heavy metals by means of mycorrhizal organo-biofertilizer at Korba STPS, Annual Report. New Delhi: TERI.
20. Thompson JR, Mueller PW, Fluckiger W, et al. 1984. The effect of dust on photosynthesis and its significance for roadside plants. Environmental Pollution (Series A), 34: 171-190
21. Vάzquez, S., Goldsbrough, P., & Carpena, R. O., 2006. Assessing the relative contributions of phytochelatins and the cell wall to cadmium resistance in white lupin. Physiology of Plant, 128, 487-495.
22. Walker, D. J., Clemente, R., Roig, A., & Bernal, M. P., 2003. The effects of soil amendments on heavy metal bioavailability in two contaminated Mediterranean soils. Environmental Pollution, 122, 303-312.

Appendix 1: The deatiled report of the various photosysnthetic parameters (*Ficus benghalensis*)

22-11-2014	17:05:35	WinControl (rev 700) report file																		
Date	Time	Type	No.	1:F	1:Fm'	1:PAR	1:Tem	1:Y (II)	1:ETR	1:Fo'	1:ETR-F.	1:qP	1:qN	1:qL	1:NPQ	1:Y (NO)	1:Y (NPQ)	1:Fo	1:Fm	1:Fv/Fm
		D		Device Nr: #1, Mini-PAM																
15-08-2013	13:30:59	SCHS		Chart Start																
15-08-2013	13:31:18	FO	83	590	2627	0	32	0.775	0	-	0.84	-	-	-	-	-	-	590	2627	0.775
15-08-2013	13:32:28	F	84	882	2079	429	32	0.576	103.8	~557	0.84	0.786	0.253	0.496	0.264	0.335	0.089	590	2627	0.775
15-08-2013	13:33:16	F	85	800	2055	429	31.8	0.611	110.1	~555	0.84	0.837	0.264	0.581	0.278	0.304	0.085	590	2627	0.775
15-08-2013	13:33:59	F	86	775	2041	429	31.8	0.62	111.7	~554	0.84	0.851	0.27	0.608	0.287	0.295	0.085	590	2627	0.775
15-08-2013	13:34:41	F	87	755	2064	429	32	0.634	114.2	~556	0.84	0.868	0.26	0.639	0.273	0.287	0.079	590	2627	0.775
15-08-2013	13:34:56	SCHS		Chart start																
15-08-2013	13:35:20	FO	88	559	2401	0	32	0.767	0	-	0.84	-	-	-	-	-	-	559	2401	0.767
15-08-2013	13:35:42	F	89	802	2402	429	32	0.666	120	~559	0.84	0.868	-0.001	0.605	0	0.334	0	559	2401	0.767
15-08-2013	13:36:14	F	90	603	2100	0	32	0.713	0	~541	0.84	0.96	0.154	0.861	0.143	0.251	0.036	559	2401	0.767
15-08-2013	13:36:45	F	91	562	2373	0	31.9	0.763	0	~557	0.84	0.997	0.014	0.988	0.012	0.234	0.003	559	2401	0.767
15-08-2013	13:37:16	F	92	562	2400	0	32	0.766	0	~559	0.84	0.998	0.001	0.993	0	0.234	0	559	2401	0.767
15-08-2013	13:37:32	SICS		Induction Curve start																
15-08-2013	13:37:36	FO	93	567	2397	0	32.2	0.763	0	-	0.84	-	-	-	-	-	-	567	2397	0.763
15-08-2013	13:38:16	F	94	917	2391	429	32.1	0.616	111	~567	0.84	0.808	0.003	0.5	0.003	0.382	0.002	567	2397	0.763
15-08-2013	13:38:36	F	95	807	1856	429	32.1	0.565	101.8	~530	0.84	0.791	0.275	0.519	0.291	0.337	0.098	567	2397	0.763
15-08-2013	13:38:57	F	96	690	1864	429	32	0.63	113.5	~531	0.84	0.881	0.272	0.678	0.286	0.287	0.083	567	2397	0.763
15-08-2013	13:39:18	F	97	724	1832	429	32.2	0.605	109	~528	0.84	0.85	0.287	0.62	0.308	0.302	0.093	567	2397	0.763
15-08-2013	13:39:40	F	98	703	1832	429	32.2	0.616	111	~528	0.84	0.866	0.287	0.65	0.308	0.293	0.091	567	2397	0.763
15-08-2013	13:39:59	F	99	704	1853	429	32.3	0.62	111.7	~530	0.84	0.868	0.277	0.653	0.294	0.293	0.087	567	2397	0.763
15-08-2013	13:40:21	F	100	704	1863	429	32.4	0.622	112.1	~531	0.84	0.87	0.272	0.656	0.287	0.293	0.085	567	2397	0.763
15-08-2013	13:40:42	F	101	699	1850	429	32.3	0.622	112.1	~530	0.84	0.872	0.279	0.661	0.296	0.291	0.087	567	2397	0.763
15-08-2013	13:41:03	F	102	696	1837	429	32.4	0.621	111.9	~529	0.84	0.872	0.285	0.663	0.305	0.29	0.089	567	2397	0.763
15-08-2013	13:41:24	F	103	691	1827	429	32.2	0.622	112.1	~528	0.84	0.875	0.29	0.669	0.312	0.288	0.09	567	2397	0.763
15-08-2013	13:41:45	F	104	693	1824	429	32.4	0.62	111.7	~528	0.84	0.873	0.292	0.665	0.314	0.288	0.092	567	2397	0.763
15-08-2013	13:42:06	F	105	684	1791	429	32.2	0.618	111.4	~525	0.84	0.874	0.308	0.671	0.338	0.285	0.097	567	2397	0.763
15-08-2013	13:42:27	F	106	683	1779	429	31.9	0.616	111	~524	0.84	0.873	0.314	0.67	0.347	0.284	0.1	567	2397	0.763
15-08-2013	13:42:37	F	107	535	1888	0	32	0.717	0	~533	0.84	0.999	0.26	0.995	0.27	0.223	0.06	567	2397	0.763

Appendix 2: The deatiled report of the various photosysnthetic parameters (*Plumeria rubra*)

22-11-2014	17:06:11	WinControl (rev 700) report file																		
Date	Time	Type	No.	1:F	1:Fm'	1:PAR	1:Temp	1:Y (II)	1:ETR	1:Fo'	1:ETR-F.	1:qP	1:qN	1:qL	1:NPQ	1:Y (NO)	1:Y (NP(	1:Fo	1:Fm	1:Fv/Fm
		D		Device Nr: #1, Mini-PAM																
08-08-2013	14:56:15	SCHS		Chart Start																
08-08-2013	14:57:02	FO	1094	844	2712	0	30.6	0.689	0	-	0.84	-	-	-	-	-	-	844	2712	0.689
08-08-2013	14:58:18	F	1095	1155	2256	0	29.9	0.488	0	~794	0.84	0.753	0.217	0.518	0.202	0.425	0.087	844	2712	0.689
08-08-2013	14:59:06	F	1096	1029	2216	0	30.9	0.536	0	~789	0.84	0.832	0.236	0.638	0.224	0.379	0.085	844	2712	0.689
08-08-2013	15:00:36	F	1097	1019	2183	0	30.5	0.533	0	~785	0.84	0.833	0.252	0.642	0.242	0.375	0.092	844	2712	0.689
08-08-2013	15:01:21	F	1098	964	2114	0	30.1	0.544	0	~776	0.84	0.859	0.284	0.691	0.283	0.355	0.101	844	2712	0.689
08-08-2013	15:02:06	SCHS		Chart start																
08-08-2013	15:03:52	FO	1099	764	2472	0	30.5	0.691	0	-	0.84	-	-	-	-	-	-	764	2472	0.691
08-08-2013	15:04:43	F	1100	1192	2493	429	30.1	0.522	94.1	~766	0.84	0.753	-0.011	0.484	-0.008	0.482	-0.004	764	2472	0.691
08-08-2013	15:05:14	F	1101	772	2228	0	29.8	0.654	0	~739	0.84	0.978	0.128	0.936	0.11	0.312	0.034	764	2472	0.691
08-08-2013	15:05:45	F	1102	772	2480	0	30.2	0.689	0	~765	0.84	0.996	-0.004	0.987	-0.003	0.312	-0.001	764	2472	0.691
08-08-2013	15:06:16	F	1103	782	2502	0	30.2	0.687	0	~767	0.84	0.991	-0.016	0.972	-0.012	0.316	-0.003	764	2472	0.691
08-08-2013	15:07:20	SICS		Induction Curve start																
08-08-2013	15:07:25	FO	1104	797	2535	0	30.1	0.686	0	-	0.84	-	-	-	-	-	-	797	2535	0.686
08-08-2013	15:08:03	F	1105	1324	2470	429	30	0.464	83.6	~790	0.84	0.682	0.033	0.407	0.026	0.522	0.014	797	2535	0.686
08-08-2013	15:08:24	F	1106	1025	2019	429	30.1	0.492	88.6	~738	0.84	0.776	0.263	0.559	0.256	0.404	0.104	797	2535	0.686
08-08-2013	15:08:45	F	1107	981	2040	429	30.1	0.519	93.5	~741	0.84	0.815	0.253	0.616	0.243	0.386	0.095	797	2535	0.686
08-08-2013	15:09:05	F	1108	972	2033	429	29.9	0.522	94.1	~740	0.84	0.821	0.256	0.625	0.247	0.383	0.095	797	2535	0.686
08-08-2013	15:09:27	F	1109	973	2112	429	30.3	0.539	97.1	~750	0.84	0.836	0.216	0.644	0.2	0.383	0.078	797	2535	0.686
08-08-2013	15:09:47	F	1110	943	2017	429	30.1	0.532	95.9	~737	0.84	0.839	0.264	0.656	0.257	0.372	0.096	797	2535	0.686
08-08-2013	15:10:08	F	1111	932	2088	429	30.4	0.554	99.8	~747	0.84	0.862	0.228	0.691	0.214	0.367	0.079	797	2535	0.686
08-08-2013	15:10:30	F	1112	916	2084	429	29.9	0.56	101	~746	0.84	0.873	0.23	0.711	0.216	0.361	0.079	797	2535	0.686
08-08-2013	15:10:51	F	1113	936	2059	429	30.1	0.545	98.2	~743	0.84	0.853	0.243	0.677	0.231	0.369	0.086	797	2535	0.686
08-08-2013	15:11:12	F	1114	903	2033	429	30.3	0.556	100	~740	0.84	0.874	0.256	0.716	0.247	0.356	0.088	797	2535	0.686
08-08-2013	15:11:32	F	1115	898	2023	429	30.1	0.556	100	~738	0.84	0.875	0.261	0.719	0.253	0.354	0.09	797	2535	0.686
08-08-2013	15:11:53	F	1116	890	2032	429	30.4	0.562	101	~739	0.84	0.883	0.256	0.733	0.248	0.351	0.087	797	2535	0.686
08-08-2013	15:12:14	F	1117	915	2091	429	30	0.562	101	~747	0.84	0.875	0.227	0.714	0.212	0.361	0.077	797	2535	0.686
08-08-2013	15:12:25	F	1118	697	2038	0	29.8	0.658	0	~740	0.84	1.033	0.253	1.097	0.244	0.275	0.067	797	2535	0.686
08-08-2013	15:12:55	F	1119	739	2213	0	30.1	0.666	0	~762	0.84	1.016	0.165	1.048	0.146	0.291	0.043	797	2535	0.686
08-08-2013	15:13:59	F	1120	743	2277	0	30.4	0.674	0	~770	0.84	1.018	0.133	1.055	0.113	0.292	0.034	797	2535	0.686
08-08-2013	15:16:04	F	1121	774	2455	0	30.1	0.685	0	~789	0.84	1.009	0.041	1.029	0.033	0.305	0.01	797	2535	0.686

Acronyms for Appendicies

F_o Basic fluorescence yield (relative units) recorded with low measuring light intensities.

F_m Maximal chlorophyll fluorescence yield when photosystem II reaction centers are closed by a strong light pulse (relative units).

$F_v/F_m = (F_m-F_o)/F_m$ maximum photochemical quantum yield of photosystem II.

qP and qL Coefficients of photochemical fluorescence quenching

qN and **NPQ** Parameters of non-photochemical quenching

Y(NO) and Y(NPQ) Yields of non-photochemical quenching

PAR Photosynthetic active radiation

ETR Relative electron transport rate

ETR-Factor Absorptance of photons by photosynthetic pigments

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Impact of Climate Change and Spatial Variability on Leaf Traits and Reproductive Attributes of an Invasive Species, *Lantana camara* L.

S.K. Pandey[1*], Purnima Raizada[1] and Hema Singh[2]

[1]School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India

[2]Ecosystems Analysis Laboratory, Department of Botany, Banaras Hindu University, Varanasi-221005 (India)

***Corresponding author:** *skpbhu2007@gmail.com*

ABSTRACT- *Lantana camara*, a dreadful invasive species across the world is invading all over India. A large number of reproductive and vegetative attributes are responsible for its invasiveness that can provide it an edge over local flora under spatial variations and changing climatic conditions. In the present work variations in specific leaf area, photosynthetic rate, stomatal conductance, water use efficiency, chlorophyll content, leaf water content, soil respiration, litter mass loss and reproductive attributes were studied on three different sites of a dry tropical environment. Specific leaf area, photosynthetic rate, stomatal conductance, chlorophyll content, leaf water conductance, soil respiration, litter mass loss, fruit weight, flower weight and fruit set increased with increasing soil moisture. However, we found no significant relationship between SLA and seed mass as predicted by other authors. It may be concluded that soil moisture plays an important role in the establishment of *Lantana camara* in the dry deciduous forest. These findings may provide the basis for further research and expected invasion areas for *Lantana camara*.

Keywords: *Lantana camara*, Climate Change, Moisture, Reproductive Attributes, specific leaf area (SLA), photosynthetic rate, soil respiration (R_s), water use efficiency (WUE), leaf water content (LWC), Dry Deciduous Forests.

1. INTRODUCTION

Lantana camara L. commonly known as *Lantana*, prickly *Lantana* or wild sage, a dreadful invader across the world, is a shrub from Verbenaceae family, which can grow to 2 - 4 meters in height. Leaves are bright green, finely hairy, rough, with serrate margins and release a pungent odour when crushed. The leaf is ovate or ovate oblong, 2 - 10 cm long and 2 - 6 cm wide, arranged in opposite pairs. The stem in cultivated varieties is frequently non-thorny and in weedy varieties with recurved prickles. It is hairy, woody, square in cross section when young, cylindrical and up to 15 cm thick as it grows older. *L. camara* is capable to climb to 15 m with the hold of other vegetation. Flower heads hold 20 - 40 flowers, generally 2.5 cm across; the colour varies from cream, white or yellow to orange pink, red and purple. Flowering arises between August and March, or all year round if sufficient moisture and light are available. Pollinators consist of lepidopteran species and thrips. The fruit is a greenish blue-black colour, 5 - 7 mm in diameter, spotless, drupaceous, with two nutlets; seed setting takes place between September to May with 1 - 20 seeds on each flower head. Completely developed plants produce up to 12,000 seeds annually. Seed germination takes place when enough moisture is present; germination is reduced by low light conditions. The root system is very tough with a main taproot and a mat of many on the surface side roots (Asia-Pacific Forest Invasive Species Network). It was introduced in India in 1809 as an ornamental hedge in Calcutta botanical garden (Kohli et al. 2006). Owing to several vegetative and reproductive attributes, such as phenotypic plasticity, allelopathy, competitive ability, fire tolerance and vegetative propagation it has spread throughout India (Sharma et al. 2005). *L. camara* produces inflorescence in abundance in which large numbers of flowers are produced and they attract large numbers of pollinators which help in high quantity of fruit set. Flowers are efficiently pollinated by butterflies and thrips, sunbirds (India) and humming birds (Brazil) resulting in 85% fruit set (Hilje 1985). Its fruits are small, greenish-blue black or blackish drupes. Seeds of *L. camara* are widely dispersed, predominantly through birds. Birds eat its ripe fruits and during their movement, seeds are dispersed over long distances (Swarbrick et al. 1998). The dispersal is also aided by sheep, goats, cattle, foxes, monkeys, kangaroos, jackals and possibly, rodents (Wells and Stirton 1988). *L. camara* has been known to germinate and proliferate well after disturbance (Hiremath and Sundaram 2005; Gentle & Duggin 1997; Duggin and Gentle 1988) but the exact phenomenon is unclear. Since specific leaf area which helps in opportunistic resource acquisition and reproduction assisting successful proliferation (Grotkopp and Rejmánek 2007) are the two most important attributes of invasive species, they need to be considered with special attention in regard to plant invasion under disturbed conditions. Photosynthesis is the formation of carbohydrates from carbon dioxide and water through the action of light energy on a light sensitive pigment, such as chlorophyll, and usually results in the production of oxygen. The amount of light, the carbon dioxide supply, the temperature, the water supply, and the availability of minerals are the most important environmental factors that directly affect A_{area} in land plants. Thus, it is important to better understand the threat of invasion under climate change scenarios for effective management of invasive plants in the 21st century (Bradley 2010). The abundance distribution of plant species are tightly regulated by both climatic factors (Woodward 1987) and biotic interactions (Araújo and Luoto 2007), so changes in climatic situation are likely to cause main changes in their population dynamics and geographic ranges Walther et al. 2002; Parmesan 2006; Walther et al. 2009). Apart from changes in the possible distributions of native species, climate change may also affect the spatial distribution of invasive species (Weitere et al. 2009; Bradley 2010; Walther et al. 2009). Earlier studies have shown that global warming has enabled alien plants to expand into regions where they previously could not survive and reproduce (Walther et al. 2009). Chlorophylls are the main pigments involved in light capture for photosynthesis and other photochemical and non-photochemical reactions; therefore the amount of light absorbed by a leaf is related to chlorophyll (Marenco et al. 2009; Niinemets 2010). The rate and fundamental mechanism of soil respiration is a matter of large number of studies, because soil CO_2 fluxes change significantly with predicted global warming, and impact the carbon cycle (Kirschbaum 1995; Davidson and Janssens 2006; Meir et al. 2008). The principal sources of soil CO_2 flux comprise microbial communities decaying soil organic matter; respiring roots, and the litter decomposition. The amount of respired carbon dioxide is mainly controlled by soil moisture, temperature and availability of substrate (Yuste et al. 2007). Transfer of nutrients in litter breakdown is an important process in nutrient recycling in terrestrial ecosystems (Swift et al. 1979).

Tropical dry deciduous forests which occupy 28.6% of the forested area in India (MoEF 2006) are under immense pressure due to increasing industrialization, repeated lopping of trees and shrubs for fuel wood or leaf fodder and heavy grazing (Jha and Singh 1990; Singh & Singh 1989). Moreover habitat fragmentation is also known to influence pollinator's abundance and specificity of pollinators (Aizen and Feinsinger 1994), ultimately influencing the fruit formation. In the present study we investigated variation in SLA, $A_{area,}$ G_s, WUE, chlorophyll content, LWC, R_s, litter mass loss and reproductive attributes of *L. camara* growing in dry deciduous forest and nearby areas to study the impact of climate change and spatial variability on these attributes *L. camara*.

2. MATERIALS AND METHODS

2.1 Study sites

Three different sites were considered for this study; Hathinala, Bokrakhari and Botanical Garden. First two sites are situated in the dry deciduous forest of Vindhayan highlands while the third site, Botanical Garden, BHU (referred to as BHU hereafter) is in the Banaras Hindu University, Varanasi. BHU is located at 25°18′ N & 80°01′ E at 126 m above the mean sea level and mean annual rainfall averages 1100 mm. Bokrakhari and Hathinala are situated at 24^0 24' 13'' N & 83^0 12' 01'' E and $24^0$18'07'' N & 83^0 05' 57'' E at 245 m and 291 m above the mean sea level, respectively. Mean annual rainfall ranges from 926 mm to 1146 mm (Pandey and Singh 1992). Soil moisture content and PAR (Photosynthetically active radiation) was measured by gravimetric method and LI-COR 6400XT, respectively, in August 2009. Physico-chemical characteristics of the soil are given in Table 1. Both the sites are under human influence and have different levels of *L. camara* cover. *L. camara* cover is denser at Hathinala than Bokrakhari. At Bokarakhari site, soil depth is 14.3 cm. Here soil is of reddish-brown colour and at Hathinala, soil is blackish-brown in colour with 21.0 cm depth.

2.2 Plant material

Tiny flower held in bunch. Colour generally orange, sometime varying from white to red in various shades and the flower frequently change colours as they ages. Flowers are having a yellow throat, in axillary head nearly all over the year. The calyx is little, corolla tube slender, the limb distribution 6 to 7 mm broad and divided in to uneven lobes. Stamen four in two pairs, included and ovary two celled, two ovuled. Inflorescences are formed in pairs in the axils of opposite leaves. Inflorescences are dense, dome shaped 2-3 cm crosswise and hold 20-40 sessile flowers (Sanjeeb et al. 2012). Reproductive attributes considered in the present study are flower number, flower weight, fruit number, fruit weight, pulp weight, seed weight and fruit set. Flowers were collected from fully grown flowering branches during their peak flowering season (August), and flower numbers and weight in each inflorescence were recorded. Fruit set for each branch was measure as described by Ricketts et al. 2004;

$$\text{Fruit set (\%)} = \frac{\text{Total number of fruits at harvest}}{\text{Original numbers of flowers}} \times 100$$

L. camara is a short upright or subscandent vigorous shrub with tetrangular stem, solid recurved pickles and a burly odour of black currents. Plant grows up to 1 to 3 meters and it can extend to 2.5 meter in width. Leaves are ovate or ovate oblong, acute or sub acute, crenate serrate, rugose above, scabrid on both sides. The leaves are 3-8 cm long by 3-6 cm wide and green in colour. Leaves and stem are covered with rough hairs (Sanjeeb et al. 2012). Ten replicate of sun facing, healthy branches were marked on each site. Three inflorescences for flowers and fruits and three leaves were collected from each branch. Similarly, fruit numbers and weight were recorded. Pulp was removed by rubbing fruits which were soaked in water overnight against a wire mesh. Pulp weight was taken after drying the recovered pulp in oven at 78-80°C for 48 hours. Weight of depulped and oven dried seeds was also measured to get the seed weight.

2.3 Parameters studied

Specific leaf area is the ratio of leaf area to leaf dry weight (Cornelissen et al. 2003). A_{area}, G_s, WUE were measured by LI-COR 6400, Chlorophyll was analyzed by crushing 0.1g of the fresh leaf in 10 ml 80% acetone and the chlorophyll concentration was then calculated following Arnon (1949). LWC was calculated as LWC = TM – DM; where TM and DM represent turgid mass and dry mass of the fresh leaf, respectively (Turner 1981). R_s measured with a LI-COR 6400, soil CO_2 flux chamber inserted 1 cm in to the soil and connected to LI-COR 6400, Portable Photosynthesis Infrared Gas Analyzer (IRGA) LI-COR Inc., Lincoln. The 1 cm depth was chosen to minimize fine root disturbance. Thirty soil respiration measurements were made at each site. Soil temperature was measured at 5 cm beneath the soil surface during soil respiration. Litter mass loss (%) studies were carried out by using the litter bag (15 × 15 cm) technique (Gilbert & Bocock 1960). Thirty litter bags were kept at each site for one month and picked up in order to study the litter mass loss rates per month. Litter mass loss was calculated as [Mass loss (%) = (Initial wt. – Final wt.) / (Initial wt.) × 100].

2.4 Statistical analysis

Effect of different sites on SLA, $A_{area,}$ G_s, WUE, chlorophyll content, LWC, CO_2 efflux, litter mass loss and reproductive attributes was statistically examined through multivariate- ANOVA and Post-hoc analyses (SPSS 1997) and regression equations calculated by using Sigma Plot (ver. 11).

3. RESULTS

Across the forest sites, moisture ranged from 18 to 20% whereas in the BHU site moisture content was 16% (Table 1). BHU soil was lowest in C and N content whereas maximum C, N was recorded for Hathinala. *L. camara* canopy growing in the BHU garden received 799.79 µ mol m^{-2} s^{-1} PAR while Bokarakhari and Hathinala received 976 and 974 µ mol m^{-2} s^{-1} (PAR), respectively. Flower number ($F_{2, 87}$ = 6.86, P = 0.002), SLA ($F_{2, 87}$ = 67.33, P = 0.000), fruit weight ($F_{2, 87}$ = 7.2, P = 0.001), pulp weight ($F_{2, 87}$ = 6.07, P = 0.003), flower weight ($F_{2, 87}$ = 5.98, P = 0.004), fruit set ($F_{2, 87}$ = 21.11, P = 0.000), A_{area} ($F_{2, 87}$ = 79.62, P = 0.000), G_s ($F_{2, 87}$ = 215.3, P = 0.000), WUE ($F_{2, 87}$ = 439.3, P = 0.000), R_s ($F_{2, 87}$ = 99.6, P = 0.000) and litter mass loss ($F_{2, 87}$ = 263.5, P = 0.000) significantly varied across the sites where as fruit number ($F_{2, 87}$ = 2.05, P = 0.129), seed weight ($F_{2, 87}$ = 2.05, P = 0.134), chlorophyll content ($F_{2, 87}$ = 0.306, P = 0.099) and LWC ($F_{2, 87}$ = 0.530, P = 0.077) did not differ significantly (Table 2).

A positive relationship between soil moisture and SLA was found in the present study (y = 43.5x - 494.6, r^2 = 0.982, where x and y correspond to soil moisture (%) and SLA (cm^2 g^{-1}), respectively). LWC increased with increase in soil moisture (y = 0.007x + 0.088, r^2 = 0.964, where x and y correspond to soil moisture (%) and LWC

Table 1: Physico-chemical characteristics of soils

Site	Moisture (%)	C (%)	N (%)	P (%)
BHU	16±0.2	1.5± 0.06	0.06±.001	0.016±.004
Bokrakhari	18±1.1	1.6± 0.02	0.07±.000	0.011±.001
Hathinala	20±1.1	1.6± 0.05	0.09±.003	0.030±.008

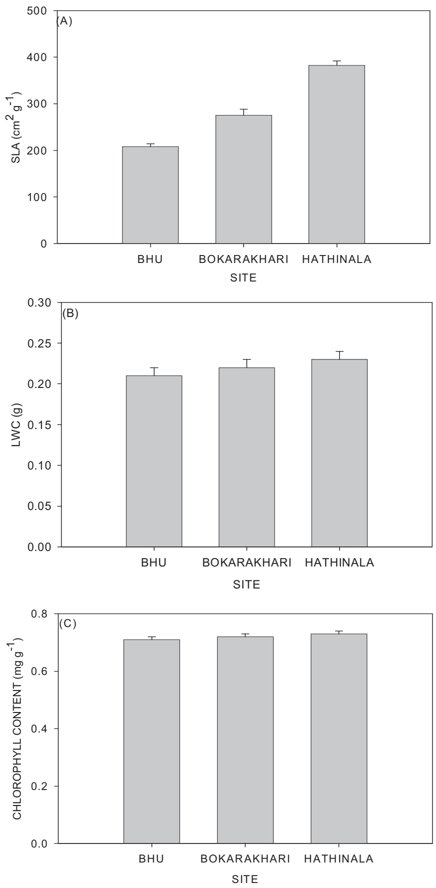

Figure 1. Variation in **A:** Specific leaf area; **B:** Leaf water content; **C:** Chlorophyll content; across sites.

(g), chlorophyll content increased with increase in soil moisture ($y = 0.007x + 0.568$, $r^2 = 0.964$, where x and y correspond to soil moisture (%) and chlorophyll content (mg g^{-1}) (Fig. 1 A-C).

Fruit set significantly increased with increase in soil moisture ($y = 4.25x + 3.833$, $r^2 = 0.972$, where x and y correspond to soil moisture (%) and fruit set (%), respectively). In addition, fruit weight was also higher in the moist sites ($y = 0.775x + 1.583$, $r^2 = 0.888$, where x and y correspond to soil moisture (%) and fruit weight (mg), respectively). Flower weight increased with increase in soil moisture ($y = 0.55x – 3.233$, $r^2 = 0.997$, where x and y correspond to soil moisture (%) and flower weight (mg) (Fig. 2).

A_{area} increased with increase in soil moisture ($y = 0.75x + 0.166$, $r^2 = 0.964$, where x and y correspond to soil moisture (%) and A_{area} (µ m $mol^{-1}s^{-1}$), G_s increased with increase in soil moisture ($y = 0.057x – 0.798$, $r^2 = 0.984$, where x and y correspond to soil moisture (%) and stomatal conductance (m mol g^{-1} s^{-1}) (Fig. 3A-B). R_s increased with increase in soil moisture ($y = 0.5x – 4.133$, $r^2 = 0.996$, where x and y correspond to soil moisture (%) and soil respiration (µ m CO_2 m^{-2} s^{-1}), leaf litter mass loss also increased with increase in soil moisture ($y = 0.75x + 23.16$, $r^2 = 0.964$, where x and y correspond to soil moisture (%) and leaf litter mass loss (%), respectively. The soil temperature and soil organic carbon increased as increase in soil moisture across sites (Fig. 4 A-D).

Table 2. Summary of ANOVA on leaf trait and flower traits

Main effect	Traits	df	F	Sig.
SITE	FLONO	2	6.855	0.002
	FRNO	2	2.095	0.129
	SLA	2	67.329	0.000
	FRWT	2	7.208	0.001
	SEEDWT	2	2.054	0.134
	PULPWT	2	6.079	0.003
	FLWT	2	5.987	0.004
	FRSET	2	21.112	0.000
	A_{area}	2	79.61	0.000
	GS	2	215.300	0.000
	WUE	2	439.278	0.000
	CHL	2	0.306	0.099
	LWC	2	0.530	0.077
	R_s	2	99.608	0.000
	MASSLOSS	2	263.505	0.000
Error	Each trait	87		

FLNO, Flower number; FRNO, Fruit number; FRWT, Fruit weight; FLWT, Flower weight; FRSET, Fruit set; A_{area}, Photosynthetic rate; G_s, Stomatal conductance; WUE, Water use efficiency; CHL, Chlorophyll content; LWC, Leaf water content; R_s, Soil respiration.

4. DISCUSSION

SLA being strongly correlated with relative growth rate, rate of photosynthesis (Weiher 1977) and competitive ability, is often considered a key trait linked to plant functioning (Reich et al. 1992; Wilson et al. 1999; Garnier et al. 2001). SLA, fruit weight, flower weight, fruit set, A_{area}, G_s, chlorophyll content, LWC, R_s and litter mass loss in *L. camara* were maximum at Hathinala site and minimum at BHU site.
A similar relationship of SLA with soil moisture is also reported by Pandey et al. (2009) for dry deciduous trees. SLA was significantly different among the sites. On the other hand, fruit weight and pulp weight were significantly higher at Hathinala site. It may be argued that fruit dispersal will be more and seed germination will be higher as fruit size and content of edible mass play an important role in fruit preference by fruit eating birds (Vila and D'Antonio 1998). Fruit set was minimum at the BHU site. Significantly higher fruit set in the forest sites than the BHU may be the result of successful pollination due to availability of more pollinators.

High specific leaf area is a trait that is often associated with small seed mass (Grotkopp et al. 2002; Lake & Leishman 2004; Hamilton et al. 2005; Leishman & Thomson 2005) but in the present study seed mass was not related to SLA. Soil moisture is among the key factors required for germination (Lee et al. 2004) and in the present study soil moisture significantly influenced the SLA, fruit weight, flower weight, fruit set, A_{area}, G_s, chlorophyll content, LWC, efflux and litter mass loss. But the strength of relationship strongly varies among plant species (Niinemets et al. 2009). G_s is a numerical measure of the maximum rate of passage of either water vapor or carbon dioxide through the stomata of the plant. Similar to our results shown, other studies also reported that Gs decreases with increasing water stress (Zhu et al. 2010). Species that display high WUE invest a large fraction of leaf nitrogen in the photosynthetic processes (Angert et al. 2009) and increases through stomatal closure and have been found to increase with dryness of site (Ares and Fownes 1999). Leaf chlorophyll is highly associated with leaf nitrogen content (Marino et al. 2010). Leaf nitrogen content may be used in combination with SLA to predict the photosynthetic rate (Reich et al. 1997).

This study is perhaps the first attempt to characterize R_s in relation to physiological and reproductive attributes of an invasive species. Growing plants can increase decomposition through inputs of labile carbon that increases the action and turnover of microbes (Cheng and Coleman 1990; Sallih and Bottner 1988). Plants also control decomposition through their effects on soil temperature and soil moisture (Mack et al. 2001; Van der Krift et al. 2002) or oxygen concentration (Allen et al. 2002). In general, the rate of decomposition is highest in species with high nitrogen content and minimal C: N ratios (Singh 1969; Finzi et al. 1998; Berg and Laskowski 2006; Kamei et al. 2009), the litter decomposition is main factor to ecosystem, as it cycles the nutrients and organic matter back to roots and soil biota (Ashton et al. 2005; Gurevitch et al. 2002). Invasive plant species naturally have a higher concentration of nitrogen in leaves than local plants and estimated to decay faster (Ehrenfeld 2003; Vitousek et al. 1987), which cause a higher discharge rate into the soil than inhabitant species

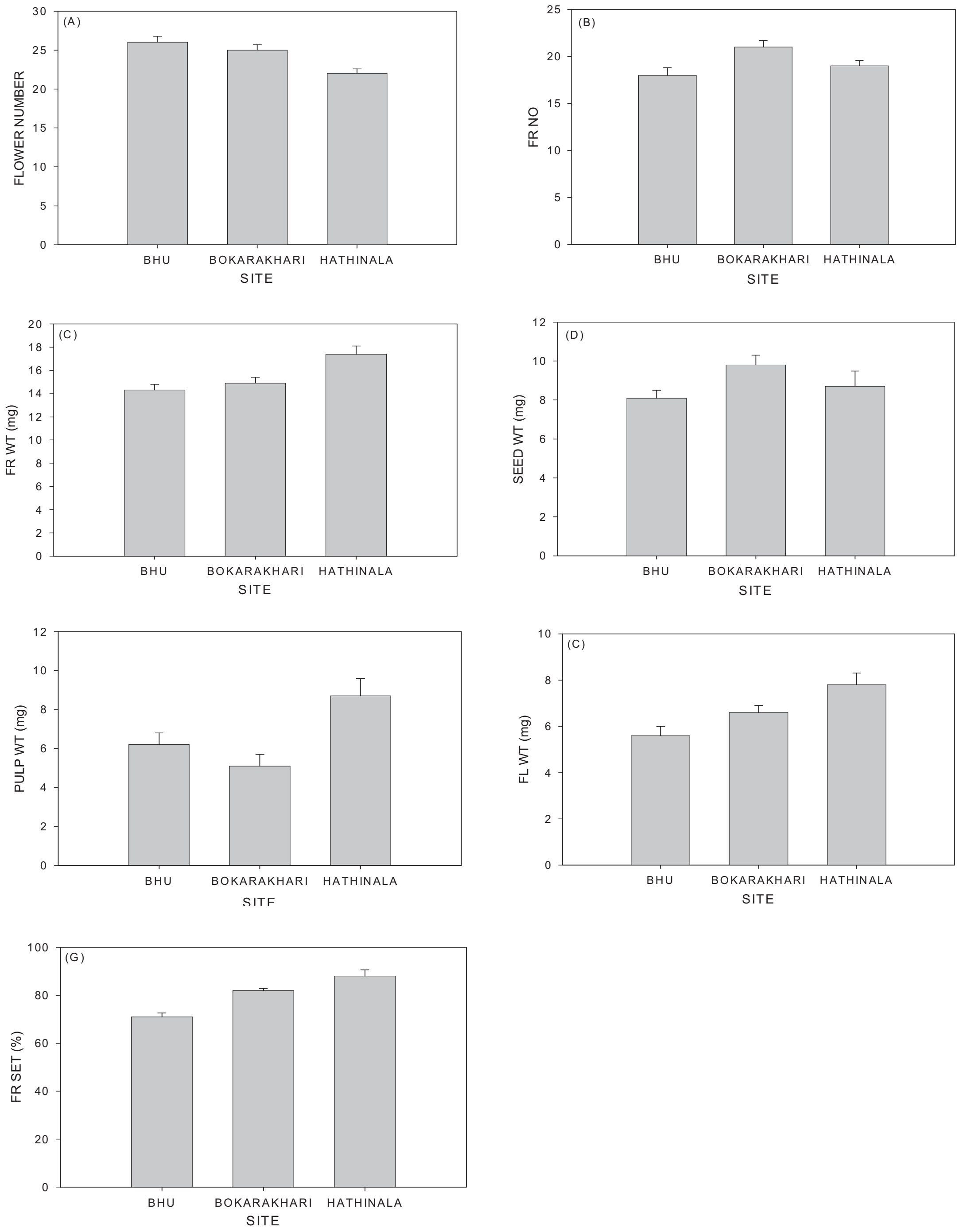

Figure 2. Variation in **A:** Flower number; **B:** Fruit number; **C:** Fruit weight; **D:** Seed weight; **E:** Pulp weight; **F:** Flower weight; **G:** Fruit set; across sites.

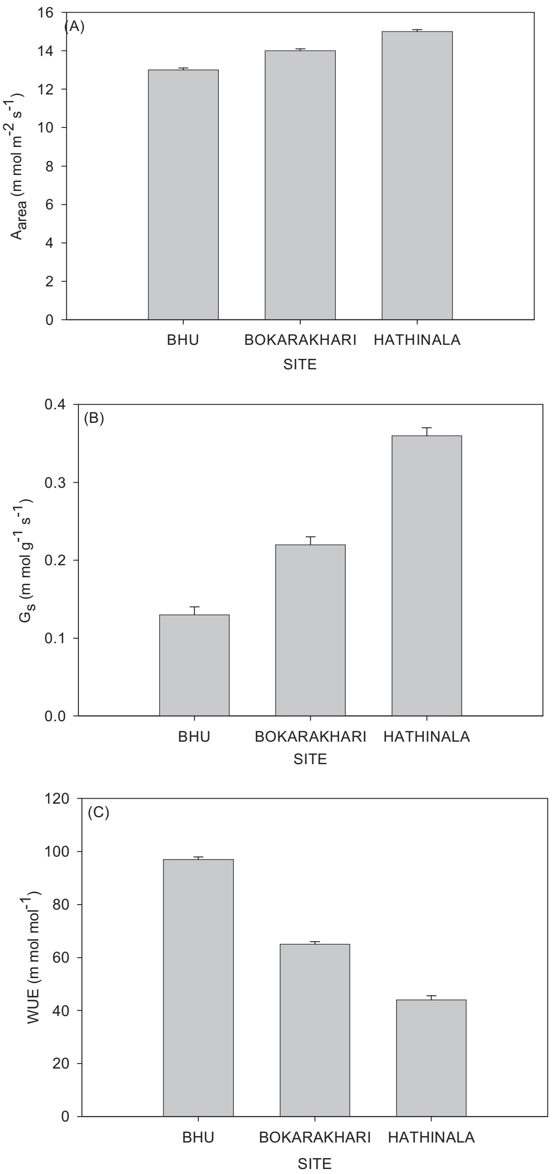

Figure 3. Variation in **A:** Photosynthetic rate; **B:** Stomatal conductance; **C:** Water use efficiency; across sites.

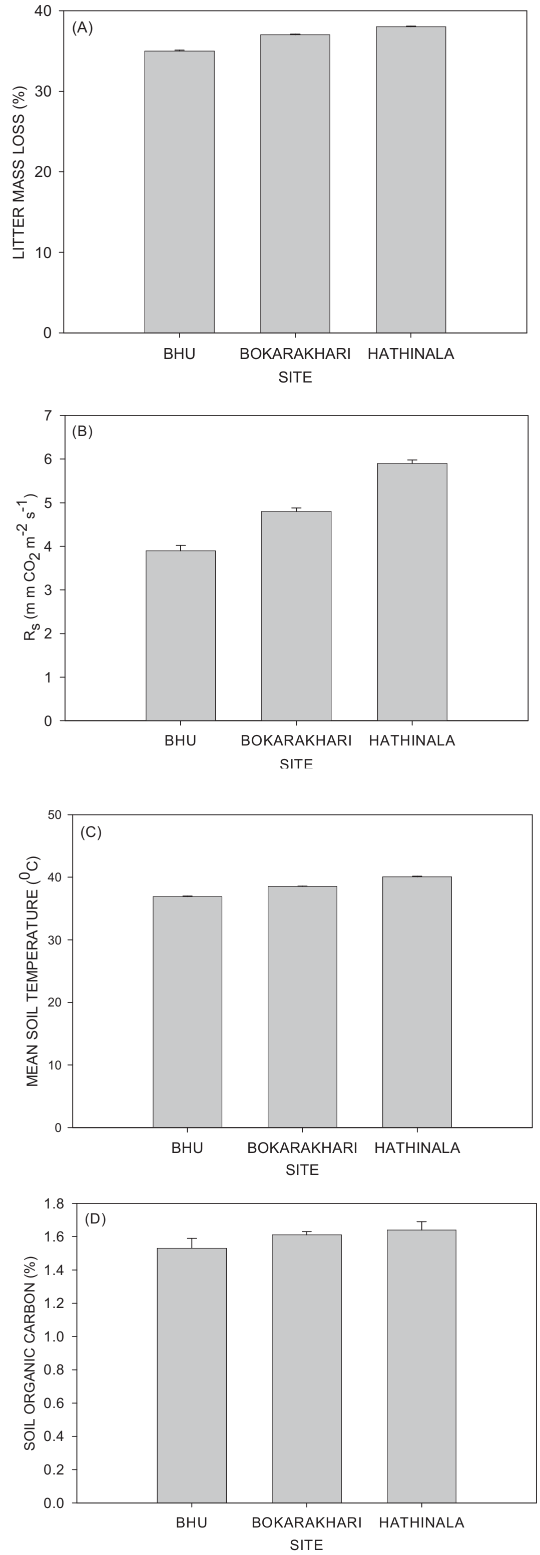

Figure 4. Variation in **A:** Litter mass loss; **B:** Soil respiration; **C:** Mean soil temperature; **D:** Soil organic carbon; across sites.

(Ashton et al. 2005), and as consequences may be support more invasive species to overrun (Simberloff and Von Holle 1999). The ability of invasive species is usually attributed to the properties of the invading species (Blossey et al. 1995; Callaway and Aschehoug 2000), those of the invaded population and environment (Davis et al. 2000; Hierro 2005). The dynamics of invasive species - their population organization, impacts and relations with environmental variables such as weather and disturbances, change with time (Strayer 2006). Often invasive plants are well-known to persist gently in low numbers for wide periods of time before exhibiting unexpected changes such as local population outburst or range spreading out which could be connected with either modify in the invading species itself or in the abiotic environment or biotic interactions (Crooks 2005). *Lantana camara* is a small perennial shrub which can grow to around 2m in height and forms thick copse in a variety of environments (Sharma 1981). Thus, litter mass loss is a critical process for regulating nutrient cycling and production in all ecosystems which promote plants growth and productivity which also associated with environmental factors. Our results provide key facts that elevated moisture and variable climate led to significant increases in growth along with physiological effect, which facilitates the invasion of *L. camara*.

5. CONCLUSION

Present study suggests that soil moisture content plays an important role in the growth of *L. camara* in the dry deciduous forest. Because the Hathinala site has more plants, promote more rain, moisture results more plant growth as compared to BHU site. Therefore, we can say that differences across sites arose from the environmental factors. Changing climatic conditions are also providing favorable niches to this invasive species. Present observations may provide important basis for the future research work pertaining to alteration in growth traits and reproductive attributes of *L. camara* in relation to environmental drivers.

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REFERENCES

1. Aizen M.A. and Feinsinger P. 1994. Habitat fragmentation, native insect pollinators, and feral honey-bees in Argentine Chaco Serrano. *Ecol Applic*. **4**, 378-392.
2. Allen A.P., Brown J.H. and Gillooly J.F. 2002. Global biodiversity, biochemical kinetics, and the energetic-equivalence rule. *Science* **297**, 1545–1548.
3. Angerta A.L., Huxmanb T.E., Chessonb P. and Venableb D.L. 2009. Functional tradeoffs determine species coexistence via the storage effect. *Proc. of Nat. Acad. Sci*. **106**, 11649–11653.
4. Araújo M.B. and Luoto M. 2007. The importance of biotic interactions for modelling species distributions under climate change. *Global Ecology and Biogeography* **16(6)**, 743–753.
5. Ares A. and Fownes J.H. 1999. Water supply regulates structure, productivity and water-use-efficiency of *Acacia koa* forest in Hawaii. *Oecologia* **121**, 458–466.
6. Ashton I.W., Hyatt L.A., Howe K.M., Gurevitch J. and Lerdau M.T. 2005. Invasive species accelerate decomposition and litter nitrogen loss in a mixed deciduous forest. *Ecol Appl*. **15**, 1263-1272.
7. Berg B. and Laskowski R. 2006. Litter decomposition: a guide to carbon and nutrient turnover. *Adv. Ecol. Res*. **38**, 20–71.
8. Blossey B. and Notzold R. 1995. Evolution of increased competitive ability in invasive nonindigenous plants: A hypothesis. *J. Ecol*. **83**, 887–889.
9. Bradley B.A., Blumenthal D.M., Wilcove D.S. and Ziska L.H. 2010. Predicting plant invasions in an era of global change. *Trends in Ecology & Evolution* **25(5)**, 310–318.
10. Callaway R.M. and Aschehoug E.T. 2000. Invasive plants versus their new and old neighbors: A mechanism for exotic invasion. *Science* **290**, 521–523.
11. Cheng W. and Coleman D.C. 1990. Effect of living roots on soil organic matter decomposition. *Soil Biol. Bioch.* **22**, 781–787.
12. Cornelissen J.H.C., Lavorel S., Garnier E., Diaz S., Buchmann N., Gurvich D.E., Reich P.B., Ter Steege H., Morgan H.D., Van Der Heijden M.G.A., Pausas J.G. and Poorter H. 2003. A handbook of protocols for standardized and easy measurement of functional traits worldwide. *Aust. J. Bot*. **51**, 335-380.
13. Crooks J.A. 2005. Lag times and exotic species: The ecology and management of biological invasions in slow-motion. *Ecoscience* **12**, 316–329.
14. Davidson E.A., Janssens I.A. and Luo Y.Q. 2006. On the variability of respiration in terrestrial ecosystems: Moving beyond Q10, (2) *Global Change Biol*. **12**, 154–164.
15. Aizen M.A. and Feinsinger P. 1994. Habitat fragmentation, native insect pollinators, and feral honey-bees in Argentine Chaco Serrano. *Ecol Applic*. **4**, 378-392.
16. Allen A.P., Brown J.H. and Gillooly J.F. 2002. Global biodiversity, biochemical kinetics, and the energetic-equivalence rule. *Science* **297**, 1545–1548.
17. Angerta A.L., Huxmanb T.E., Chessonb P. and Venableb D.L. 2009. Functional tradeoffs determine species coexistence via the storage effect. *Proc. of Nat. Acad. Sci*. **106**, 11649–11653.
18. Araújo M.B. and Luoto M. 2007. The importance of biotic interactions for modelling species distributions under climate change. *Global Ecology and Biogeography* **16(6)**, 743–753.
19. Ares A. and Fownes J.H. 1999. Water supply regulates structure, productivity and water-use-

efficiency of *Acacia koa* forest in Hawaii. *Oecologia* **121**, 458–466.

20. Ashton I.W., Hyatt L.A., Howe K.M., Gurevitch J. and Lerdau M.T. 2005. Invasive species accelerate decomposition and litter nitrogen loss in a mixed deciduous forest. *Ecol Appl*. **15**, 1263-1272.
21. Berg B. and Laskowski R. 2006. Litter decomposition: a guide to carbon and nutrient turnover. *Adv. Ecol. Res*. **38**, 20–71.
22. Blossey B. and Notzold R. 1995. Evolution of increased competitive ability in invasive nonindigenous plants: A hypothesis. *J. Ecol*. **83**, 887–889.
23. Bradley B.A., Blumenthal D.M., Wilcove D.S. and Ziska L.H. 2010. Predicting plant invasions in an era of global change. *Trends in Ecology & Evolution* **25(5)**, 310–318.
24. Callaway R.M. and Aschehoug E.T. 2000. Invasive plants versus their new and old neighbors: A mechanism for exotic invasion. *Science* **290**, 521–523.
25. Cheng W. and Coleman D.C. 1990. Effect of living roots on soil organic matter decomposition. *Soil Biol. Bioch.* **22**, 781–787.
26. Cornelissen J.H.C., Lavorel S., Garnier E., Diaz S., Buchmann N., Gurvich D.E., Reich P.B., Ter Steege H., Morgan H.D., Van Der Heijden M.G.A., Pausas J.G. and Poorter H. 2003. A handbook of protocols for standardized and easy measurement of functional traits worldwide. *Aust. J. Bot*. **51**, 335-380.
27. Crooks J.A. 2005. Lag times and exotic species: The ecology and management of biological invasions in slow-motion. *Ecoscience* **12**, 316–329.
28. Davidson E.A., Janssens I.A. and Luo Y.Q. 2006. On the variability of respiration in terrestrial ecosystems: Moving beyond Q10, (2) *Global Change Biol*. **12**, 154–164.
29. Davis M.A., Grime J.P. and Thompson K. 2000. Fluctuating resources in plant communities: a general theory of invasibility. *J. Ecol*. **88**, 528–534.
30. Duggin J.A. and Gentle C.B. 1988. Experimental evidence on the importance of disturbance intensity for invasion of *Lantana camara* L. in dry rainforest–open forest ecotones in north-eastern NSW, Australia. *Forest Ecol. and Manag*. **109**, 279-292.
31. Ehrenfeld J.G. 2003. Effects of exotic plant invasions on soil nutrient cycling processes. *Ecosystems* **6**, 503-523.
32. Finzi A.C., van Breemen N. and Canham C.D. 1998. Canopy tree-soil interactions within temperate forests: species effects on soil carbon and nitrogen. *Ecol. Appl*. **8**, 440–446.
33. Garnier E., Laurent G., Bellmann S., Debain S., Berthelier P., Ducout B., Roumet C. and Navas M.E. 2001. Consistency of species ranking based on functional leaf traits. *New Phytol*. **152**, 69-83.
34. Gentle C.B. and Duggin J.A. 1997. *Lantana camara* L. invasions in dry rainforest–open forest ecotones: the role of disturbances associated with fire and cattle grazing. *Aust. J. Ecol*. **22**, 298-306.
35. Gilbert O. and Bocock K.L. 1960. Changes in the leaf litter when placed on the surface of soils with contrasting humus types. II. Changes in the nitrogen content of oak and ash litter. *J. Soil Sci.* **11**, 10–19.
36. Grotkopp E. and Rejmánek M. 2007. High seedling relative growth rate and specific leaf area are traits of invasive species: phylogenetically independent contrasts of woody angiosperms. *Amer. J. Bot*. **94**, 526-532.
37. Grotkopp E., Rejmanek M. and Rost T.L. 2002. Toward a causal explanation of plant invasiveness: seedling growth and life-history strategies of 29 pine (Pinus) species. *Amer. Naturalist* **159**, 396-419.
38. Gurevitch J., Scheiner S.M. and Fox G.A. 2002. The ecology of plants Sinauer Associates, Inc., Sunderland, Massachusetts.
39. Hamilton M.A., Murray B.R., Cadotte M.W., Hose G.C., Baker A.C., Harris C.J. and Licari D. 2005. Life-history correlates of plant invasiveness at regional and continental scales. *Ecol. Letters* **8**, 1066-1074.
40. Hierro J.L., Maron J.L. and Callaway R.M. 2005. A biogeographical approach to plant invasions: the importance of studying exotics in their introduced and native range. *J. Ecol*. **93**, 5–15.
41. Hilje L. 1985. Insectos visitadores y efficiencia reproductiva de *Lantana camara* L. (Verbenaceae). *Brenesia* **23**, 293-300.
42. Hiremath A.J. and Sundaram B. 2005. The fire-lantana cycle hypothesis in Indian forests. *Conser. Soci*. **3**, 26-42.
43. Jha C.S. and Singh J.S. 1990. Composition and dynamics of dry tropical forest in relation to soil texture. *J. Veg. Sci*. **1**, 609-614.
44. Kamei J., Pandey H.N. and Barik S.K. 2009. Tree species distribution and its impact on soil properties, and nitrogen and phosphorus mineralization in a humid subtropical forest ecosystem of northeastern India. *Can. J. For. Res*. **39**, 36–47.
45. Kirschbaum M.U.F. 1995. The temperature dependence of soil organic matter decomposition, and the effect of global warming on soil organic C storage (6). *Soil Biol. Biochem*. **27**, 753–760.
46. Kohli R.K., Batish D.R., Singh H.P. and Dogra K.S. 2006. Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum conyzoides* L., *Lantana camara* L.) in India. *Biol. Invasion* **8**, 1501–1510.
47. Lake J.C. and Leishman M.R. 2004. Invasion success of exotic plants in natural ecosystems: the role of disturbance, plant attributes and freedom from herbivores. *Biol. Conser*. **117**, 215-226.
48. Lee C.S., Kim J.H., Yi H. and You Y.H. 2004. Seedling establishment and regeneration of Korean red pine (*Pinus densiflora* S. et Z.) forest in Korea in relation to soil moisture. *Forest Ecol. Manag.* **199**, 423–432.

49. Leishman M.R. and Thomson V.P. 2005. Experimental evidence for the effects of additional water, nutrients and physical disturbance on invasive plants in low fertility Hawkesbury Sandstone soils, Sydney, *Australia. J. Ecol*. **93**, 38-49.
50. Mack M., D'Antonio C. and Ley R. 2001. Alteration of ecosystem nitrogen dynamics by exotic plants: a case study of C4 grasses in Hawaii. *Ecol. Appl.* **11**, 1323–35.
51. Marenco R.A., Antezana-Vera S.A. and Nascimento H.C.S. 2009. Relationship between specific leaf area, leaf thickness, leaf water content and *SPAD-502* readings in six Amazonian tree species. *Photosynthetica* **47**, 184-190.
52. Marino G., Aqil M. and Shipley B. 2010. The leaf economics spectrum and the prediction of photosynthetic light–response curves. *Funct. Ecol*. **24**, 263–272.
53. Meir P., Metcalfe D.B., Costa A.C.L. and Fisher R.A. 2008. The fate of assimilated carbon during drought: Impacts on respiration in Amazon rainforests. *Philos. Trans. R. Soc. B*. **363**, 1849–1855.
54. MoEF 2006. Report of the national forest commission. Government of India, Ministry of Environment and Forests. New Delhi, India.
55. Niinemets 2010. A review of light interception in plant stands from leaf to canopy in different plant functional types and in species with varying shade tolerance. *Ecol. Res*. **4**, 693-714.
56. Niinemets Ü., Diaz-Espejo A., Flexas J., Galmes J. and Warren C.R. 2009. Role of mesophyll diffusion conductance in constraining potential photosynthetic productivity in the field. *J. Exp. Bot*. **60**, 2249-2270.
57. Pandey C.B. and Singh J.S. 1992. Rainfall and grazing effects on net primary productivity in a tropical savanna, India. *Ecology* **73**, 2007-2021.
58. Pandey S.K., Singh H. and Singh J.S. 2009. Species and site effects on leaf traits of woody vegetation in a dry tropical environment. *Current Sci*. **96**, 1109-1114.
59. Parmesan C. 2006. Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution, and Systematics* **37**, 637–669.
60. Reich P.B., Walters M.B. and Ellsworth D.S. 1992. Leaf life-span in relation to leaf, plant, and stand characteristics among diverse ecosystems. *Ecol. Monog*. **62**, 365-392.
61. Reich P.B., Walters M.B. and Ellsworth D.S. 1997. From tropics to tundra: global convergence in plant functioning. USA. *Proc. Nat. Acad. Sci*. **94**, 349-357.
62. Ricketts T.H., Daily G.C., Ehrlich P.R. and Michener C.D. 2004. Economic value of tropical forest to coffee production. *Proc. Nat. Acad. Sci*. **101**, 12579-12582.
63. Sallih Z. and Bottner P. 1988. Effect of wheat (*Triticum aestivum*) roots on mineralization rates of soil organic matter. *Biol. Fert. Soils* **7**, 67–70.
64. Sanjeeb K., Gaurav K., Loganathan K., Kokati V.B.R. 2012. A Review on Medicinal Properties of *Lantana camara* Linn. *Research J. Pharm. and Tech*. **5(6)**, 711-715.
65. Sharma G.P., Raghubanshi A.S. and Singh J.S. 2005. Lantana invasion: An overview. *Weed Biol. Manag*. **5**, 157-167.
66. Sharma O.P. 1981. "A Review of the Toxicity of Lantana camara (Linn) in Animals". doi:10.3109/15563658108990337. *Clinical Toxicology* **18 (9)**, 1077–1094.
67. Simberloff D. and Von Holle B. 1999. Positive interactions of non-indigenous species: invasional meltdown? *Biol. Invasions* **1**, 21-32.
68. Singh K.P. 1969. Studies in decomposition of leaf litter of important trees of tropical deciduous forest at Varanasi. *Trop. Ecol*. **10**, 292-311.
69. Singh V.P. and Singh J.S. 1989. Man and forests: a case study from the dry tropics of India. *Envir. Conser*. **16**, 129-136.
70. SPSS/ P.C. 1997. SPSS/PC for the IBM PC/XT/AT. Chicago, IL.
71. Strayer D.L., Eviner V.T., Jeschke J.M. and Pace M.L. 2006. Understanding the longterm effects of species invasions. *Trends Ecol. Evol*. **21**, 645–651.
72. Swarbrick J.T., Willson B.W. and Hannan-Jones M.A. 1998. *Lantana camara* L. R. G. & F. J. Richardson, Melbourne. In: The Biology of Australian Weeds (ed. by Panetta F.D., Groves R.H. and Shepherd R.C.H.). 119-136.
73. Swift M.J., Heal O.W. and Anderson J.M. 1979. Decomposition in Terrestrial Ecosystems [M]. Oxford: Blackwell. 372pp.
74. Turner N.C. 1981. Techniques and experimental approaches for the measurement of plant water status. *Plant Soil* **58**, 339-366.
75. Van der Krift T.A.J., Kuikman P.J. and Berendse F. 2002. The effect of living plants on root decomposition of four grass species. *Oikos* **96**, 36–45.
76. Vilà M. and D'Antonio C.M. 1998. Fruit choice and seed dispersal of invasive vs. Non-invasive Carpobrotus (Aizoaceae) in coastal, California. *Ecology* **79**, 1053-1060.
77. Vitousek P.M., Walker L.R., Whiteaker L.D., Mueller-Dombois D. and Matson P.A. 1987. Biological invasion by Myrica faya alters ecosystem development in Hawaii. *Science* **238**, 802-804
78. Walther G.R., Post E., Convey P., Menzel A. and Parmesan C. 2002. Ecological responses to recent climate change. *Nature* **416,** 389–395.
79. Walther G.R., Roques A., Hulme P.E., Sykes M.T. and Pysek P. 2009. Alien species in a warmer world: risks and opportunities. *Trends in Ecology and Evolution* **24(12)**, 686–693.
80. Weitere M., Vohmann A., Schulz N., Linn C. and Dietrich D. 2009. Linking environmental warming to the fitness of the invasive clam *Corbicula fluminea*. *Global Change Biology* 15, 2838–2851.

81. Wells M.J. and Stirton C.H. 1988. *Lantana camara* a poisonous declared weed. *Farm. S. Africa – Weeds* A. **27**, 1-4.
82. Wilson P.J, Thompson K. and Hodgson J.G. 1999. Specific leaf area and leaf dry matter content as alternative predictors of plant strategies. *New Phytol*. **143**, 155-162.
83. Woodward F.I. 1987. Climate and Plant Distribution. *Cambridge University Press*.
84. Yuste J.C., Baldocchi D.D., Gershenson A., Goldstein A., Misson L. and Wong S. 2007. Microbial soil respiration and its dependency on carbon inputs, soil temperature and moisture(9). *Global Change Biol*. **13**, 2018–2035.
85. Zhu Y., Siegwolf R.T.W., Durka W. and Körner C. 2010. Phylogenetically balanced evidence for structural and carbon isotope responses in plants along elevational gradients. *Oecologia* **162**, 853–863.

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Climate Change: Mathematics and Some New Techniques

Mamta Amol Wagh*
Department of Mathematics, Deen Dayal Upadhyaya College
University of Delhi, Karampura, Shivaji Marg, New Delhi – 110015
***Corresponding author:** nigam.mamta@gmail.com

Abstract: Mathematics is involved at every level of understanding climate change, including the description, prediction and communication of climate change. In the present era the knowledge of mathematics is a must for every one if we wish to save our planet earth. Mathematics education can play a very important role in understanding and even tackling climate change. In this paper, we shall be discussing the mathematics used in the models which is nothing but a collection of some mathematical equations which collectively make some sense and gives a meaningful outcome after its analysis. This outcome is the key to understand the fast changes arising in climate due to our mistakes and how we can play our role in making it a better place. We shall also give some new mathematical techniques (Quaternions, bicomplex numbers), which can be useful to solve these mathematical models and the results could be faster and easier by using them.

Key words: Climate Change, Quaternions, Bicomplex Numbers

1. INTRODUCTION

1.1 Scientific accountability under Climate Change

Climate change has become one of the most pressing issues of the 21st century. The evidence that human activity is altering our planetary ecosystem is diverse and compelling (see, in particular, IPCC, 2008). The science of climate change is often complex and technical, despite being based on some fairly basic principles (e.g. the greenhouse effect). It also involves a good deal of mathematics. There are three ways that mathematics is involved: *description, prediction* and *communication*. The *description* of climate change is mostly based on descriptive statistics. Prediction is done on the basis of analysis of any data (which can be related to rainfall, minimum temperature, maximum temperature etc.) for a fixed interval of time. Indeed without mathematics, we would have little awareness of climate change as a system-wide phenomenon. In our daily newspaper we see many graphs related to our climate, rainfall in an area, weather reports, graphs depicting flood areas, draught areas and many more. These graphs are nothing but a simple mathematics which when written in the forms of graphs gives the information which is more understandable. No rigorous mathematics is required to understand these things. A common human being who knows a little of mathematics can understand these things if we give them a proper direction to go to and this can be done if we impart this knowledge to our kids, students through their curriculum in schools and colleges. If we do not have this minimum knowledge, the information which depicts the climate changes happening in today's era is meaningless and if we cannot understand we cannot play our role in making the situation better too. So with the study of pure academic subjects it is necessary to give them some applied part so that they can at least understand the things properly and can come out of their comfort zones. These days children have a very luxurious life and they do not know what is happening in the outer world even they do not know that they are participating in the global warming by just searching a useless stuff on the internet. However, if the heat generated by each computer per hour is to be calculated and is multiplied by the number of computers per unit area and as a whole the contribution to global warming can be calculated. So it is very important that we teach our kids the value of energy that we have and do not waste it in useless things and be a part of global change in a positive sense not negative. We know that climate is a long term trend and on the other hand weather consists of daily and seasonal variations. So if we take care of our daily activities with the help of which we contribute in temperature balance, it could be really helpful in reducing global warming and making our planet earth a better place to live for ourselves. In fact we are taking only our lives to danger by doing this imbalance. Human industrialization and population growth are the factors which are responsible for it. A critical mathematics education can offer students some insight into how mathematics is part of their lives and the consequences it can have – including consequences for the Earth's climate.

1.2 Mathematics of Climate Change

We should understand the mathematics behind the climate change. Mathematical models are nothing but a collection of some mathematical equations which collectively make some sense and give a meaningful outcome after its analysis. Science is about figuring out how nature works, so that we can predict what it will do in the future. Models play a very important part in this process. The key feature of models is that they are simplified representations of the thing that they represent, designed to describe some aspects of it quite accurately, but omitting many less relevant or important details in the interests of clarity and simplicity. The idea of mathematical modelling is to keep this basic approach, i.e., we keep with us only those variables which are important and affecting our model in major and get away from those which are less relevant and could be assumed negligible. Mathematical models have nothing to do with physical representation part. In fact they describe the modeled system by some equations rather than by a physical object. They are abstract models which use mathematical language to describe the behavior of a system. Thus we all should be clear in our mind about the appearance of a mathematical model and it is totally different from a scientific model.

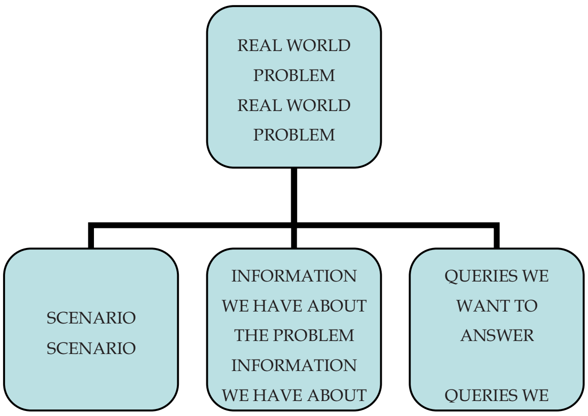

Figure 1. Structure of the Problem

In order to construct a mathematical model of a real world problem, first we observe it and formulate it into a mathematical problem. Then we find mathematical solution to this problem. This solution can be interpreted to give the solution to our real problem. We can also make mathematical program and then computer model after which simulation is done and finally conclusion. Thus mathematics with computer gives solution to real world problem. Mathematical models are usually composed of relationships and variables. Relationships can be described by operators, such as algebraic operators, functions, differential operators, etc. Variables are abstractions of system parameters of interest that can be quantified. Operators can act with or without variables. Models can be of different types like linear, nonlinear, static, dynamic, explicit, implicit, discrete, continuous, deterministic, probabilistic or stochastic etc.

It is evident that human activity is altering our planetary eco-system, we can see the IPCC, 2008 report. Scientists do research for their whole life and give results. We have to take them seriously and think what we should learn from them and improve our planet. Despite the weight of scientific evidence and consensus, not everyone is convinced or concerned. Public media often report these disagreements as an on-going scientific debate, leading to much public confusion. Politicians and policy-makers struggle to interpret the science and propose minimal measures based on their acceptability to the general population. The result is widespread uncertainty and disinterest. Politicians and policy-makers should work in the interest of our whole society and in other sense whole earth but not in their political interest. There should be a linkage among scientists and politicians so that they can make new laws in view of new results and findings in favour of our ecosystem. In other words we should response to what we are learning. No model gives the accurate predictions. So we need to take a variety of models and run them with a diverse set of parameters, so that the real range of uncertainty in the climate change be captured. It is important to understand how to develop and interpret mathematical models of climate change. As with any model, many assumptions will be made but it does not mean that the results of the model are useless and unrealistic. On the other hand, in interpreting the results of the model, one must keep in mind the assumptions that were made. Even though the model may not be perfectly accurate, it can still provide us with useful information and, perhaps, lead us to ask questions for future research. There are many assumptions that we have while making the mathematical model of any problem but when we work towards the solution of it, we gradually break down each assumption one by one, although some will remain.

"Mathematics of Climate Change", 2007 by Dana Mackenzie, a publication from MSRI *(Mathematical Science Research Institute)*, has written in its introduction that the years 2006 and 2007 are the turning points in the history of climate change – a time when climate change ceased to be seen as a "green" issue and became an "everyone" issue [Mackenzie, 2007].

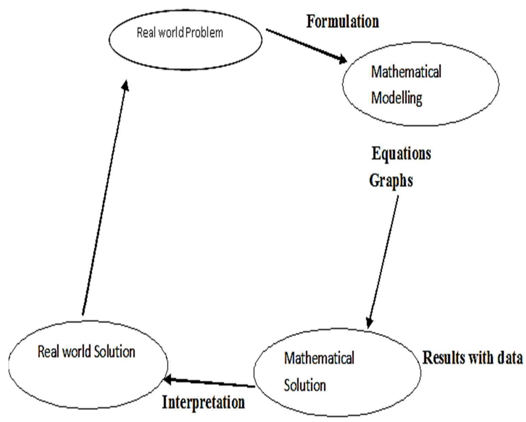

Fig. 2 Diagramatic Representation of Mathematical Model

Model

We have a number of mathematical models for climate change and most of them give their own predictions, i.e., we have a wide range of predictions. This difference is because these models prioritize the processes on the physical side of equations – particularly the processes that are not well understood, such as convective mixing in the atmosphere and ocean, and the formation of clouds, and hence represent them differently. To some extent, this divergence among models is a good thing. Most climate modelers agree that there is no such thing as a "best model", and it is useful to have a variety of models to sample the space of different possibilities. In fact when weather models are run on the time scale of months, to make seasonal predictions, an ensemble of several models performs better than any individual one. Another reason that models differ is that the climate system itself is inherently unpredictable.

2. MATHEMATICAL TECHNIQUES

Governments around the world are formulating policies and laws in response to the threat of climate change. These measures include attempts to regulate greenhouse gas emissions or changes in energy policy, as well as mitigation measures, such as the construction of new flood defences. Such responses are largely in response to the predictions of mathematical models (rather than actual observations of the climate) but have increasingly real effects. It is impossible for an individual to experience climate change on a planetary scale. Our response to climate change is, therefore, changing the structure of our society based on climate models. Mathematical models are nothing but a collection of some mathematical equations which collectively make some sense and give a meaningful outcome after its analysis. This outcome is the key to understand the fast changes arising in climate due to our mistakes and how we can play our role in making it a better place.

Year 2013 was declared a special year for the mathematics of Planet earth [MPE2013.org]. Many scientific societies, universities, research institutions, and organizations all over the world have come together to dedicate 2013 as a special year for the Mathematics of Planet Earth. They are doing research to protect our planet earth and to give us a better tomorrow.

MPE2013 enjoyed the patronage of UNESCO. It was endorsed by the International Council of Science (ICSU), the International Mathematical Union (IMU) and the International Council of Industrial and Applied Mathematics (ICIAM). The objective of MPE2013 is to identify fundamental research questions about the Planet Earth and reach out to the general public. MCRN – Mathematics and Climate Research Network is an active partner of MPE2013. Nodes of MCRN are US, UK, Netherland, Australia and India. They organised a number of activities which include long term programmes, Celestial Mechanics, Mathematics of Bio – economics, Mathematical Biology, Mathematics of Oceans, Mathematical modelling and analysis of complex fluids and active media in evolving domains, Biodiversity and evolution, Mathematics for Fluid Earth, Mathematics of Planet Earth Exhibition in India, Mathematical and Statistical Ecology and Infectious disease dynamics which is about disease modelling. A number of summer schools were also organised which includes AMSI Summer School: "Mathematical Epidemiology" and "Complex Networks", Women in Mathematics Summer School, ICTP, Mathematics behind Biological Invasions, Introduction to the Mathematics of Seismic Imaging. A number of workshops, Meetings, Special sessions, Colloquia and Seminars and Public Lectures were organised during the year 2013 by different nodal countries.

If I talk about the abstract mathematics, then it can also be seen in our environment. We know about the symmetry groups. A very few of us know about Crystallography. It is the branch of science devoted to the study of crystalline structure. It has far-reaching applications in mineralogy, chemistry, physics, mathematics, biology and materials science. A crystallographic point group is a group of symmetry operations all of which leave at least one point unmoved. Symmetry or self-similarity is the subject of numerous studies in geometry, theoretical modeling and other mathematical fields. It is also a fundamental concept in design oriented disciplines. Retired professor Steve Dutch's template, developed for studies in field of applied science, was used as the foundation of an investigation of the symmetry principle in a 2 dimensional environment [Fig. 3]. The outline of an isometric profile corresponds to three crystallographic axes of equal length and at right angles to each other. The template's outline has been transferred in a raster environment to create this visualization. Black and white shading and texture were added to give the lines a sense of weigh distance and a triadic color scheme was selected to bring the composition elements together [http://imaginary.org//gallery/the-lorenz-attractor].

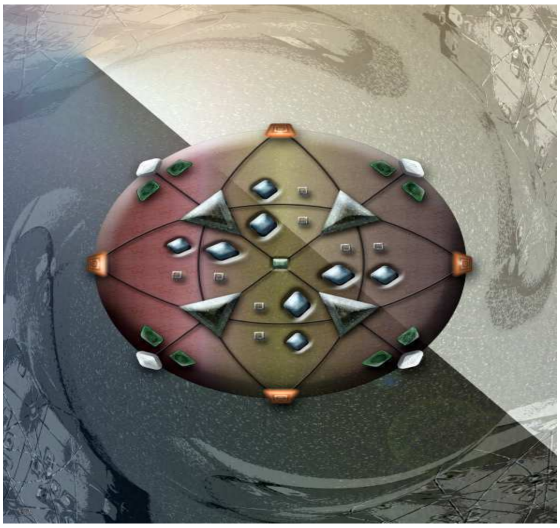

Figure 3. Symmetries in the Environment.

In 1963, Edward Lorenz (1917–2008), who was very interested by the problem of convection in the Earth's atmosphere, drastically simplified the Navier Stokes equations of fluid mechanics, well-known for their intricate complexity. Physicists use to call Lorenz' atmospheric model a toy model: although it is so oversimplified that it does not have much to do with reality anymore, Lorenz soon realized that this model was very interesting [Fig. 4]. If we consider two almost identical atmospheres (two points that are extremely close in Lorenz' model), we tend to quickly see the separation of the two evolutions in a significant way: the two atmospheres become completely different. Lorenz saw on his model the sensitive dependence on initial conditions: chaos. Moreover, what is very interesting is that, starting from a large number of virtual atmospheres, even if they follow paths that seem a little bit crazy and unpredictable, they all accumulate on the same object shaped like a butterfly, a strange attractor [http://imaginary.org/gallery/jean-constant-crystallographic-points-groups].

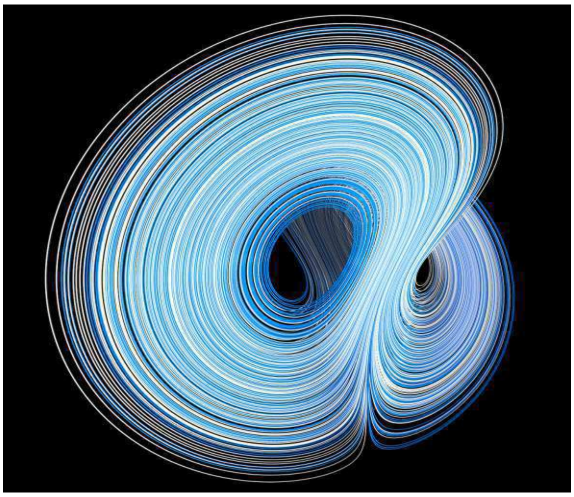

Figure 4. Lorenz' model

The key feature of models is that they are simplified representations of the thing that they represent, designed to describe some aspects of it quite accurately, but omitting many less relevant or important details in the interests of clarity and simplicity. Same applies with Mathematical models too. Mathematical Model keep with it only those variables which are important and affecting our model in major and get away from those which are less relevant and could be assumed negligible. Examples of such models are Exponential growth and decay models, Half-life, Radioactive decay etc. The main content of mathematical models representing the physical situation are the differential equations. Advanced techniques should be used in order to solve these differential equations to get the results fast and accurate so that these results can be used to improve the climate.

James Walsh and Richard McGehee [2013] have presented a dynamical systems approach to climate modelling in their paper by considering the questions posed above. Their focus is on the insight the simplest energy balance models provide into the behavior of large scale aspects of climate, such as the position and movement of glaciers. Along the way, they have also highlighted aspects of this approach appropriate for the undergraduate curriculum which is very important if we are doing research, in an area which is going to be helpful to human being in near future. Gerald North (1975) has rightly said that: Though the path to understanding global climate is obviously complicated, it is clear that mathematical modelling is the best starting point to test assumptions against geological and present day evidence.

The focus of McGehee is on the insight the simplest energy balance models provide into the behavior of large scale aspects of climate, such as the position and movement of glaciers. His models describe the basic interactions among the atmosphere, the shallow ocean, and the deep ocean, and are accessible to undergraduates. The model consists of only three differential equations and these are vastly simplified models which make predictions within the range of the predictions described in the IPCC report. Using the standard assumption that the increased temperature would be a logarithmic function of the CO_2 concentration, McGehee found that this simple model not only agrees well with the twentieth century, but falls within the range of the IPCC predictions for the twenty-first century global mean temperatures.

Modelers have been working in this direction but we need more detailed models are clearly needed. Much more sophisticated methods including the Navier-Stokes equations (a type of differential equation) have been used by Gordon Swaters, an applied mathematician and theoretical physical oceanographer at the University of Alberta, to model deep ocean flow patterns. The dynamics of deep (called "abyssal") ocean currents in the North Atlantic ocean beginning in the East Greenland and Labrador Seas have been studied by him and then determines the path they take as they flow toward the equator. In one of the symposium held at San Diego, Swaters introduced the audience to a "simple" mathematical model that describes the most important aspects of the dynamics of abyssal ocean currents. He displayed nine nonlinear PDEs with two related algebraic equations, and described these governing equations as "hopelessly simple". Swaters added, "I'm not truly modeling climate change and these equations are not a climate model, but they do get a large chunk of the large scale physics for these abyssal flows correct. In that sense what I am describing here is a process-study that is trying to determine the dominant physics that must be captured in climate models if they are to improve their representation of these flows." He likened being an applied mathematician working in this area as being "between a rock and a hard place. The numerical ocean modeler is working with large sets of complicated PDEs that appear all but hopelessly intractable to classical mathematical analysis. On the other hand, mathematical reductions that result in tractable equations often seem to be completely missing the point physically to the computational oceanographer."

Anastassiu, Prodromos and Kaklamani (2013) have proved that Bicomplex (Quaternion) algebra can be used to solve the problems of fundamental electromagnetics in such a way that the exercise of solving the problem reduces to exactly half than the previous one. In this paper, the mathematical concept of bicomplex numbers (quaternions) is introduced in electromagnetics, and is directly applied to the derivation of analytical solutions of Maxwell's equations. It is demonstrated that, with the assistance of a bi- complex vector field, a novel entity combining both the electric and the magnetic fields, the number of unknown quantities is practically reduced by half, whereas the Helmholtz equation is no longer necessary in the development of the final solution. The most important advantage of the technique is revealed in the analysis of electromagnetic propagation through inhomogeneous media, where the coefficients of the (second order) Helmholtz equation are variable, causing severe complications to the solution procedure.
We know that mainly differential equations are used to construct a mathematical model and mainly real numbers are used in these equations. But we must know that there is an advantage of using complex numbers over these real numbers as the exercise of solving the differential equations is reduced and we can take two variables at a time in place of one variable which we were taking in case of real numbers.

2.1. Complex Numbers
The origin of complex numbers was started in 17th century by **Sir Carl Fredrich Gauss** (1777 – 1855). The concept of complex numbers has had its origin in the fact that the solution of the quadratic equation $ax^2+bx+c=0$ was not meaningful for $\left(b^2-4ac\right)<0$, in the then universal set, i.e., the set of real numbers. It had an advantage over the functions of two real variables where we have to take the limit one by one but in $x+iy$, $\lim(x,y)$ tends to *(0,0)* together. In this context, **Euler** (1707 – 1783) was the first mathematician who introduced the symbol, i, for $\sqrt{-1}$ with the property, $i^2=-1$, and accordingly for a root of the equation $x^2+1=0$. He also called the symbol, i, "imaginary number". In contradiction to this, the numbers developed before the advent of the symbol i, came to be called "Real numbers". Also a symbol of the form $a+ib$ where a, b are any real numbers, is called a complex number. The complex numbers and various compositions in the set of complex numbers can be geometrically represented.
Then came quaternions which has four variables at a time and mathematical models consists of a number of variables so this was a boon in that sense but there was a disadvantage of these numbers, that they don't follow commutative law, which is very important and if we have it, solving the differential equations become easier. This disadvantage was overcome by bicomplex numbers.

2.2 Quaternions (Given by Hamilton, 1833):
Quaternion is a number of type $x_1+ix_2+jx_3+kx_4$ where x_1, x_2, x_3, x_4 are real numbers and $i^2=j^2=k^2=-1, ij=-ji=k, jk-kj=i$ and $ki=-ki=j$. Norm of $x_1+ix_2+jx_3+kx_4$ is norm of (x_1, x_2, x_3, x_4) in R^4.
Quaternion operations have extended applications in electrodynamics, general relativity and 3 – D video game programming.

$$S=\left\{\begin{array}{l}x_1+i\,x_2+j\,x_3+k\,x_4, x_i\in R, 1\le i\le 4, i^2=j^2=k^2=-1,\\ ij=-ji=k, jk=-kj=i, ki=-ik=j\end{array}\right\}$$

is the set of quaternions. Hamilton visualized that many problems in Physics, which could not be solved by 3 – D, can be solved by quaternions by taking fourth dimension as time. The entire theory of relativity can be explained using quaternions. The weak point of quaternions was that commutativity was not there. It was a big handicap; therefore quaternions were not used where commutativity is essential.

2.3 Bicomplex Numbers (Given by Corrado Segre, 1892):
In 1892, **Corrado Segre** (1860 – 1924) published a paper [Segre, 1892] in which he defined an infinite set of algebras and gave the concept of multicomplex numbers. He talked about infinite set of algebras, that is, an algebra at every stage. He defined the *n* – complex algebra. At *n* = 2 we get bicomplex algebra. The set of bicomplex numbers is denoted by C_2 and is defined as follows:

$$C_2=\{x_1+i_1\,x_2+i_2\,x_3+i_1\,i_2\,x_4 : x_1, x_2, x_3, x_4\in C_0\}$$

or equivalently $C_2=\{z_1+i_2\,z_2 : z_1, z_2\in C_1\}$

where, $i_1{}^2=i_2{}^2=-1$, $i_1 i_2=i_2 i_1$ and C_0, C_1 denote the space of real and complex numbers respectively. Thus, the handicap of quaternions was removed as here commutativity was followed. Here i_1, i_2, $i_1 i_2$ are independent. The bicomplex space C_2 has two imaginary units i_1 and i_2 and bicomplex space can be viewed as combination of two complex spaces.
Unlike conventional methods, bicomplex algebra invokes merely first order differential equations, solvable even when their coefficients vary, and hence enables the extraction of several closed form solutions, not easily derivable via standard analytical techniques.
"The influence of climate change on mathematical

research in the twenty-first century could be comparable to physics' a century ago," claimed Gerald North of the Department of Atmospheric Sciences at Texas A and M at the Joint Mathematics Meetings in San Diego in January 2008. His was the introductory talk at the second large gathering of scientists and economists with mathematicians to learn from each other about their climate change research and to recruit more mathematicians to become involved. The symposium was cosponsored by the AMS and the Society for Industrial and Applied Mathematics (SIAM). Modelers can work a lot in this direction because we use Maxwell's equations and many other partial differential equations are being used in the mathematical models, the solutions to which can be found using the above techniques and more accurate and fast results could be found.

REFERENCES

1. Anastassiu Hristos T., Kaklamani Dimitra L., 2013. Applications of Bicomplex Atlamazaglou Prodromos E., (Quaternion) Algbra to fundamental Electromagnetics, IEEE Transactions on Antennas and Propagation, 51 (8), 2130 – 2136.
2. G. North, 1975. Analytical solution to a simple climate model with diffusive heat transport, J. Atmos. Sci. 32 (1), 1301–1307;
3. http://imaginary.org/gallery/the-lorenz-attractor
4. http://imaginary.org/gallery/jean-constant-crystallographic-points-groups
5. Mackenzie D., 2007. Mathematics of Climate Change, Mathematical Science Research Institute, Barkeley, CA, 1-27.
6. Math. Ann., 40, 413-467.
7. MCRN Report for MPE2013, available at mathclimate.org
8. MPE2013.org, as visited on 25.07.2015
9. MT1007. Climate Change, A Case Study
10. Naomi Hamermesh, 2010. Mathematical Modelling of Climate Change, Examining the Diurnal Temperature Range, Maths Dept., Baryn Mawr College, ,
11. Patricia Clark Kenschaft , 2008. Climate Change: A Research Opportunity for Mathematics? , Notices of the AMS, 55, (6), 695-698.
12. R. McGehee and C. Lehman, 2012. A paleoclimate model of ice-albedo feedback forced by variations in Earth's orbit, SIAM J. Appl. Dyn. Syst. 11 (2), 684–707
13. R.McGehee and E.Widiasih, A finite dimensional version of a dynamic ice-albedo feedback model, preprint. 13.
14. Segre C., 1892. Le Rappresentazioni Reali Delle Forme complesse e Gli Enti Iperalgebrici,
15. Theory of energy-balance climate models, 1975. J. Atmos. Sci. 32 (11), 2033–2043
16. Walsh James and Richard McGehee, 2013. Modeling Climate Dynamically, The College Mathematics Journal , 44 (5), 350-363.

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Effect of Nanoparticles on Environment and Human Health

Saloni Bahri[1*], Smriti Sharma Bhatia[2] and Sushma Moitra[1]
[1]Department of Botany, Miranda House, University of Delhi, Delhi-110007
[2]Department of Chemistry, Miranda House, University of Delhi, Delhi-110007
***Corresponding Author:** saloni3bahri@gmail.com

Abstract— Nanoparticles (NPs) are increasingly being used in commercial applications and eventually will percolate into aquatic, terrestrial and atmosphere environments. The most alarming thing is that their behaviour in these environments is largely unknown. This article concerns the effect of both natural and man-made or engineered nanoparticles on weather patterns and human health all over the world. These nanoparticles can change cloud formations affecting the weather all over the world. Atmospheric nanoparticles can lead to acidic deposition and material damage. They can also reduce visibility. Few studies have focused on the effects and mechanism of uptake of nanomaterials on plants of different ecosystems. We still do not know with certainty whether nanoparticles have a promotory or inhibitory effect on plant growth. In the long run, it has great ramifications on the agriculture sector. There are studies indicating the adverse effect of nanoparticles on human health. The large surface area of NPs makes them more reactive and toxic. The inhaled nanoparticles can enter the blood stream, finally reaching to all the important parts of the body such as liver, heart, kidney, bone marrow, spleen and brain. They can cause problems such as oxidation stress, pulmonary inflammation and cardiovascular diseases. Nanotechnology has immense potential applications in science and technology. But, there are challenges associated with the use of engineered nanoparticles as not much data is available on their potential risks. The environmental and human health impact of nanoparticles can be staggering. According to the authors, there is a dire need to explore the effects of nanoparticles on human health and environment.

Keywords: Nanoparticles, Weather Pattern, Plant Growth, Human Health, Ecosystems

1. Introduction

Nanoparticles with at least one dimension between 1 and 100 nm are atomic or molecular aggregates (Ball, 2002; Roco, 2003). The activity of nanoparticles varies depending on their size or shape and their chemical composition (Brunner et al., 2006). NPs are classified as natural, incidental and engineered on the basis of their origin. The unknown nature of effects of nanoparticles on human health and environment has led to concerns for our health and safety. However, a very few studies are available regarding the toxic and environmental effects of exposure to naturally occurring NPs (NNPs) and man-made or engineered NPs (ENPs).The causal diagram developed by Smita et al. 2012 gives an overview of sources of NPs and their interactions with environmental processes that can be detrimental for environment and human health. The most important point is that NNPs can affect dust cloud formation and decrease sunlight intensity which obviously has a direct and indirect impact on human health and environment. There are several dangerous effects of exposure to NNPs and ENPs and their subsequent accumulation in biological systems such as microbiota, plants and humans (Smita et al., 2012). Engineered nanoparticles may enter the environment either during the manufacture of nanomaterials or through the use and disposal of such products containing nanoparticles, including personal care products such as cosmetics and sunscreens (Nohynek et al., 2010).

2. EFFECTS OF NPS ON THE ENVIRONMENT

Due to their ubiquitous use, the concentration of nanoparticles is growing steadily in the environment. It is believed that the rapid growth of certain types of organic vapors in the nano range scatter light back into space, resulting in a cooling effect. It is in a way, a reverse 'greenhouse effect' leading to change in Earth's weather patterns (Wang et al., 2010). Wang and his co-workers (2010) measured nanoparticles using new methods and assessed the impact of nanoparticles on atmosphere by forming new models and simulations. According to their study, the formation of nanoparticles can change cloud formations which can have serious damaging effect on changing the weather all over the world. It is actually a global problem and not restricted to one country. NPs can also be formed near petrochemical plants and other factories. Furthermore, many trees and plants can also contribute to their formation via natural processes. Though nanoparticles are very small they can have a huge impact on global weather. It can lead to negative change in the atmospheric composition locally, regionally, and also globally. Serious problems can be caused by these atmospheric aerosols such as reduced visibility, acidic deposition and cooling the planet by reflecting sunlight back to space. There may be direct emission of these atmospheric particles but majority of these are formed in the atmosphere by transformation of gaseous emissions such as sulfur oxides, nitrogen oxides, and volatile organic substances. Accumulation of NPs in the environment may alter dust cloud formation, ozone depletion, environmental hydroxyl radical concentration, or stratospheric temperature change (Smita et al. 2012, Fig 1).

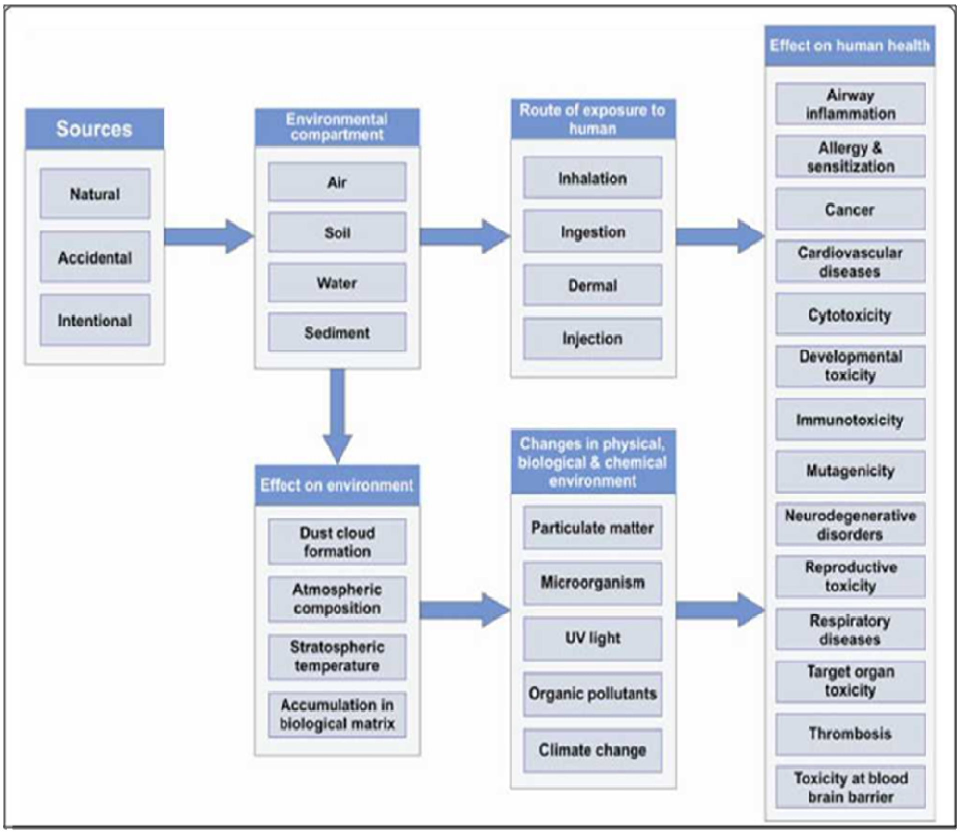

Figure 1. Proposed cause-effect diagram of NPs on environment and human health. (Smita et al., 2012, *Source: http://www.ehjoumal.net/content/11/S1/S13).*

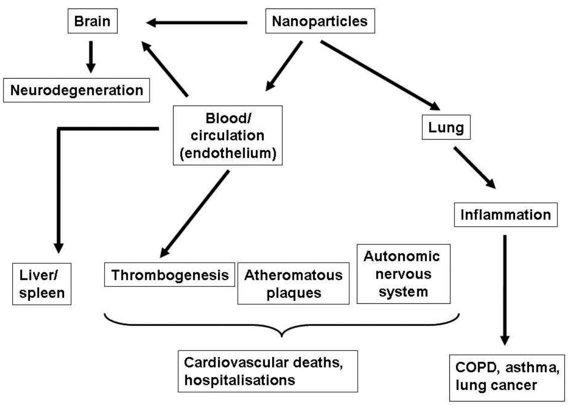

Figure 2. Systemic health effects of atmospheric nanoparticles. Adapted from Terzano et al. (2010).

3. EFFECTS OF NPS ON HUMAN HEALTH

The primary route of human exposure to NPs is inhalation. The respiratory system is most affected by the inhalation of nanoparticles. The human respiratory tract with its different organs - nose, larynx, airways, lungs act as a filter for nanoparticles. But since nanoparticles are very small they can reach the lungs very easily. The major sources of nanoparticles in urban areas are motor vehicle emissions and the combustion of fossil fuels (http://copublications.greenfacts.org/en/nanotechnologies/). Occupational exposure to nanoparticles may occur in chemical and pharmaceutical companies, research and development sector of nanotechnology, factories where cement and paints are manufactured, and during baking, welding and polymer processing where nanoparticles are by-products (http://copublications.greenfacts.org/en/nanotechnologies). Nanoparticles if ingested can travel from the gut to other parts of the body through different mechanisms. Skin exposure may occur on applying nanoparticle based pharmaceutical or cosmetic preparations. Once adsorbed through the skin, NPs may travel in the blood stream affecting other parts of the body (http://copublications.greenfacts.org/en/nanotechnologies). As a result of changed weather pattern because of release of NPs into the atmosphere, human health is negatively affected (Figure 2). People suffering from breathing problems, such as asthma, emphysema or other lung ailments, can be at risk (Wang et al., 2010). The NPs can lead to pulmonary inflammation, cardiovascular problems and oxidation stress (Buseck & Adachi, 2008; Nel et al., 2006). Some reports suggest that aluminium oxide and barium preparations are already being dumped into the atmosphere in mass quantities leading to serious health issues like Alzheimer's and cancer. A very serious consequence is the change in the pH level of soil which can become so toxic that even survival of plant life becomes impossible as aluminium and barium are toxic heavy metals. Barium is known to disrupt the immune system and aluminium (especially aluminium oxide) disrupts the nervous system (http://2020science.org/2010/09/13/).

4. CONCLUSION

Nanotechnology offers numerous potential applications in almost all the fields such as medicine, agriculture, electronics, biotechnology, materials, alternative energy sources and many other such areas. But there are many challenges arising with the use of nano-particles especially the engineered nanoparticles. One of the challenges is the effect of NPs on environment and human which is of great concern today. Not much information is available on these aspects. The need of the hour is to develop methods and models through a multidisciplinary approach to evaluate the toxicity of engineered nanomaterials and to predict their potential impact on human health and environment.

REFERENCES

1. Ball, P., 2002. Natural strategies for the molecular engineer. Nanotechnology, 13: 15-28.
2. Brunner, T. I., Wick, P., Manser, P., Spohn, P., Grass, R. N., Limbach, L. K., Bruinin, K. A., Tark, W. J., 2006. In vitro cytotoxicity of oxide nanoparticles: comparison to asbestos, silica, and effect of particle solubility. Environmental Science & Technology, 40: 4374-4381.
3. Buseck, P.R., Adachi, K., 2008. Nanogeoscience: nanoparticles in the atmosphere. Elements, 4 (6): 389-394, ISSN 1811-5209.
4. http://2020science.org/2010/09/13/could-precisely-engineered-nanoparticles-provide-a-novel-geoengineering-tool/
5. http://copublications.greenfacts.org/en/nanotechnologies
6. http://dx.doi.org/10.5772/54775
7. Nel, A., Xia, T., Madler, L. Li, N., 2006. Toxic potential of materials at the nanolevel. Science,311 (5761): 622–627, ISSN 0036-8075.
8. Nohynek, G.J., Antignac, E., Re, T., Toutain, H., 2010. Safety assessment of personal care products/cosmetics and their ingredients. Toxicol and Appl Pharmacol, 243: 239-259.
9. Roco, M. C., 2003. Broader societal issue of nanotechnology. Journal of Nanoparticle Research, 5: 181-189.
10. Smita, S., Gupta, S. K., Bartonova, A., Dusinska, M., Gutleb, A. C., Rahman, Q., 2012. Environment: assessment using the causal diagram approach Environmental Health, 11(Suppl 1):S13 doi:10.1186/1476-069X-11-S1-S1.3.
11. Terzano, C., Di Stefano, F., Conti, V., Graziani, E. & Petroianni, A., 2010. Air pollution ultrafine particles: Toxicity beyond the lung. European Review for Medical and Pharmacological Sciences, 14 (10): 809-821, ISSN 1128-3602.
12. Wang, L., Khalizov, A. F., Zheng, J., Xu, W., Ma, Y., Lal, V., Zhang, R., 2010. Atmospheric nanoparticles formed from heterogeneous reactions of organics. Nature Geoscience, DOI: 10.1038/ngeo778.

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Influence of Temperature Stress on Lipoxygenase, Oxylipin Production and Antioxidant Enzymes

Misha Yadav[1*] and Smita Tripathi[1]
Shivaji College (University of Delhi), Raja Garden, Delhi 110027, India
***Corresponding author:** *dr.mishayadav@gmail.com*

Abstract— Global climatic changes such as increased temperature, carbon dioxide and ozone can alter growth characteristics of plants. These parameters include membrane lipid peroxidation, osmotic adjustment and activity of antioxidant enzymes such as superoxide dismutase, catalase, and peroxidase. To understand the impacts produced by temperature stress and whether exposure to heat stress would lead to oxidative stress, studies have been performed in plants such as *Zea mays*, *Agrostis palustri, Phalaenopsis*, *Olea europaea. It* has been reported that heat stress affects photochemical efficiency, chlorophyll content of leaves, lipid peroxidation of membranes, malondialdehyde production and activities of antioxidant enzymes including superoxide dismutase, catalase, and peroxidase. Decrease in activity of antioxidant enzymes result in an enhanced lipid peroxidation of cell membranes. Fatty acids constituents of membranes function as modulators of a many signal transduction pathways induced by environmental stimuli. In response to specific stresses, plants produce distinct oxylipin signature. Oxylipins are synthesized upon the action of lipoxygenase on polyunsaturated fatty acids. Linoleic acid is oxidized into highly reactive compounds such as 9- or 13-hydroperoxy-octadecatrienoic acids, or a mixture of both, by lipoxygenase. Such compounds are metabolized into different secondary metabolic pathways, responsible for distinct biological functions which also include jasmonates. Oxylipin precursor of 12-oxo-phytodienoic acid has also been reported to be expressed during water stress in *Arabidopsis*, such plants exhibited reduced stomatal apertures and enhanced drought tolerance. Temperature-stress induced activities of reactive oxygen scavenging enzymes indicate that antioxidants enzymes and metabolites both may play an important role in protecting cells against the temperature-stress. Thus, an understanding of physiological and biochemical factors involved in temperature stress would help improve heat tolerance of plant species facing abiotic stress induced by climatic changes.

Keywords: Lipoxygenase, Malondialdehyde, Oxylipins, Temperature Stress

1. Introduction

Temperature stress is a major concern worldwide due to changing climate. It has prominent effects on plants. High temperature is one of the major abiotic stresses for restricting crop production as growth and metabolic processes of plants have optimum temperature limits for every plant species (Kang and Saltveit, 2002). Temperature is a critical factor for plant growth and affects photosynthetic efficiency. High temperature stress is defined as the rise in temperature beyond a critical threshold for a period of time which is sufficient to cause irreversible damage to plant growth and development. Chilling stress results from temperatures cool enough to produce injury without forming ice crystals in plant tissues, whereas freezing stress results in ice formation within plant tissues (Badea and Basu, 2009). The growth and development of plants involve multitude of biochemical reactions, all of which are sensitive to some degree to temperature. Plant responses to change in temperature vary with the extent of the temperature increase, its duration, and the plant type. The cellular changes induced by temperature stress include excess accumulation of toxic compounds, especially reactive oxygen species (ROS). The end result of ROS accumulation is oxidative stress. Plants have evolved a variety of responses to extreme temperatures which minimize damages and ensure the maintenance of cellular homeostasis. Reactive oxygen species scavenging and plant stress tolerance under temperature extremes are directly linked. The improvement of temperature stress tolerance is often related to enhanced activities of enzymes involved in antioxidant systems of plants (Almeselmani et al., 2006). Plants exposed to extreme temperatures use several non-enzymatic and enzymatic antioxidants to cope with the harmful effects of oxidative stress. Higher activities of antioxidant defense enzymes are correlated with higher stress tolerance in plants. Different plant studies have revealed that enhancing antioxidant defense confers stress tolerance to heat stress.

2. Physiological Impacts of Temperature Stress

Various types of abiotic stress faced by plants include heat, high temperature, drought, desiccation, salinity, chilling, heavy metals, ultraviolet radiations, air pollutants and intense light intensity. Among various physical stresses, temperature stress is most relevant. The physiological impacts of temperature stress include reduction in plant growth, reduction of crop productivity, reduction in quality, water loss, seed germination and emergence, alteration in dry matter partitioning, improper development, alteration in phenology, cell membrane damage, oxidative stress etc. In response to increase temperature enzymatic of various proteins is affected, there is change in rate of respiration and photosynthesis, which leads to drastic changes in growth rates.

3. Oxidative Stress

High temperature causes oxidative stress which is marked by the generation of harmful chemical entities, known as reactive oxygen species (ROS; Kang and Saltveit, 2002; Choudhary et al., 2013). These species include superoxide anion (O_2^-), hydrogen peroxide (H_2O_2), hydroxyl radical (OH^-), singlet oxygen (O_2), hydroperoxy radical, (HOO^-), nitric oxide, (NO^-), peroxynitrite, ($ONOO^-$) and other reactive nitrogen species. In cells, ROS play certain functional roles. These species act as signaling molecules to activate the defense response of plants against stress. They also activate pathogen-response and programmed cell death-response signaling in plants. During stress they accumulate and cause oxidative damage to cellular components. The main harmful effects of ROS are peroxidation of membrane lipids and pigments, modification of membrane permeability and functions, damage to cell structure, disturbance of cellular homeostasis and also cell death in extreme cases. Lipid peroxidation, protein denaturation and DNA mutation are caused when the above mentioned species of oxygen react with lipids, proteins and nucleic acid. ROS cause oxidation of sulfhydryl groups, and modification of amino acids. ROS may also damage protein by fragmentation, aggregation results in the loss of biological activity of proteins. The polyunsaturated lipid molecules of cell membranes are particularly susceptible to damaging free radicals process and it results in membrane lipid peroxidation. They also cause DNA strand breaks, fragmentation of bases and deoxyribose, which results in cytotoxicity and mutations. At high temperature conditions, the chloroplastic, mitochondrial, and plasma membrane linked electron transport systems of higher plants create more ROS. In order to avoid cellular damage, plants adopt various strategies to control ROS levels. They remove ROS through various defensive enzymatic and non-enzymatic scavenging systems. Intracellularly, organelles with high oxidizing activity or with an intense rate of electron flow can produce ROS. Such sites include chloroplast performing photosynthesis, mitochondria carrying out respiration, peroxisomes during photorespiration, membrane bound NADPH oxidase, cell wall bound peroxidase, apoplastic amine oxidase and peroxidase (Suzuki and Mittler, 2006).

4. Lipoxygenase, Lipid Peroxidation and Oxylipin Synthesis

Lipoxygenases (linoleate: oxygen oxidoreductase; EC 1.13.11.12) are a class of non-heme iron containing fatty acid dioxygenases (Yadav and Bhatla, 2011). Plant LOXs are multifunctional enzymes, catalyzing at least three different types of reactions: (i) dioxygenation of lipid substrates (dioxygenase reaction), (ii) secondary conversion of hydroperoxy lipids (hydroperoxidase reaction), (iii) formation of epoxy leukotrienes (leukotriene synthase reaction). Under physiological conditions, their most prevalent reaction involves regio- and stereospecific dioxygenation (addition of molecular oxygen) of polyunsaturated fatty acids having (Z,Z)-1,4-pentadiene system to produce fatty acid hydroperoxide (Siedow, 1991; Schneider, 2009). The hydroperoxy fatty acid products of the LOX reaction can be converted to a multitude of different compounds through the action of enzymes participating in several other pathways. This group of acyclic or cyclic compounds formed, are collectively called oxylipins (Mukhtarova et al., 2011). LOX gene expression is regulated by different factors which also include stress, such as temperature stress. Hydroperoxides formed by the action of LOXs are directed into separate biosynthetic pathways that result in the accumulation of compounds with distinct physiological functions. The 13-monohydroperoxides are precursors of biologically active compounds, such as traumatin, jasmonic acid, and methyl jasmonate, which serve hormone-like regulatory and defence-related roles in plants (Siedow, 1991). Oxylipins play role in biotic and abiotic stress responses (Savchenko et al., 2014b). The pattern of oxylipins formed also changes during stress conditions (Mukhtarova et al., 2011). Both high and low temperature stress significantly induces lipoxygenase activity and enhances membrane damage due to lipid peroxidation (Lee et al., 2005). Therefore, lipid peroxidation is a commonly utilized stress indicator of membrane damage, detected by increase in lipoxygenase activity and malondialdehyde content. Buildup of malondialdehyde at higher temperatures, indicating enhanced lipid peroxidation levels due to lipoxygenase activity has been reported in *Phalaenopsis* (Ali et al., 2005a). In *Olea europea* plants under heat stress, high lipoxygenase activity, proline and malondialdehyde accumulation has been reported (Sofo et al., 2004). Oxylipin precursor of 12-oxo-phytodienoic acid has also been reported to be expressed during water stress in *Arabidopsis*. The plants producing higher 12-oxo-phytodienoic acid exhibited reduced stomatal apertures and enhanced drought tolerance (Savchenko et al., 2014a).

5. Antioxidant Defense in Plants

Plants generate ROS during growth, but the generation of ROS significantly increases when the plant is under stressful conditions such as temperature stress, which causes severe oxidative damage to different cell organelles and biomolecules leading to physiological and biochemical symptoms of stress (Naji and Devaraj, 2011, Kotapati et al., 2014). Under such conditions, mainly two types of adaptation mechanisms are adopted by plants, avoidance mechanisms and tolerance mechanisms. To prevent damage caused by ROS plants may use avoidance mechanism that prevent the production of ROS in cells, such as changes in antenna protein structure and composition to reduce light-driven ROS production, use of CAM and C4 mechanisms to fix CO_2, movement of chloroplasts within cells so as to avoid direct light and various anatomical adaptations. Amongst the tolerance mechanisms, action of antioxidant is one of the methods employed to offset stress-induced biochemical and physiological alterations. Other tolerance mechanisms involve ion transporters, specific proteins, osmoprotectants and control at transcriptional level. Antioxidants prevent the transfer of electron from O_2 to organic molecules, stabilize free radicals and terminate free radical reactions. ROS scavenging enzymatic antioxidants include superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), guaiacol peroxidase (GPOX), glutathione reductase (GR), monodehydroascorbate reductase (MDHAR), dehydroascorbate reductase (DHAR), glutathione S-transferases (GST) and glutathione peroxidase (GPX; Ali et al., 2005b; Liu and Huang, 2000; Almeselmani et al., 2006). Superoxide dismutase catalyzes the dismutation (or partitioning) of the superoxide (O^{2-}) radical into either ordinary molecular oxygen (O_2) or hydrogen peroxide (H_2O_2). SOD out competes damaging reactions of superoxide, thus protecting the cell from superoxide toxicity. Hydrogen peroxide is also damaging, but much less, and it is degraded by other enzymes such as catalase. Catalase is a tetrameric heme containing enzyme found mainly in peroxisomes. It catalyzes the decomposition of hydrogen peroxide to less reactive water and oxygen. Hydrogen peroxide is a harmful byproduct of many normal metabolic processes; to prevent damage to cells and tissues, it is quickly converted into other, less harmful substances (Baek and Skinner, 2012). Glutathione peroxidase is a selenium-dependent cytosolic enzyme used to get rid of hydrogen peroxide (H_2O_2) and some lipid peroxide. It requires reduced glutathione (GSH) as substrate and produces oxidized glutathione (GSSG) as product. The enzymes of ascorbate peroxidase class detoxify peroxides such as hydrogen peroxide using ascorbate as a substrate. The reaction they catalyse is the transfer of electrons from ascorbate to peroxide, producing dehydroascorbate and water as products. Glutathione peroxidase reduces lipid hydroperoxides to their corresponding alcohols and to reduce free hydrogen peroxide to water. This family has peroxidase activity with main function to protect the organism from oxidative damage. Glutathione reductase catalyzes the reduction of glutathione disulfide (GSSG) to the sulfhydryl form glutathione (GSH), which is a critical molecule in resisting oxidative stress and maintaining the reducing environment of the cell. Glutathione reductase functions as dimeric disulfide oxidoreductase and utilizes an FAD prosthetic group and NADPH to reduce one mole of GSSG to two moles of GSH (He and Huang, 2010) and Mittler, 2006). ROS scavenging non-enzymatic antioxidants include ascorbic acid, glutathione, proline, alpha-tocopherols, carotenoids and flavonoids. Thus, better tolerance in plants can be accomplished by having more efficient antioxidative mechanisms (Kotapati et al., 2014).

6. Summary

Due to global warming, plants are negatively affected. Therefore, it is important to understand the mechanism of heat stress in plants to counter act the effect of global warming. The production of ROS is enhanced during stress responses including heat stress. ROS are toxic but also play a key role in various signal transduction processes important for plants. Cells contain many different molecules, pathways and mechanisms to detoxify ROS. The level of ROS is to be tightly regulated as ROS control many cellular processes. A delicate balance between ROS-scavenging and ROS-producing mechanisms is maintained in cells to achieve steady-state of ROS in cells. Reactive oxygen species scavenging and plant stress tolerance under temperature extremes are directly linked. Plants exposed to extreme temperatures use several non-enzymatic and enzymatic antioxidants to cope with the harmful effects of oxidative stress. The improvement of temperature stress tolerance is often related to enhanced activities of enzymes involved in antioxidant systems of plants. Higher activities of antioxidant defense enzymes are correlated with higher stress tolerance. Different plant studies have revealed that enhancing antioxidant defense confers stress tolerance to heat stress. The ROS scavenging enzymes for example ascorbic peroxidase, catalase, guaiacol peroxidase and superoxide dismutase are enhanced by heat stress. Normally, these oxidative enzymes control oxidative damage by processing ROS, however, cellular damage occurs when ROS production exceeds the antioxidant defense capacity. Studies have shown that tolerance to high temperature in crop plants is linked to the increase in antioxidant enzymes activity. An understanding of antioxidant mechanisms for heat stress is important for improving heat tolerance plant species. Thus, it is important to screen genotypes which are most thermotolerant so that such genotypes can be grown to get better yield.

References

1. Ali MB, Hahn E, Paek K, 2005a. Effects of light intensities on antioxidant enzymes and malondialdehyde content during short-term acclimatization on micropropagated *Phalaenopsis* plantlet. Environ. Exp. Bot. 54, 109-120.
2. Ali MB, Hahn E, Paek K, 2005b. Effects of temperature on oxidative stress defense systems, lipid peroxidation and lipoxygenase activity in *Phalaenopsis*. Plant Physiology and Biochemistry. 43: 213-223.
3. Almeselmani M, Deshmukh PS, Sairam RK, Kushwaha SR, Singh TP, 2006. Protective role of antioxidant enzymes under high temperature stress. Plant Sci. 171, 382–388
4. Badea C, and Basu SK, 2009. The effect of low temperature on metabolism of membrane expression lipids in plants and associated gene expression. Plant Omics Journal. 2, 78-84.

5. Baek K and Skinner DZ, 2012. Production of reactive oxygen species by freezing stress and the protective roles of antioxidant enzymes in plants. J. Agric. Chem. Environ. 1, 34-40
6. Choudhury S, Panda P, Sahoo L, Panda SK, 2013. Reactive oxygen species signaling in plants under abiotic stress. Plant Signal Behav. 8:4, e23681. doi: 10.4161/psb.23681.
7. He Y and Huang B, 2010. Differential responses to heat stress in activities and isozymes of four antioxidant enzymes for two cultivars of Kentucky bluegrass contrasting in heat tolerance. J. Amer. Soc. Hort. Sci. 135, 116-124.
8. Kang H and Saltveit ME, 2002. Antioxidant enzymes and DPPH-radical scavenging activity in chilled and heat-shocked rice (*Oryza sativa* l.) seedlings radicles. J. Agric. Food Chem. 50, 513-518.
9. Kotapati KV, Palaka BK, Kandukuri A, Pamuru RR, Ampasala DR, 2014. Response of antioxidative enzymes and lipoxygenase to drought stress in finger millet leaves (*Eleusine coracana* (L.) Gaertn). Int. J. Plant Animal Environ. Sci. 4, 644-653.
10. Lee SH, Ahn SJ, Im YJ, Cho K, Chung G-C, Cho B-H, Han O, 2005. Differential impact of low temperature on fatty acid unsaturation and lipoxygenase activity in figleaf gourd and cucumber roots. Biochem. Biophys. Res. Comm. 330, 1194-1198
11. Liu X and Huang B 2000. Heat Stress Injury in Relation to Membrane Lipid Peroxidation in Creeping Bentgrass. Crop Science. 40, 503-510.
12. Mukhtarova LS, Mukhitova FK, Gogolev YV, Grechkin AN. 2011. Hydroperoxide lyase cascade in pea seedlings: Non-volatile oxylipins and their age and stress dependent alterations. Phytochemistry. 72, 356-364.
13. Naji KM and Devaraj VR (2011) Antioxidant and other biochemical defense responses of *Macrotyloma uniflorum* (Lam.) Verdc. (Horse gram) induced by high temperature and salt stress. Braz. J. Plant Physiol. 23, 187-195.
14. Savchenko T, Kolla VA, Wang CQ, Nasafi Z, Hicks DR, Phadungchob B, Chehab WE, Brandizzi F, Froehlich J, Dehesh K, 2014a. Functional convergence of oxylipin and abscisic acid pathways controls stomatal closure in response to drought. Plant Physiol. 164, 1151-1160.
15. Savchenko TV, Zastrijnaja OM, Klimov VV, 2014b. Oxylipins and plant abiotic stress resistance. Biochemistry Mosc. 79, 362-75.
16. Schneider C, 2009. An update on products and mechanisms of lipid peroxidation. Mol. Nutr. Food Res. 53, 315 – 321.
17. Siedow JN, 1991. Plant lipoxygenases: Structure and function. Ann. Rev. Plant Physiol. Plant Mol. Biol. 42: 145-188
18. Sofo A, Dichio B, Xioloyannis C and Masia A, 2004. Lipoxygenase activity and proline accumulation in leaves and roots of olive trees in response to drought stress. Physiologia Plantarum. 121, 58-65.
19. Suzuki N and Mittler R, 2006. Reactive oxygen species and temperature stresses: A delicate balance between signaling and destruction. Physiologia Plantarum. 126, 45–51
20. Yadav MK and Bhatla SC, 2011. Localization of lipoxygenase activity on oil bodies and in protoplasts using a novel fluorescence imaging method. Plant Physiol. Biochem. 49, 230-234.

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Heavy Metal Speciation of Fly Ash Leachate and its Genotoxicity Assessment Using Trad-MCN Bioassay

Neelima Meravi[1] and Santosh Kumar Prajapati[1*]
[1]Department of Botany, School of Life Sciences,
Guru Ghasidas Vishwavidyalaya, C.G., 495009
***Corresponding Author:** *sntshprjpt@rediffmail.com*

Abstract— The present study was conducted for estimating the heavy metal contents of the fly ash leachate. The leachate is coming from the fly ash which are being produced in huge quantity from coal fired thermal power plants and later deposited in dykes. At the same time the genotoxicity test of the leachate was performed. The heavy metals were measured with the help of atomic absorption spectrophotometer. The *Tradescantia* micronucleus bioassay test (Trad-MCN bioassay) was used for assessing the genotoxicity of fly ash leachate. The leachate was contaminated by different heavy metals and the *Tradescantia* plants that were treated with leachate showed the formation of micronuclei. The study confirmed that fly ash can be genotoxic in nature and therefore the groundwater may be contaminated from the fly ash leachate.

Keywords: Genotoxicity, heavy metals, micronuclei, fly ash leachate

1. INTRODUCTION

Heavy metal pollution has increased in recent years due to increase numbers of mining industries, electroplating industries, thermal power plants, textile, and leather and tanning industries etc. Among these fly ashes coming from thermal power plants are important sources of heavy metals/metalloids in the environment. Huge amount of fly ash is generated in India from the coal fired thermal power plants leading to environmental pollution[1]. The fly ash contains several heavy metals/metalloids such as As, Mo, Se, Cd and Zn[2]. Presence of metals/metalloids may make the fly ash genotoxic which may have deleterious impacts on human health by the inhalation of dust originating from the power plants and through the leachates from the fly ash dykes. Environmentally released metals are mainly deposited in soils and are mobilized either by leaching or by uptake into plants[3]. Genotoxicity assessment using Trad-MCN bioassay is a promising technique for the environmental pollutants including heavy metals[4].

2. MATERIALS AND MEHODS

Fly ash and leachate were collected from the fly ash pond of NTPC, Sipat, Bilaspur, (22°07' N and 82°16' 43 E). The heavy metals/metalloids concentrations were estimated by AAS, Shimadzu7000. *Tradescantia pallida* plants were planted in plastic pots and treated with leachate of fly ash. *Tradescantia*-micronucleus (Trad-MCN) bioassay was performed using the protocols established by Ma[5].

3. RESULTS AND DISCUSSIONS

The heavy metals/metalloids concentrations of fly ash and fly ash leachate are given in table 1. The table clearly indicated the presence of various heavy metals/metalloids in varying concentration. The concentration of Fe was maximum and Cd minimum while Mo was absent in fly ash and leachate. These pollutants may reach aquatic bodies through air (fly ash) and leachate from fly ash pond. At these concentrations of heavy metals/metalloids, micronuclei (MCN) were formed in *Tradescantia pallida*. For MCN estimation early tetrads were only taken. The formation of micronuclei indicated that these heavy metals/metalloids are genotoxic in nature and have the capability of chromosomal breakage during the meiosis (figure 1). MCN are DNA-containing extracellular bodies surrounded by a plasma membrane, which are formed as a consequence of chromosomal breakage.

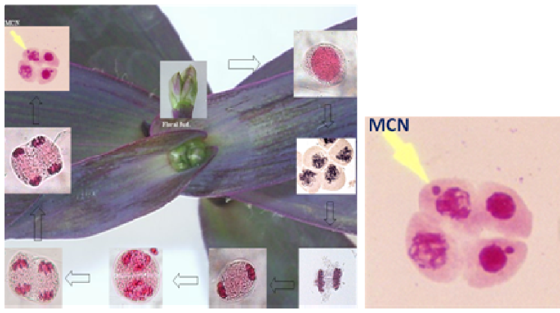

Figure 1. Micronuclei formed as a consequence of chromosomal breakage in *Tradescantia pallida* treated with fly ash leachate.

Table 1. Heavy metals/metalloids concentration of fly ash and leachate collected from fly ash pond

	Pb	Fe	Cr	Cd	Zn	Ni	V	Mo	Co	Cu	Pb	Fe
Fly ash (*µg g^{-1}* d.w. fly ash)	2.82	34.26	1.23	0.05	4.65	0.14	3.98	0	1.01	2.62	2.82	34.26
Leachate (*ppm*)	3.92	44.35	2.4	0.85	6.94	0.93	3.98	0	1.19	3.45	3.92	44.35

4. CONCLUSIONS

The present study demonstrates that fly ash is an important source of heavy metals/metalloids and the leachate coming from fly ash pond is also contributing the heavy metals/metalloids to water. The presence of heavy metals/metalloids in water is genotoxic in nature and there is serious problem associated with the leachate of fly ash pond as it contaminates the ground water and other aquatic bodies.

REFERENCES

1. el-Mogazi, D., Lisk, D. J., & Weinstein, L. H., 1988. A review of physical, chemical, and biological properties of fly ash and effects on agricultural ecosystems. The Science of the Total Environment, 74, 1–37.
2. Ma T.H., Cabrera G.L., Chen R., Gill B.S., Sandhu S.S., Vandenberg A.L., 1994. Tradescantia micronucleus bioassay. Mutation Research, 310:221–30.
3. Ma TH. Tradescantia micronucleus bioassay and pollen tube chromatid aberration test for in situ monitoring and mutagen screening. Environ Health Perspect, 1981; 37:85–90.
4. Prajapati S K. 2012. Biomonitoring and speciation of road dust for heavy metals using Calotropis procera and Delbergia sissoo. Environmental Skeptics and Critics, 1(4): 61-64.
5. TERI (Tata Energy Research Institute)., 2000. Reclaiming ash ponds and immobilizing heavy metals by means of mycorrhizal organo-biofertilizer at Korba STPS, Annual Report. New Delhi: TERI.

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Problem in ecology' or 'an ecological problem': The Role of Human/Social Sciences in Environmental Education

Rohit P.*
Department of English, Deen Dayal Upadhyaya College (University of Delhi)
Karampura, New Delhi-110015
***Corresponding author:** p.rohith@gmail.com

Abstract— In the popular imagination and in the public conception, science, which is regarded as value free, universal, and objective, and literature, deemed to be imaginative and culture specific, are considered to be irreconcilable. This belief has informed and shaped our attitude towards environment and the global ecological crisis. Introduction of environmental studies in the school and undergraduate levels throughout the country in the recent years is an attempt to initiate the young generation to this grievous issue. However, the syllabi and structure of such courses are informed by the above mentioned notion of science. This paper attempts to underscore the need for revisiting the given that the environmental crisis is a scientific issue. In doing so, this paper argues that any effort to alert the young minds against the environmental doom must be complemented both inside and beyond the classroom by literature and other human sciences.

Keywords: Environmental Education, Ecological Problems, Ecology, Human/Social Sciences

The essentialist notion that only ecologists, and by extension practitioners of natural sciences, are competent enough to impart environmental education results in it being construed as a scientific discipline. Thus, most non-scientific subjects or teachers are obviously regarded as unfit for imparting environmental knowledge. It might be true that most non-natural sciences and practitioners are not competent enough to scientifically judge problems in ecology. And so, they are dismissed from the realm of environmental education by academicians and policy makers. However, like the "cynics" referred to by Southern in his 1969 presidential address to the British Ecological Society, this paper argues that ecology is too important a subject to be left to ecologists alone (1). And this "cynical" statement is voiced time and again by a multitude of people. According to Passmore, the solution of ecological problems cannot safely be left to scientists "because the solution of ecological problems demands a moral or metaphysical revolution" (X). In the words of McIntosh (313), ecological crisis is thoroughly enmeshed in "the ecological conscience," "ecology and social institutions", and "the metaphysics of ecology".

Ecology, for the most part, is understood as defining the interdependence of organisms and the relationship between organisms and their environment. Hence, the goal of environmental education is not to deify nature or to reduce it to its several constituents such as trees, rivers, birds, animals, insects, mountains, forests and so on. The prevailing views unwittingly separate human life from nature and distances ordinary men and women from it. Environmental education should enable learners to challenge such perceptions and must create and promote in them a sense of interdependence between nature and all aspects of their lives.

Along with the need for salvaging nature from human excess, there must be awareness on socio-political causes of the environmental crisis. In fact, such an awareness should equip them to eco-socially assessing their society. Furthermore, without limiting to the purely ecological, such an education must help in linking environmental problems with social concerns generated by the so called developmental process. Such an approach is significant as it will allow them to realise that the anxiety over nature and the anxiety over society are not mutually exclusive. Instead of objectively viewing nature, this allows them to organically relate to nature. As Deming, Nelson and Sanders remark, no one is complete, safe and sane without a community which, in turn, requires the vigour and abundance of the earth to thrive.

One of the reasons for the lackadaisical response of administrators and policy makers for environmental issues is the disconnect evident between the environmental crisis and the socio-cultural realms of specific societies. The discernable absence of social and cultural elements from the environmental discipline prevents the future administrators and policy makers from appreciating the principles of environmentalism. Obviously, this must change. The cultural and livelihood aspects associated with the environmental crisis are to be valued and recognised.

While trying to understand the need for a new framework for environmental studies in the Indian context, it is important to comprehend what is termed as ecological struggles/movements in India. India, a country with pre-industrial, industrial and post-industrial economies existing side by side and with a population of over a billion and limited resources, has witnessed many ecological struggles due to conflicting interests and the dominant group's exploitative enterprises. The *Chipko* Movement in Utter Pradesh resisted massive deforestation and its bad effects on the rural community that had forest at the centre of its economy and culture. At Balliapal in Orissa, locals agitated against a proposed missile base that would have destroyed fertile cultivable land and got the project abandoned. In Madhya Pradesh, Gujarat and Maharashtra, tribes people opposed the construction of the Sardar Sarovar Dam on the river Narmada as thousands of them would go homeless once the dams are constructed, as the locality they are living in would be under water. At Mavoor in Kerala, people resisted the pollution of air and the waters of the river Chaliyar by the wastes from a rayon mill. In Orissa, members of the Dongria Kondh tribe campaigned against the mining of bauxite-rich Niyamgiri hills by Vedanta Resources, which would have destroyed their livelihood, identity, culture and Gods. Such agitations have been of importance in terms of the gravity of the struggles and their repercussion on the socio-political situation of the state/country. These were mass movements, wherein illiterate and poor tribes people or village communities were fighting for their habitats, livelihood, health and social justice, to which intellectual support was extended by social activists later. The sole catchword used by those who wanted to implement these projects was "employment for thousands" and a life that would evolve structuring itself around the project and the benefits the locals can have from it. The rhetoric almost always employed development and ecology as binaries. But due to the harm the proposed projects did to the respective communities, they stood up against it and fought it.

It is obvious from this that conservation of nature is not just an ecological project. Quite often, such efforts are due to socio-cultural and economic factors. If on the other hand, the rhetoric of conservation—the preservation of rainforests for their ecological significance, the protection of biodiversity, the maintenance of conducive natural habitat for various species and the protection of endangered species—even at the cost of economic and industrial development is insisted, a large portion of the public could be distanced from the conservation campaign. Along with this, a majority of the population considers the projected deleterious effect of economic/developmental activities like the clearing of forests on the climatic stability as well as the seismological and hydrological effects of such projects insignificant. The truth is that in relation to the real needs and raised expectations, these pressing, though not concrete environmental concerns failed to capture the public interest.

In such socio-political givens, it is imperative that any endeavour to convince the students regarding conservation cannot just be scientific and technological. Instead of simply focussing on the principles of scientific ecology, the cultural, socio-economic and experiential aspects of nature must be emphasised. Environmental education must strive to stress the idea that humans have both practical and moral obligations to care for the nature. The environmental curriculum will inculcate a benign attitude towards nature that is characterised by stewardship, restraint and ethics. Such a course will foreground the interdependence among various species and between species and their environment. Despite being repetitious of already known scientific/ecological facts, the focus must be on creatively reinforcing such well-established ideas.

One of the ways in which this can be realised is to link ecological wisdom to traditional religious practices. Sacred groves, conservation oriented religious and cultural institution in various parts of the nation, for instance, can be used. Most often, such institutions are projected as a proof of India's primitive ecological wisdom. Besides the emphasis on sacred groves, the rural existence may also be extol and idealise. The ecological benignity of traditional, pre-modern cultures can be used to counter the dissipative lifestyle that squanders natural resources. This idealization, instead of glorifying and eulogising a socially decadent past and calling for its reinstallation, must suggest the possibility of alternative systems of life. This must urge the learner to juxtapose the "ecologically benign, "socially just" past over the ecologically and socially decadent present.

The objective of pointing towards the ecologically benign aspects of our traditions is to foreground the unprecedented and alarming rate in which nature is stripped leading to the possibility of a bleak future. Such a political perspective will make these efforts non-reactionary and non-nostalgic. The awareness that the fight for clean land, water and atmosphere and for preservation of forests and sacred groves is deeply entangled in the intricate web of cultural, spiritual and socio-political dimensions has to be reiterated. This will enable students realise how nature is variously perceived. While some perceive rivers, waterfalls and forests as resources waiting to be utilised, harnessed and exploited, others regard them as wells of aesthetic and ecologic abundance. The attempt should be to foreground and counter the prevailing tendency to regard things as mere resources on call for our use when required.

The existing belief among governments and trans-national corporations that those who "desire the health of nature" are at heart similar to deep ecologists who prefer limiting, or doing away with, human activities and human beings" (Kroeber 311) is to be challenged. The multilayered relations between humans and their non-human, non-living compatriots is to be unravel. The concern must predominantly be the nature that environs us. Or to take the phraseology of Bonnie Costello, our concern should be "nature in our midst, not just a remote or lost nature" (573). This is quite important as the middle class, as Salleh observes […], can "coexist quite comfortably with capitalist despoliation of the world, because it can afford to eat organically grown food and buy houses in unpolluted places […], since much of their fortune comes from investment in the environmental crimes of a multinational mining industry (5). Consequently, schools and universities must strive to bring about radical changes in the cultural and social life of their students. This will eventually induce them to change their perception of environment. The challenge here is the effectiveness with which the course material and the class room as well as field activities can convince learners that the existing affluence-seeking attitude is detrimental in the long run for both humans and their environment.

Once these objectives are understood, we can devise strategies to reinforce and sustain ecological consciousness among the students. One way of doing this is to historicise environmental struggles through creative as well as scientific literatures, so that a universal character is imparted to such concerns. This may be achieved by means of referring or linking contemporary local/regional issues to other environmental movements in India and the rest of the world. This could be achieved either through diachronic or through synchronic juxtaposition. Diachronically, environmental concerns may be exposed best by introducing learners to communities such as the Bishnois of Rajasthan and the American Indians. Even religious/mythical texts are of much use here. Synchronically, contemporary environmental issues like the pollution of rivers such as the Thames, the Ganges, the Rhine, the Chaliyar; industrial and nuclear accidents at Bhopal, Three Mile Island; siltation in the Aswan and in other dams and natural calamities like the Uttarakhand floods can be discussed with a view to disclose the spatial pervasiveness of anthropogenic interferences.

The contribution of human and social sciences to the environmental discourse assumes significance as mitigation of environmental problems mostly require political and policy level actions from the concerned government. Anyone can (though with a certain degree of observation) sketch the seriousness of the present crisis or can blame the government for not doing enough. In a democracy like ours, government heavily depends on people's mandate. Hence, in the absence of real popular yearning, governments are very much likely to carry on with the misguided developmental agenda. Thus the responsibility of creating awareness among the public is crucial and the now compulsory environmental science course should strive to bring about the required change in the popular perception of progress. The public is much less likely to accept this unless the esoteric aspect of the ecological discourse is abandoned.

This can be achieved only through incorporating environmental awareness creation into disciplines like Literature, Philosophy, History, Geography, Economics, and other human and social sciences. As described above, various aspects of environmental crisis and the various responses to it have to be reiterated through unpinning environmental education from environmental studies. Creation of environmental awareness and sensibility is a continuous process and a semester/paper of environmental studies packed with statistics, acts, enumeration of threats certainly will not lead us towards an environmental friendly society. The need of the hour is a sustained effort to create awareness and spread sensibility through continuous and subtle reinforcement. Such reiterations through various disciplines and perspectives will undoubtedly facilitate the swelling of eco-consciousness among students.

This literary and social action for evolving a sensible approach towards nature and human progress, based on the principles of ecology, ecophysiology, ekistics and bioethics, should be the first meaningful step toward modern coconsciousness. The linking of ecological concerns to socio-economic, political and cultural issues is extremely important as only such an approach can effectively subvert the prevailing dichotomies of nature - culture, nature - society, human - non-human, development - environment, progress - conservation and so on. The subversion of these binaries is significant as the aspects of nature that we strive to protect and preserve are not external — the exotic nature or the wilderness out there, rather these are the different facets of nature that we imperceptibly find ourselves in as we go on with our ordinary lives. The focus should be to see the threat to our immediate surrounding as a symbol of human societies' insensitivity to the environment. In other words, the thrust of environmental awareness is to drive home the idea that the nature which is to be protected and preserved is an integral part of all societies. Moreover, the artistic/social intervention should strive to equip the learners to counter the notion that nature is extraneous to humanity. Trees, for example, are not just natural elements, but most often spirits and life-preservers.

Nature is not merely a void, culturally insignificant space where the modern, urban, industrial and capitalistic societies could enact their economic/industrial games. What I mean is that nature, even in its so called pristine state, is not free from human interests. All through the environmental discourse, forest is often cited as an abstract category without any geographical specificities or regional moorings. Forests, in particular, are extolled for their wildness, biological richness and diversity and for their other ecological functions. These perceptions of nature—as an ecologically significant biome or as an economically valuable resource—could be extremely detrimental. What is usually ignored when such perceptions are evoked is the fact that forests, besides being resource or biome, are culturally significant.

The literary and social sciences' involvement in environmental education must be understood in the backdrop of the distinction proposed by Passmore between a 'problem in ecology' and an 'ecological problem'. According to his formulation a problem in ecology signifies the failure of scientists to comprehend certain ecological phenomena, which have to be solved through tests and ecological experiments. An ecological problem, he maintains, is a special type of social problem arising out of our transactions with nature. "It is problematic not because we fail to understand how it comes about, rather because we think we would be better off without it" (43). The former is purely scientific, while the latter is socio-cultural. Unlike a problem in ecology that has to be explained scientifically, an ecological problem has to be solved politically and legally. Media and popular culture too play an important role in turning a scientific problem in ecology into an ecological problem. I have attempted to draw a clear picture of the manner in which the environmental education can be used to transform the bickering over the ecological crisis into a socio-cultural and public concern by linking the destruction of ecosystems to various socio-economic, political, human rights and developmental issues.

The distinction between a problem in ecology and an ecological problem that I discussed above is also a question of attitudes and approaches. Though we know that such distinctions overlap, from its very scientific nature, a problem in ecology is chiefly a concern of the specialists. As long as the human transformation of natural environment remains an esoteric issue, the need for self-regulation will evade most human beings. In other words, ecological awareness among the specialists alone does not constitute environmentalism or environmental activism. Only a transformation of this awareness into a popular socio-cultural concern can realise the move towards environmentalism. The need for creating public awareness through sharing esoteric information and sustaining informed debates is, therefore, crucial for transforming a potential problem in ecology into an ecological problem that demands, more than scientific measures, and political, social as well as cultural solutions.

REFERENCES

1. Costello, Bonnie. 1998. "What to Make of a Diminished Thing: Modern Nature and Poetic Response." *american literary history* 10: 569-605.
2. Deming, Alison Hawthorne; Richard Nelson and Scott Russell Sanders.1995. "A Call to Action." *Orion* Autumn :http://arts.envirolink.org/arts_and_activism/ACallToAction.html>
3. Kroeber, Karl.1997. "Ecology and American Literature: Thoreau and UnThoreau." *American Literary History* 9 : 309-328.
4. McIntosh, Robert P.1985. *The Background of Ecology: Concept and Theory*. Cambridge Studies in Ecology. Cambridge: Cambridge, UK.
5. Passmore, John. 1974. *Man's Responsibility for Nature*. London: Duckworth.
6. Salleh, Ariel.1997. *Ecofeminism as Politics: Nature, Marx and the Postmodern*. London and New York: Zed Books.
7. Southern, H. N.1970. "Ecology at the Crossroads." *Journal of Ecology* 58: 1-11.