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CLIMATE SMART GOVERNANCE

An initiative to conduct three capacity building programs annually, targeting different sectors and stakeholders, sensitizing them on different aspects of climate smart governance

Annual Project Report 2017-2018

Sponsored By

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Prof. Vinod K. Sharma Dr. Shyamli Singh Dr. Anshu Sharma

EXECUTIVE SUMMARY

IIPA in collaboration with SEEDS Technical Services is implementing a project "Climate Smart Governance" sponsored by Department of Science and Technology, Govt. of India. The National Action Plan on Climate Change (NAPCC) has launched eight National Mission that are: National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable habitat, National Water Mission, National Mission for Sustaining the Himalayan Eco-system, National Mission for a Green India, National Mission for Sustainable Agriculture, National Mission on Strategic Knowledge for Climate Change. DST, Ministry of Science and Technology has been assigned with the responsibility of coordinating two of the above mentioned eight national missions. This project on capacity building was designed to facilitate the Climate Change Mission of DST to meet its objective.

The main objective of the project is to target selected stakeholders and to sensitize them on Climate Change issues, adaptation needs and options. The annual report entails details of the activities that was undertaken by IIPA and STS in order to achieve the project objectives and outcomes in first year of project implementation (2017-18).

The report provides a roadmap for successful completion of the project for the first year. Project duration is for three years, it is scheduled to conduct three capacity building programs each year targeting different groups such as academia, scientists, policy makers, legislators, middle level officers, senior level administrators. Customized training modules were developed dwelling upon different sectors viz. Water resources, Agriculture, Human health, Socio-economic vulnerability and livelihood, Disaster risk reduction and management.

The annual report has been chaptered as Background, Objectives, Project Execution and Deliverables. Background describes the Climate change issues and need for capacity building. The project objectives are to conduct capacity building programs, understand Climate Change, its impacts and adaptation needs and options and also to engage sectoral stakeholders. Project execution briefly explains project design, framework development and training phase. Deliverables includes three training programmes, pedagogy used such as videos, multiple choice quizzes, animations, pictures, brainstorming sessions, case studies, lectures, papers, discussion papers and the like.

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ABBREVIATIONS

CBP	Capacity Building Programme
CC	Climate Change
CoP	Conference of the Parties
CSG	Climate Smart Governance
DST	Department of Science and Technology
DRR	Disaster Risk Reduction
FDP	Faculty Development Programme
GHG	Green House Gasses
IIPA	Indian Institute of Public Administration
IPCC	Intergovernmental Panel on Climate Change
MHA	Ministry of Home Affairs
MoEF & CC	Ministry of Environment, Forest and Climate Change
MoWR	Ministry of Water Resources
NAPCC	National Action Plan on Climate Change
NDMA	National Disaster Management Authority
NMSHE	National Mission for Sustaining Himalayan Ecosystem
NMSKCC	National Mission on Strategic Knowledge for Climate Change
STS	SEEDS Technical Services
ToT	Training of Trainers
UNFCCC	United Nations Framework Convention on Climate Change

1. PROJECT LEAD

INDIAN INSTITUTE OF PUBLIC ADMINISTRATION was established by Pandit Jawaharlal Nehru on March 29, 1954. As the Institute's first President for a decade, Prime Minister Nehru placed great emphasis on 'de-colonialising' the mind- set of administration, making it more people-oriented and he placed a great responsibility on IIPA to enhance the frontiers of knowledge in public policy and governance through applied research and education as well as training of administrators to serve the people of India. Enhancing leadership and managerial qualities on one hand and developing a service- orientation on the other. The thrust areas of the Institute are education and training activities. Its faculty is involved with research work mainly to simplify procedures and suggest policy changes to ensure improved delivery of public services. The Institute nurtures close academic association with universities, research centers, training institutions and government departments. Another important sponsorship is the series of managerial skill-development engagements for senior scientists supported by the Department of Science and Technology. Customized programs for industry, especially in areas of their interface with Government at all levels and activating knowledge centers in Ministries and State Governments are some of the new initiatives.

IIPA houses a full-fledged Centre for Environment, Climate Change and Drought Administration and has the proficiency to conduct capacity building programs related to Climate Change and other environmental issues. IIPA connects with a range of clientele of different ministries including MoWR River Development & Ganga Rejuvenation, MHA, MoEF& CC, DST, and NDMA besides World Bank, UN, UNICEF and other international agencies. The institution has a fully active DST wing which conducts training programmes

sponsored by DST throughout the year. The major activities of the Institute are: training, research, advisory and consultancy services, information dissemination and exchange.

2. PROJECT PARTNER

SEEDS TECHNICAL SERVICES is a professional organization that seeks to protect the lives and livelihoods of people exposed to natural disasters and living in disaster prone areas by providing technical services to government, non-profit organizations, corporate agencies and communities. STS provides research, planning and training services in the fields of disaster management, climate change, urban planning and architecture. STS is a social business; a consulting firm that works with communities. Over the years, STS has worked with governments, private firms, multinational donors and national civil society organizations. Its portfolio consists of projects ranging from planning to actual implementation. It is an affiliate of the non-profit organization SEEDS that primarily engages in shelter reconstruction and adopts locally based approaches to reduce the impact of future disasters on communities at risk.

SEEDS Technical Services with its small team of committed individuals has reached out to families affected by earthquakes, floods and cyclones; restored schools and homes; and has invariably put its faith in education to build long term resilience. It continues to advocate for and involve with communities across Asia to ensure a safer and sustainable world.

3. PROJECT OBJECTIVES

The objective of this project is to conduct human- capacity building programs for climate change. This project is very timely, catering to a large number of stakeholders ranging from teachers, professionals, scientists, middle level officers, policy makers, senior level administrators and legislators. The distinct, innovative and unique component of the project includes the design of training modules incorporating innovations and uniqueness so as to generate intuitiveness in the process. The other pedagogical tools are movies, multiple choice quizzes, animations, enlargements and pop-ups within, pictures and maps. Different groups have been targeted and sensitized on different aspects of climate smart governance.

Broad themes covered under capacity building programs are Climate Change Science, Climate Change Adaptations and Climate Change Mitigations. The training modules cover science and history of Climate Change, sectoral impacts of climate change, International, National and state action plans, Climate Change Adaptation with reference to Indian context and mitigation. The major sectors selected are water resources, agriculture, human health, social-economic vulnerability and livelihood, extreme events, disaster risk reduction and management. The other theme is climate change mitigation entailing renewable energy options, energy efficiency, and sustainable habitat.

KEY OBJECTIVES:

- Understand the basic science behind climate change
- Comprehend the sectoral climate change affects
- Explain the projections of climate change and its links
- Develop and carry out sectoral impacts, vulnerability and adaptive capacity assessment in relation to climate change
- Translate results of the assessment into adaptation needs and options
- Develop adaptation strategy and national/sub-national health action plans
- Engage stakeholders and other sectors
- Recognize, promote and integrate co-benefits of mitigation measures in other sectors

BROAD SECTIONS

- Climate change Science
- Climate Change Adaptation
- Climate Change Mitigation

BRIEF DESCRIPTION

Climate change refers to the rise in average surface temperature of earth. Major cause of climate change is greenhouse gas emissions. Temperature rise will results in rise in sea level, flooding, affecting ecosystems, leading to extreme weather events. Due to its severe and long lasting effects climate change is a serious issue of concern. The Paris Agreement elevated the importance of capacity building for climate change action. The agreement creates an opportunity to foster enhanced, strategic and sustained approaches supporting transformational change and enabling all Parties and stakeholders to build the capacities needed to mitigate and adapt to climate change – indeed, the Paris Agreement's premise is the participation of all, and capacity building is a fundamental precondition for this goal.

The project mainly emphasizes on human capacity building by conducting capacity building programs. **Capacity building** is the process by which individual and organizations obtain, improve, and retain the skills and knowledge needed to do their jobs competently and also helps in decision making. The major objective of these programs is to make better understanding of climate change issue and its mitigation and adaptation which will be helpful in informed decision making. Broad theme for these programs is climate change adaptation and mitigation.

Climate change adaptation is a response to global warming and climate change, that seeks to reduce the vulnerability of social and biological systems to relatively sudden change and thus offset the effects of global warming. It is a process through which societies increase their ability to cope with extreme climatic conditions by taking appropriate measures to reduce the impacts of Climate Change[1]. There is a need to address the need of adaptation and related issues.

[1] UNFCCC. 2007. Climate Change: Impacts, Vulnerabilities and Adaptations in Developing Countries. UNFCCC. 2009. Least Developed Countries under the UNFCCC.

The International Panel on Climate Change (IPCC)[2] defines mitigation as: "An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases." In the present situation where Climate Change impacts are already being experienced in the form of extreme weather conditions we are having a proactive approach of mitigation measure and also measure to live with the consequences of global warming by adaptation. Adaptation and Mitigation are two faces of same coin and combined set of actions to reduce the causes and impacts of Climate Change. Climate change Mitigation includes:

- Energy efficiency
- Renewable energy
- Sustainable habitat
- Reduction of GHGs emissions
- Green jobs

[2] IPCC, 2007: 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.

4. PROJECT BACKGROUND

The Climate is a complex and interactive system consisting of the atmosphere, lithosphere, hydrosphere and living things. Climate patterns play an important role in shaping natural ecosystems and human economies. But the Climate is rapidly changing with disruptive impacts on ecological balance. Climate Change is a global issue and serious threat to sustainable development. The main reason behind it is rise in level of carbon dioxide and other greenhouse gases causing wide- ranging impacts, including rising sea level, melting snow/ice, more extreme heat events, fires and drought, extreme storms, rainfall and floods. Scientists have projected that these trends will continue, posing significant risks to human health, forests, agriculture, water sources, coastlines and other natural resources that are vital to the economy, environment and our quality of life.

IPCC defines Climate Change as *"a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity".* India's geographic location and low adaptive capacity makes it vulnerable to the effects of Climate Change. Variation in temperature and rainfall are likely to increase with Climate Change and will have a major impact on water resources, agriculture, human health, social- economic vulnerability and livelihoods etc. The Intergovernmental Panel on Climate Change (IPCC) state that climate change has become unavoidable. The third IPCC assessment report 2001 recommended that new strategies should be taken into consideration to respond to the threat of climate change. Science, therefore, has an indispensable role to play in efforts to understand and manage the complete implications of climate change. Climate change also presents many opportunities for India and could serve as a catalyst to build more efficient, low-carbon economies to guarantee future development. To realize this goal, there is an imperative need to develop innovative policies for climate change. Therefore, science, technology and innovation policy for climate change is required to build capacity to respond effectively to the numerous threats and opportunities of climate change.

Commitments of the Developed vs. Developing Countries

The United Nations Framework Convention on Climate Change aimed at achieving stabilization of greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. 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 and to enable economic development to proceed in a sustainable manner.[3] As a first step, the Convention called upon the developed countries to restrict their greenhouse gas emissions. In 1997, Kyoto Protocol was adopted to strengthen the commitment of the developed countries towards reduction of carbon emissions. The Convention recognizes that the developed countries has the largest share in historical and current status of GHGs emissions, Also the developed countries has the greater capacity than the developing countries to meet the costs of the global response to climate change challenge. This has to be taken into consideration that economic and social development and poverty eradication are the first and overriding priorities of the developing countries.

Climate Change and the world's poor

Vulnerability to climate change has a strong linkage with poverty. Across developing countries, millions of the people are living below poverty line and due to severe climatic effects (such as droughts, storms and floods) they are enable to built a better life for themselves and their children.

Today, it is the poor who are bearing the brunt of global warming and climate change. Tomorrow, it will be humanity as a whole. Climate change will results in transforming human settlement patterns and undermining the viability of national economies. The world's poor walk the Earth with a light carbon footprint, but the vulnerabilities due to climate change are being found majorly in rural communities.

[3] Article 2, United Nations Framework Convention on Climate Change

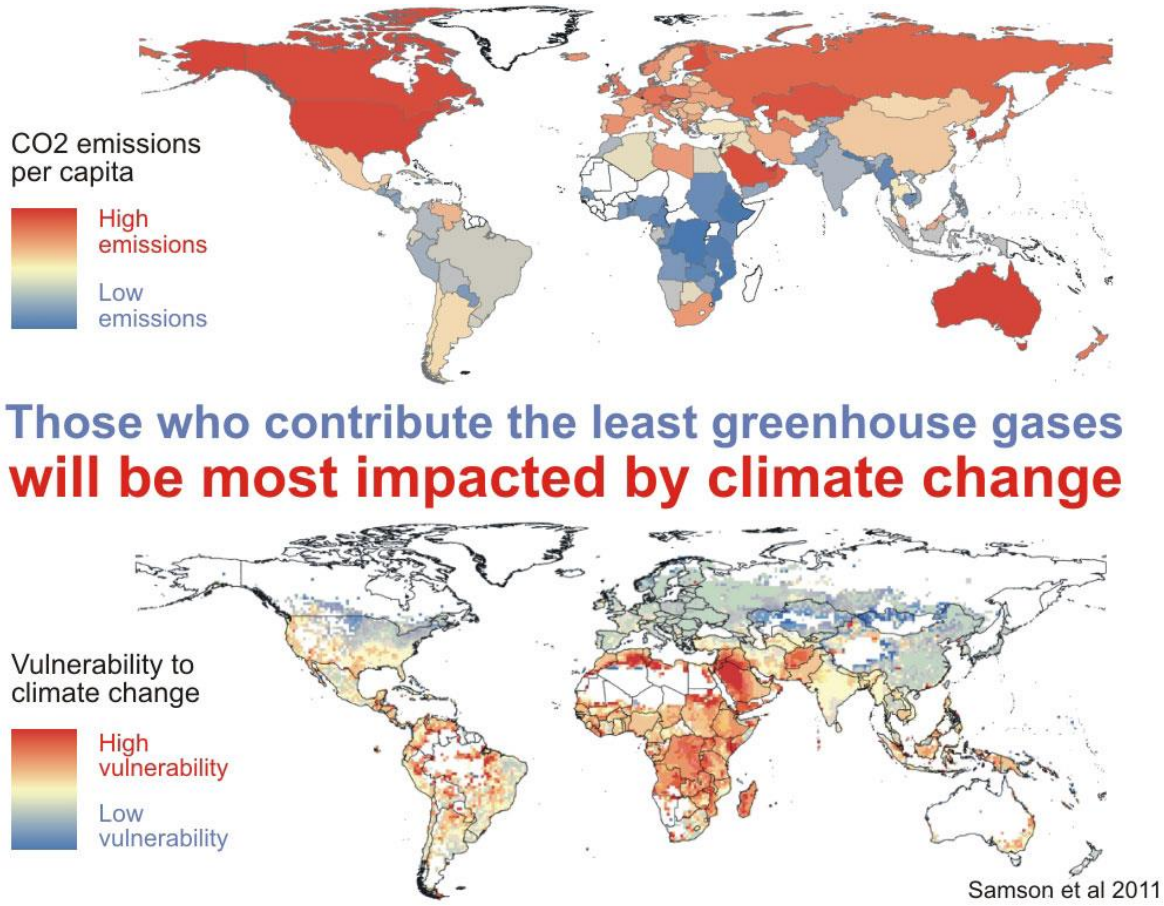


Figure 1: Vulnerable Countries
(Source:https://www.skepticalscience.com/graphics.php?g=15)

INDIAN SCENARIO

Climate change is "a change which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods"[4].

Climate of India is highly diverse, ranging from subfreezing Himalayan winters to the tropical climate of south. The states of Assam and west Bengal experience extremely rainy and humid conditions, while the regions of Rajasthan and Gujarat make up part of the Desert. About 12% (40 million hectares) of India is flood prone; while 16% (51 million hectares) is drought prone[5]. Environmental challenges in India have been sharper in the past two decades. A 4° C rise in global temperature will result in extreme climatic events such as heat waves,

[4] Article 1, United Nations Framework Convention on Climate Change.
[5] Cwc, 2011. Retrived from **http://environment.yale.edu/climate-communication-OFF/files/Climate-Change-Indian-Mind.pdf**

sea level rise, more storm surges, droughts and flooding in the South Asian region including India. Major vulnerable areas of India are coastal and deltaic regions which poses a risk of flooding including two Indian cities of Mumbai and Kolkata. Due to melting of glaciers and loss of snow cover, the Ganges, Indus and Brahmaputra are at significant risk of flooding[6].

In both its greenhouse gas emissions and its vulnerability to climate change, India is one of the major significant countries in the world. Climate change is impacting the natural ecosystems and is expected to have substantial adverse effects in India, mainly on agriculture on which 58% of the population still depends for livelihood, water storage in the Himalayan glaciers which are the source of the major rivers and groundwater recharge, sea-level rise, and threats to a long coastline and habitations. Climate change will also cause increased frequency of extreme events such as floods, and droughts. These in turn will impact India's food security problems and water security[7]. Major cause behind climate change is increasing Greenhouse gases emissions. Per capita CO_2 emission is directly proportional to a country's economic development and standard of living.

Global climate projections, given inherent uncertainties, indicate several changes in India's future climate:

- Global observations of melting glaciers suggest that climate change is well under way in the region, with glaciers receding at an average rate of 10–15 meters per year.
- If the rate of glacial melt increases, flooding is likely in the river valleys fed by these glaciers, followed by a diminished flow, resulting in a scarcity of water for drinking and agricultural irrigation.
- All models show a trend of general warming in mean annual temperature as well as decreased range of diurnal temperature and enhanced precipitation over the Indian subcontinent.
- A warming of 0.5°C is likely over all India by the year 2030 (approximately equal to the warming over the 20th century) and a warming of 2-4°C by the end of this century, with the maximum increase over northern India.
- Increased precipitation is likely to come in the form of fewer rainy days but more days of extreme rainfall events, with increasing amounts of rain in each event, leading

[6] World Bank report. June 2013. Turn Down the Heat: Climate extremes, Regional Impacts and the case of Resilience.
[7] Ministry of Finance, Economic survey. 2012-13, pp.256-57. Govt. of India

to significant flooding. Fine precipitation (drizzle-type) that replenishes soil moisture is likely to decrease.

- Increased warming is likely to lead to higher levels of tropospheric ozone pollution and other air pollution in India's major cities.
- Most global models suggest that the Indian summer monsoons will intensify with a warming climate. The timing may also shift, causing a drying during the late summer growing season.
- Climate models also predict an earlier snowmelt, which could have significant adverse effects on agricultural production, both irrigated and non-irrigated.
- Growing emissions of aerosols from energy production and other sources may suppress rainfall, leading to drier conditions with more dust and smoke from the burning of drier vegetation, affecting both regional and global hydrological cycles and agricultural production.

For the allied processes of mitigation, adaptation and development in the face of Climate Change, India needs a continuous coordination process to:

- Create a broad, knowledgeable, well-resourced and connected scientific community
- Develop a new innovation policy for Climate Change especially for low carbon technologies
- Ensure access to up-to- date technological resources, tailored to needs
- Generate a community of stakeholders capable of managing climate risks
- Create public awareness and interest in Climate Change issues.

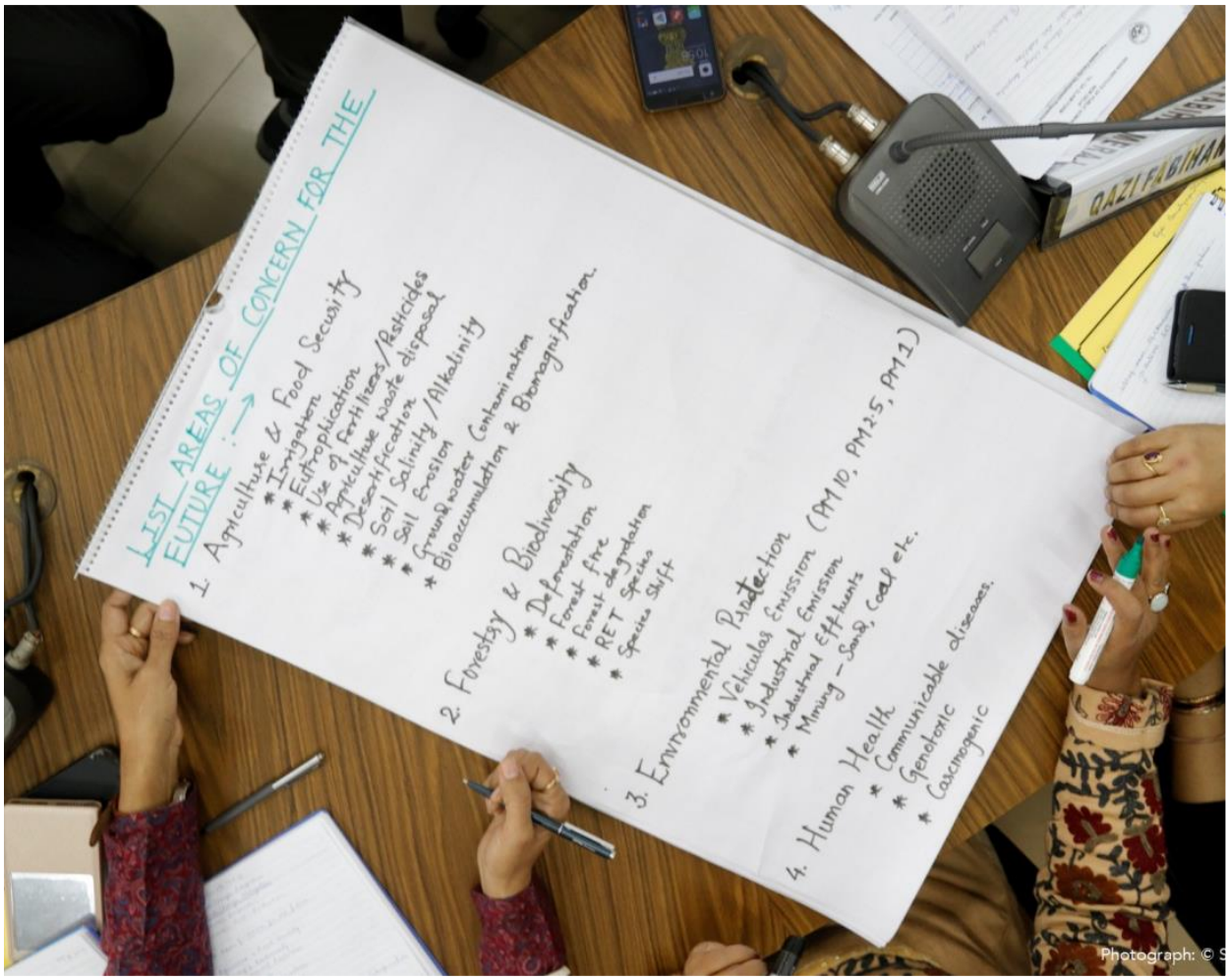
India launched National Action Plan on Climate Change in 2008 to address Climate Change issue. NAPCC address the concern for the country and identifies measures that promote sustainable development. There are eight national missions for achieving the goals in the face of Climate Change.

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Eco-system
- National Mission for a Green India

- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change.

Amongst them National Mission on Strategic Knowledge for Climate Change serves as a support system for all other seven National Missions. DST, Ministry of Science & Technology is entrusted with the responsibility of Climate Change Mission. This Mission has been launched with the broad objectives of mapping the information and data resources relevant to climate change and formulation of framework for building strategic knowledge for various departments of government, formulation of global technology watch groups and also to create new dedicated centres for Climate Change framework within the existing institutional framework. Project "Climate Smart Governance" proposed by IIPA in collaboration with STS has been designed in such a way so as to facilitate the Climate Change Mission of DST to meet its objective. The Institute has the expertise and infrastructure to conduct capacity building programs.

5. SECTORAL IMPACTS OF CLIMATE CHANGE



5.1 GLIMPSES OF SECTORAL MODULES

Due to lack of resources, developing countries face more risk of economy and social catastrophes. Climate change can impact through loss of livelihood opportunities and income, loss in terms of public health, reduced resilience to future shocks and reduced affordability to public services. Indirect impact of climate change is the increase in the rate of migration. The gap between water supply and demand is also projected to increase as drought- affected areas expand and the episodes of floods intensify. Overall, climate change and increased climate variability will alter the environmental baseline, such as the temperature regimes and precipitation patterns. Shifts in climate and increased frequency of extreme events have direct impacts on water availability and quality, flooding and drought periodicity. These dynamic changes will affect system processes within multiple sectors, increasing the uncertainty under which urban managers and decision makers must operate[8]. With this as a back drop project emphasis on following sector:

- Agriculture
- Water resources
- Health
- Social-Economic vulnerability and livelihood
- Energy
- Extreme events

[8] Mehrotra, S., Claudia E. Natenzon, Ademola Omojola, Regina Folorunsho, Joseph Gilbride and Cynthia Rosenzweig.(2009). 'Framework for City Climate Risk Assessment', Paper Prepared for the World Bank's 5th Urban Research Symposium on Cities and Climate Change: Responding to an Urgent Agenda, Marseille, France, June 28-30.

5.1(a) Climate change in Indian agriculture

Climate is a direct input into the agricultural production process. India is a predominantly agriculture- oriented economy, as 52% of the population directly depends on agriculture either as farmers or agricultural laborers, and their concentration is higher at 76% in the villages[9]. Climate Change could result in problems with food security and may threaten the livelihood activities upon which much of the population depends. According to world Bank Report "Turn Down The Heat: Climate Extremes, Regional Impacts and the case for Resilience" 2013, an expected 2 °C rise in the world's average temperature in the next decades will make India's summer monsoon highly unpredictable. Also by 2040's India will see a significant reduction in crop yields because of extreme heat. Shifting monsoon patterns will result in floods in some area and water scarcity in other areas, inadequate water supply for power generation, irrigation and in adverse cases even for drinking. In India, more than 60% of the crop area is rain fed, making it highly vulnerable to climate induced changes in precipitation patterns. It is estimated that by the 2050's, water for agricultural production in the river basis of the Indus, Ganges and Brahmaputra will reduce further and may impact food adequacy for some 63 million people[10]. Indian agriculture system is already under stress to meet the demand for food of increasing population. With a high vulnerability to climate change, agriculture sector and related livelihood activities are struggling for secure future. Unpredictable monsoon patterns, less crop yield and water availability affects the life poor farmers of the nation. Productivity of most crops may decrease due to increase in temperature and decrease in water availability, especially in Indo-Gangetic plains. This apart, there would be a decline in the productivity of *rabi* as compared to *kharif* season crops. Rising temperature would increase fertilizer requirement for the same production targets and result in higher GHG emissions, ammonia volatilization and cost of crop production.[11] Increased frequencies of droughts, floods, storms and cyclones are likely to increase agricultural production variability. Therefore, we have to place equal emphasis on saving lives and sustaining livelihoods.[12]

[9] Shivay, Y. S., Rahal, A. (2013). Climate Change- Impact on Agriculture and Adaptive and Mitigating Measures. Kurukshetra, p. 39
[10] World bank. (2013). Warming Climate in India to pose Significant Risk to Agriculture, press release.
[11] Effect of Global Warming on Crop Productivity, Y.S. Shivay and Anshu Rahal, Kurukshetra, July 2008, p.19
[12] M.S. Swaminathan, For an Action Plan for Bihar, The Hindu, 5 September, 2008

5.1(b) Impacts of climate change on water situation in India

India stands to face major challenges on many fronts in so far as the impact of climate change is concerned. Water security is one of the most important threats in this regard. Water resources will come under increasing pressure in the Indian subcontinent due to the changing climate.

As a result of increase in temperature significant changes in rainfall pattern have been observed during the 20th century in India. A serious environmental problem has also been witnessed in the Indo-Gangetic Plain Region (IGPR) in the past whereby different rivers (including Kosi, Ganga, Ghaghara, Son, Indus and its tributaries and Yamuna) changed their course a number of times. The recent devastating floods in Nepal and Bihar due to change of course of River Kosi is a case in point.

Available study suggests that food production has to be increased to the tune of 300 mt by 2020 in order to feed India's ever-growing population, which is likely to reach 1.30 billion by the year 2020. The total foodgrain production has to be increased by 50 per cent by 2020 to meet the requirement. It is feared that the fast increasing demand for food in the next two or three decades could be quite grim particularly in view of the serious problem of soil degradation and climate change.

Photo 1: Herobhanga river, West Bengal

The rise in population will increase the demand for water leading to faster withdrawal of water and this in turn would reduce the recharging time of the water tables. As a result, availability of water is bound to reach critical levels sooner or later.

During the past four decades, there has been a phenomenal increase in the growth of groundwater abstraction structures. Growing demand of water in agriculture, industrial and domestic sectors, has brought problems of overexploitation of the groundwater resource to the fore. The falling groundwater levels in various parts of the country have threatened the sustainability of the groundwater resources.

At present, available statistics on water demand shows that the agriculture sector is the largest consumer of water in India. About 83% of the available water is used for agriculture alone. If used judiciously, the demand may come down to about 68% by the year 2050, though agriculture will still remain the largest consumer. In order to meet this demand, augmentation of the existing water resources by development of additional sources of water or conservation of the existing resources and their efficient use will be needed.

It is evident that the impact of global warming threats are many and alarming. Water security in terms of quantity and quality pose problems for both developed and developing countries. However, the consequences of future climatic change may be felt more severely in developing countries such as India, whose economy is largely dependent on agriculture and is already under stress due to current population increase and associated demands for energy, freshwater and food.

5.1(c) Climate Change and Public Health

The relationship between climate change and human health is multidimensional. The fourth assessment report of IPCC, 2007 has identified three areas, in which human health has already being affected by climate change. These are: (i) Alteration in distribution of some infectious disease vectors, (ii) Seasonal distribution of some allergenic pollen species, and (iii) Increased heat wave related deaths. Though India has contributed only 2 percent of the total carbon emissions from fossil fuels burning over the last 100 years[13], still it is likely to experience greater effects from the 'extreme weather' events. For example, the warmer the climate the likelihood of its impact on human health becomes worse. Available studies suggest that there will be an increase in health problems. It is anticipated that there will be an increase in the number of deaths due to greater frequency and severity of heat waves and other extreme weather events.

Climate change and the resulting higher global temperatures are causing increasing frequency of floods and droughts leading to the risk of disease infections. By 2090s climate change may bring a doubling in the frequency of extreme drought events. Lack of freshwater during droughts and contamination of freshwater supplies during floods compromise hygiene, thus increasing rates of diarrheal disease. Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in hydrological cycle. Flooding also creates opportunities for breeding of disease carrying insects such as mosquitoes. Areas affected by frequent floods and drought conditions also witness large scale migration of populations to relatively stable regions leading to overcrowding and unhygienic conditions resulting in transmission of diseases like Japanese encephalitis and malaria.

Climate change is a major factor in the spread of infectious diseases. Diseases, confined to one specific geographic region spread to other areas. The World Health Organization (WHO) in their studies have indicated that due to rising temperatures, malaria cases are now being reported for the first time from countries like Nepal and Bhutan. It has also been predicted that an additional 220-400 million people could be exposed to malaria- a disease that claims around 1 million lives annually. Dengue fever is already in evidence at higher levels of

[13] Marland G, Boden T. A. and Andres R. J. (2000). Global, regional and national CO_2 emission trends: A compendium of data on global change. Oak Ridge, Tennessee, USA: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U. S. Department of Energy.

elevation in Latin America and parts of East Asia.[14] Studies suggest that climate change may swell the population at risk of malaria in Africa by 90 million by 2030, and the global population at risk of dengue by 2 billion by 2080s.

Rising temperatures and changing patterns of rainfall are projected to decrease crop yields in many developing countries, stressing food supplies. This will ultimately translate into wider prevalence of malnutrition/ under nutrition. In some African countries, yields from rain-fed agriculture could be reduced by up to 50 per cent by 2020.[15]

Emission of the Green House Gases have been responsible for the depletion of ozone layer, which protects the Earth from the harmful direct rays of the sun. Depletion of stratospheric ozone results in higher exposure to the ultra violet rays of the sun, leading to an increase in the incidents of skin cancer. It could also lead to an increase in the number of people suffering from eye diseases such as cataract. It is also thought to cause suppression of the immune system.

The projections by WHO and IPCC[16] suggest that the negative effects of climate change on health are greater. In addition, the negative effects are concentrated on poor populations that already have compromised health prospects, thus widening the inequality gap between the most and the least privileged. The balance of positive and negative health impacts will vary from one location to another, and will alter over time as temperatures continue to rise.

Major health effects due to changing climate can be broadly classified as follows[17]:

- Extreme weather- related health effects
- Air pollution- related health effects
- Water and food- borne diseases
- Vector- borne diseases
- Effects of food and water shortages
- Psycho- social impacts on displaced populations

[14] UNDP Human Development Report 2007-2008
[15] Climate Change 2007: Impacts, Adaptation and Vulnerability (Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Summary for Policymakers and Technical Summary)
[16] Climate Change 2007: Synthesis Report, IPCC, Geneva, 2007
[17] Joon, V. Jaiswal, V. (2012). Impact of Climate change on Human Health in India: an overview. Health and Population-Perspectives and Issues. 35(1), pp. 11-22.

5.1(d) Impacts on Livelihoods

Climate projections through 2030 suggest that the likely impact of changing temperatures will be concentrated in four major regions in India: the Himalayan region, the Western Ghats, northeast India and the coastal zone.[18] These regions are not only home to hundreds of millions of people; they also host some of India's most important economic sectors and industries – with manufacturing activities on the southeastern and western coastlines and tea and coffee cultivation in the hills of the Western Ghats and the northeastern state of Assam, to name a couple examples.

Photo 2: Livelihood and vulnerable communities

Himalayas In the Himalayan region, increasing forest fires will result in a loss of wood and other fuels used for heating. Glacier melts will produce flash floods and landslides, leading to a loss of valuable agricultural land and undermining access to fresh water in the region. Over time, places where drinking water is no longer easily available become uninhabitable, fueling migration. Lastly, the region should expect to see higher incidences of malaria due to expansions of transmission windows at higher latitudes.

500 million people depend on glacial melt water from the Himalayas.

- Precipitation will increase 5-13% by the 2030s as compared to the 1970s, leading to flooding and landslides and threatening agriculture.
- Increased frequency of forest fires will endanger a major source of fuel: wood.

[18] Indian Network for Climate Change Assessment (INCCA). 2010. Climate change and India: A 4 x4 Assessment. Weblink: http://www.indiaenvironmentportal.org.in/files/fin-rpt-incca.pdf

Western Ghats In the Western Ghats – a north-south mountain chain near the western coastline – variable rain patterns, rising sea levels, an increase in flash floods and soil erosion are the likely effects of climate change. Variable rain patterns will decrease crop yields, threatening both farmers' livelihoods and food security. Given that the Western Ghats are home to most of India's coffee production as well as some of its tea plantations, these diminishing crop yields will also impact the companies that depend on this supply chain. Unprecedented flooding and soil erosion caused by increased rainfall will result in a loss of lives and temporary distress migration. Rising sea levels will increase the incidence of floods, exacerbate soil erosion, and raise water tables. Resulting migration could take the form of 'managed retreat' or 'progressive abandonment' of land and structures in extremely susceptible areas, wherein inhabitants eventually seek permanent resettlement as a reaction to rises in sea levels and erosion.

50 million people are supported by the Western Ghats ecosystem.

- Unpredictable rain will threaten the livelihoods of those who depend on the region's critical tea and coffee industries.
- Increased amount and intensity of rainfall will produce soil erosion and flooding.
- Flash floods are likely to cause temporary distress migration frequency during summer rains.

The Northeast India is one of the most troubled regions in the nation. Separatist movements, political instability and inaccessible terrain make this one of the most difficult regions to develop. As a result, the economy largely depends on agriculture, which climate change is already disrupting. The region is home to a highly concentrated and productive tea industry in the state of Assam. But changes in rainfall patterns and high temperatures are threatening the sustainability of the tea plantations, which employ roughly one million workers. While evenly distributed rain previously made year round tea processing a possibility, more heavily concentrated rain today means that harvesting happens less predictably. Only large plantations, as opposed to smallholder farms, have the capacity to cope. If the result is worker layoffs, it will reduce the bargaining power of tea plantation laborers, who have been striving to organize themselves and recently succeeded in arguing for a higher minimum wage.

01 million people depend on the tea industry in northeast India for their livelihood.

- Tea plantations will experience negative consequence due to soil erosion, rising temperatures and unpredictable rainfall.
- Due to changing weather conditions, rice production will fall while cereal production has the potential to increase.
- Landslides and runoffs will increase in frequency during summer rains.

Coastal zones India's coastal zones stand to witness some of the most deleterious effects of climate change. First of all, coastal flooding through sea level rise and storm surges has the potential to spread waterborne diseases, such as cholera. These changes will also bring salt intrusion, rendering fertile farmland useless for the crops it currently supports. Sea level rise will also negatively impact the tourism industry, upon which millions of people in the states of Kerala and Goa depend for their livelihood. Dwindling fishing yields will also result from changing currents and water temperatures. Taken together, these negative impacts on employment will make circular migration and some permanent out-migration more frequent. Climate change will cause a significant increase in distress migration in all of these four regions. Currently, Delhi and the states of Gujarat and Maharashtra are top destinations for circular migrants. Migrants will leave their homes to gain short-term access to food, water and shelter, and will seek out temporary income generation activities. Such temporary forms of employment tend to be precarious. Moreover, migrant workers enjoy little to no legal protections when they migrate making them particularly susceptible to exploitation.

50cm sea level rise will be seen by India by 2100.

- An increase in intensity of cyclones will bring storm surges and salinity intrusion in critical farmland.
- Rainfall intensity will increase, while rainfall frequency will decrease, causing extra stress on the agriculture sector.
- Sea level rise will submerge crucial habitats and ecosystems, such as mangroves.

For example, many of those who migrate due to climate-related changes will wind up working in the construction industry, which employs about 45 million people across India. Construction is one of the most hazardous and precarious sectors, particularly for women. About 97 percent of women working in construction in India are informal workers, hired on short-term verbal contracts or as day laborers.

5.1(e) Temperature, Energy Demand, and Energy Supply

Increases in temperature will likely increase our energy demand, as well as change our ability to produce electricity and deliver it reliably. In a warmer climate, people will use more electricity for air conditioning. Since demand for electricity for cooling is expected to increase as a result of temperature increase and extreme heat events, the balance in energy delivery is likely to shift from natural gas and fuel oil used for heating to electricity used for air conditioning. Changes in energy demand will likely affect greenhouse gas emissions, but the net effect depends on which energy sources, including alternative energy, are used for electricity and heating.

Warming is likely to increase summer peak electricity demand in most regions. Meeting increases in this peak demand could require investments in new energy generation and distribution infrastructure, and new mechanisms will need to manage system reliability and peak demand, which can be more expensive than average demand levels. A warmer climate may reduce the efficiency of power production for many existing fossil fuel and nuclear power plants because these plants use water for cooling. The colder the water, the more efficient the generator. Thus, higher air and water temperatures could reduce the efficiency with which these plants convert fuel into electricity.

5.1(f) Climate change and increasing disasters- Is there a link?

The CRED report states that 'there is increasing conclusive evidence which confirms that global climate change will have an impact on the occurrence and magnitude of extreme events. These impacts are envisaged to increase human vulnerability to natural disasters, thus emphasizing the need for improved measures of preparedness in every part of the world'. Climate change manifesting in extreme weather events such as cyclones, storms, floods, droughts, heat waves etc results in catastrophic loss of human lives, damage to infrastructure and environment. Disasters resulting from climatic variability and other climatic and meteorological causes are hydro-meteorological disasters and are commonly known as 'climate disasters' in disaster studies. These climate disasters are distinct from geological disasters (such as earthquake, volcanic eruptions etc)[19]. Climate change leads to condition for extreme weather events and increase the risk of exposure to climate disasters.

Source: SSDMA, Sikkim

Photo 3: Sikkim earthquake, 2011

According to the The Indira Gandhi Institute of Development Research, if the process of global warming continues to increase, resulting climatic disasters would cause a decrease in India's GDP to decline by about 9%, with a decrease by 40% of the production of major crops. A 2° C increase in temperature in India is projected to displace seven million people, with a submersion of the major cities of India like Mumbai and Chennai.

[19] CRED, 2007. Annual Disaster Statistical Review: Numbers and Trends 2006. Report by the Centre for Research on the Epidemiology of Disasters (CRED), School of Public Health, Catholic University of Louvain, Brussels, Belgium May 2007.

6. PROJECT EXECUTION

The initial phase of the project includes programme design for capacity building programs and desktop research. With this as the back drop, module development and capacity building programme was conducted for different target groups ranging from teachers, professionals, scientists, middle level officers, policy makers, senior level administrators, legislators and the like. Project Advisory Committee was constituted to guide and mentor the successful implementation of project and to follow systemic approach to realize and take the objective to its logical conclusion. The minutes of first and second PAC meeting are attached in Annexure II. Members of the advisory committee are:

1. Dr. T. Chatterjee (Chairman), Director, Indian Institute of Public Administration and former secretary, Environment and forests, Govt. of India.
2. Dr. Subodh K. Sharma, Retired Advisor, Ministry of Environment, Forest and Climate Change
3. Prof. C. K. Varshney, Former Dean JNU
4. Dr. K. J. Ramesh, DGM, Indian Meteorological Department
5. Dr. Shashi Kumar, Director, Indira Gandhi National Forest Academy, Dehradun
6. Dr. Akhilesh Gupta, Head SPLICE, Department of Science & Technology
7. Dr. Manu Gupta, Director SEEDS

Photo 4: First Project Advisory Committee Meeting

For successful execution of the project, the work progresses is reported in three phases with predefined timeline: Project design, framework development and training phase.

6.1 Project Design

The project design phase emphasized on strategic framework for the project by visualizing the start-up activities and the inception planning to be initiated which included

- Desktop research
- Resource persons
- Identification of the target groups
- Content development
- Development of Blended Learning

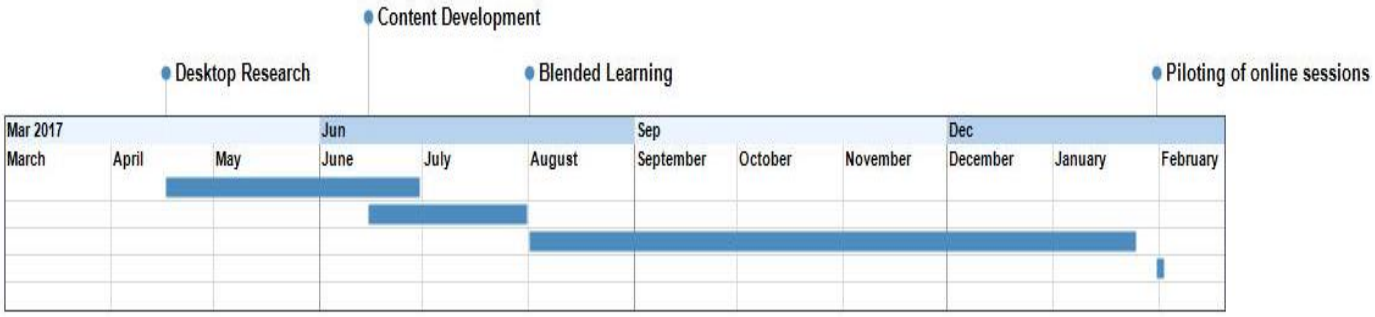


Figure 2: Project Design timeline

Blended learning methodology is a training approach of capacity building programmes. This methodology adopts blending of classroom sessions with online sessions. Blended learning (Virtual Internet Participation) course module uses the classroom time for group activities and panel discussions followed by virtual internet participation by the participants to access the training modules and can get the solution to their queries. This includes development of offline schedule, online course content, pedagogy and online assessment system. This helps the participants to focus on application to the real world policy frame work in addition with gaining knowledge about the module.

6.2 Framework Development

It was emphasized that the training techniques, pedagogy and ToT modules should be customized for target areas and groups. The participants should be sensitized on Climate Change in such a way that they can relate to its local impact on their livelihoods rather than be subjected to mere theory and concepts at the macro level. Training pedagogy should have forward and backward integration and locally relevant case studies should be included in the modules. Data collation from IMD and Bhuvan web portal was also done for preparation of case studies and research papers.

- Selection of participants
- Training modules
- Collection/development of pedagogical tools
- Case studies
- Data analysis

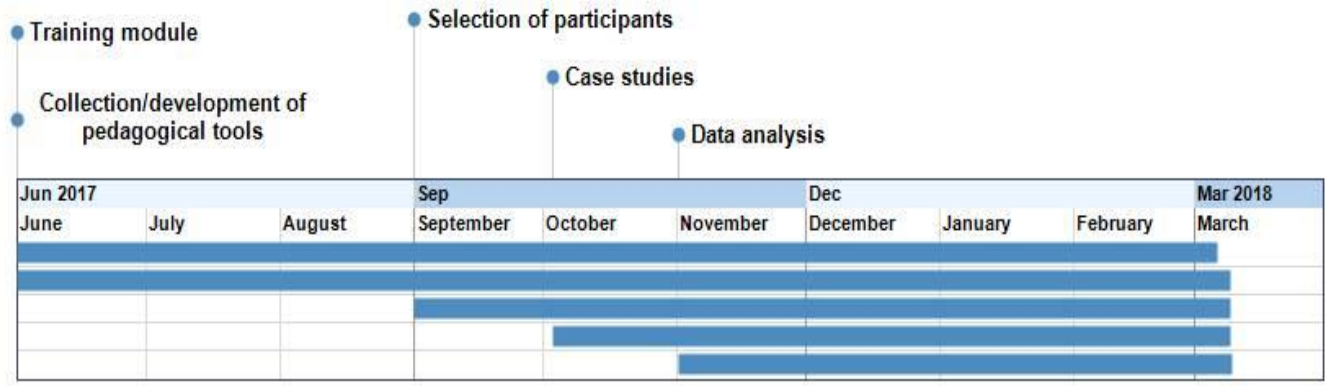


Figure 3: Framework development timeline

6.3 Training Phase

The capacity building circuit entails new knowledge arising from research to be fed back into appropriate levels of the education, training and human resource development as required by the rapidly evolving science role of with respect to the society. Education and training system is not only a science support mechanism, as it also guarantees the fulfillment of new job needs to address incoming societal challenges. To contribute to the establishment of the educational landscape of Climate science, reinforcing the peculiarities of the different sectors in relation to a more general Climate change related notions, preliminary awareness about the context is essential.

The fact that current climate change related training practices are largely ad hoc and not based on clear identification of training needs call for a systematic approach to training. There seems to be a global consensus that training in order to be effective has to be based on a systematic approach.

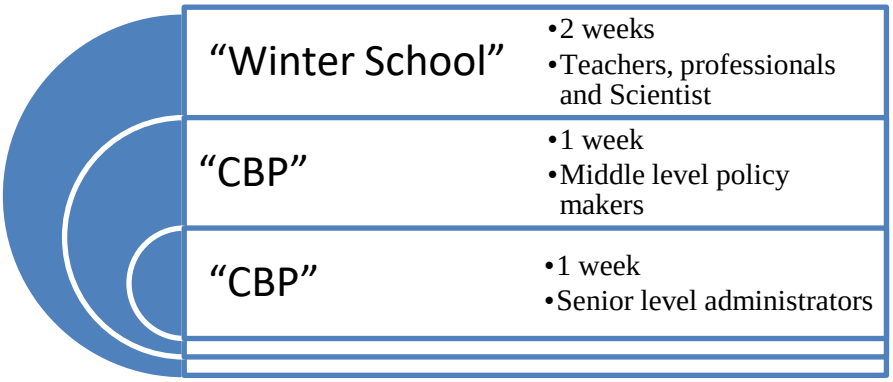
A systematic approach to training (SAT) pre-supposes the following:

- Training is based on identified training needs and is in response to real and not imagined needs of the functionaries involved
- Participants are selected on the basis of training needs and not on other factors including their easy availability for training
- Impact of training is evaluated and learning used to improve the training design and delivery further for better results

Three capacity building programme were conducted under Climate Smart Governance project.

- Two weeks Faculty Development Programme (December 4-15, 2017) for university faculty and research scholars
- One week Blended Capacity Building (29th January- 2nd February, 2018) for middle level officers
- Blended Capacity Building programme for senior level officers (19th- 27th March, 2018)

Target audience



Training methodology

Training approach- an interactive, two way communication process with combined theory and practical exercises. Training pedagogy includes expert presentations, hands on exercises, group exercise and presentation, field visits and case studies with reference to practical examples.

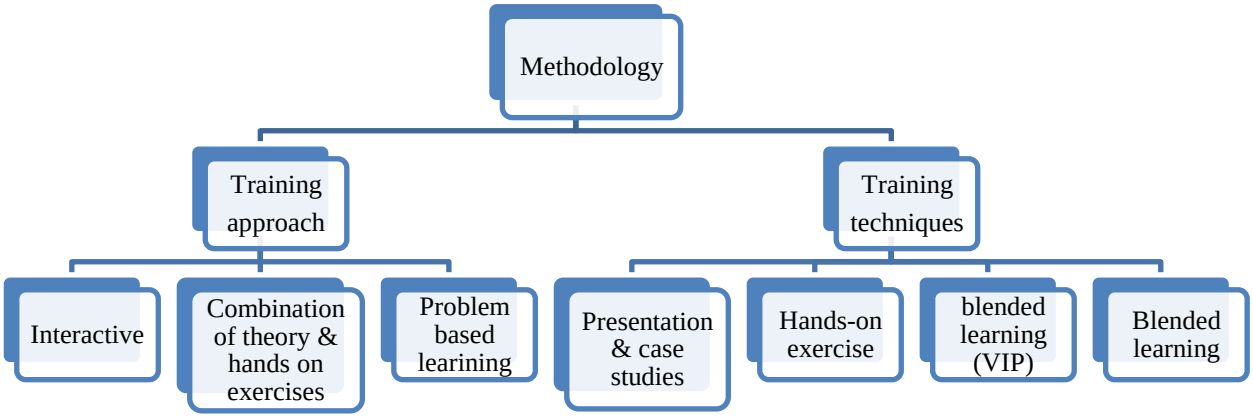


Figure 4: Training methodology

For all capacity building programmes, training modules was customized according to the target groups and also the training approach varied from group to group. A standard module was prepared covering all the major aspects of Climate Change science, impacts, mitigation and adaptation and then customized according to the target groups and target areas.

7. DELIVERABLES

7.1 Three Capacity building Programme

Three capacity building programmes on "Climate Smart Governance"[20]:

1. Capacity Building Programme conducted was "Two weeks Faculty Development Programme on Climate Smart Governance" from December 4-15, 2017. Target audiences for the same were university faculty and research scholars from various parts of the country.

Photo 5: Participants of "Two weeks Faculty Development Programme"

[20] Note: Complete details of three capacity building programme is covered in subsequent series

2. Blended Capacity Building Programme was conducted for Middle level officers from 29th January to 2nd February, 2018. It consisted of two days classroom sessions followed by three days online sessions.

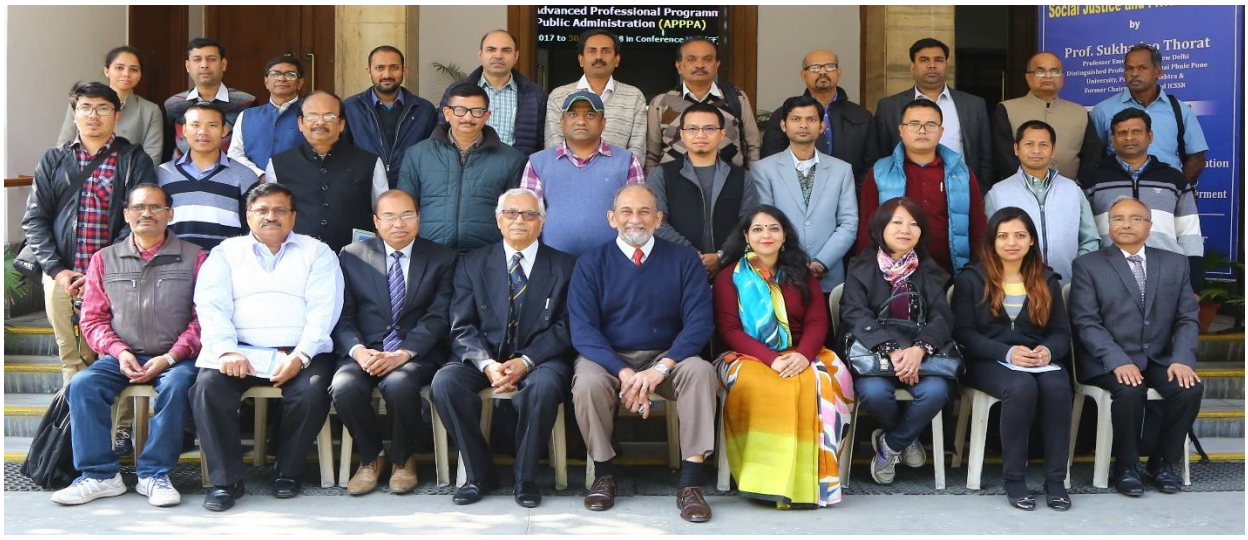


Photo 6: Participants of One week Blended Capacity Building Programme

3. Blended Capacity Building Programme for Senior Level officer of Gujarat. Online Training from 19 - 25th March 2018 (24 credit hours (equivalent to 3 days) spread over a week) followed by Workshop at on 26th & 27th March 2018 at Gujarat Institute of Disaster Management, Gujarat.

Photo 7: Participants of Blended Capacity Building Programme at GIDM

7.2 Pedagogy

Capacity Building Programmes for different target groups undertakes following pedagogical tools for dissemination of course content.

- Classroom sessions
- Case studies
- Short films/ videos
- Panel discussions
- Hands-on training
- Simulation exercise
- Study tour
- Field visit (outstation/local)
- Presentations by participants
- Online sessions
- Handouts

7.3 Research, analysis and documentation

Climate Data Analysis

Global climate change impacts and trend are recorded and published in many research papers. The participants should be sensitized on Climate Change in such a way that they can relate to its local impact on their livelihoods rather than be subjected to mere theory and concepts at the macro level. Training pedagogy should have forward and backward integration and locally relevant case studies should be included in the modules. In this regard climate data analysis has been done for Delhi state and presented to participants. Climate data analysis is useful in many ways:

- Past Climate trend analysis
- Climate modelling
- Trend analysis of past climate trend
- Climate change projections
- Climate change downscaling
- Scenarios of extremes events

Participants are more interested in knowing the current scenario with respect to past in reference to their local region and the area to which they belong. Delhi which was tagged as most polluted city in the country has been receiving much of the headlines. Its climate data analysis has been showing more issues other than this viz. rainfall variability and increase in minimum temperature. Climate data analysis mainly consist of estimates of its mean value and its variability for a particular parameter. Statistics is an important tool in climate research. Large amount of data can be analyze for various parameters and can be interpreted in useful information.

Changes in rainfall patterns, intensity and extreme events are some of the impacts of climate change. Temporal rainfall variability can be directly or indirectly linked to climate change. Several studies have shown that the rainfall variability is the result of Climate Change. Such variability in rainfall increases the vulnerability of communities towards climate change. Increasing urbanization and unplanned developmental activities, the air quality is deteriorating. Data analysis shows that the rainfall variability due to increasing

level of greenhouse gases. Climate data consisting of various climatic parameters was collected from Indian Meteorological Department, Pune for the state of Delhi from 1901-2015 and analyzed using Mann-Kendall test for time-series data analysis. Mann- Kendall test is a statistical tool helps in analysis of trend in the given data sets. The slope of the trend can be measured through Sen's slope estimator. Data was analyzed monthly, seasonally and yearly. The actual rainfall differs from the normal trend of the rainfall. Through this analysis it can be projected that there will be increase in pre- monsoon rainfall than the actual monsoon season. Pre monsoon rainfall causes cooling effect and results in drier monsoon season. This will increase the vulnerability of communities towards Climate Change and also effect related developmental activities.

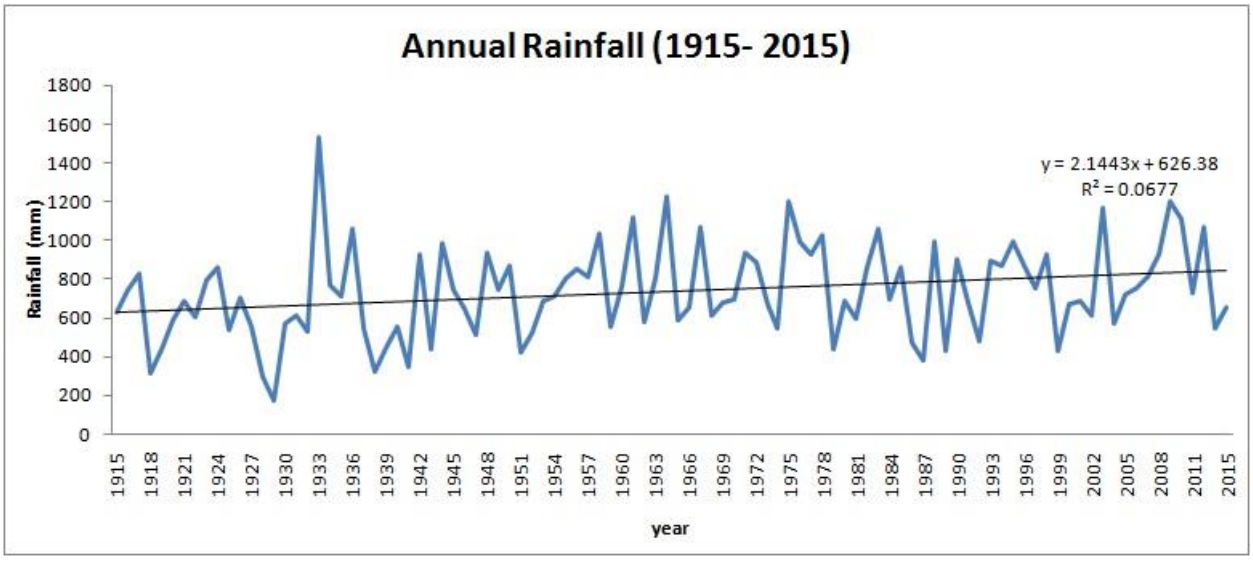


Figure 5: Graph showing increasing trend of rainfall in

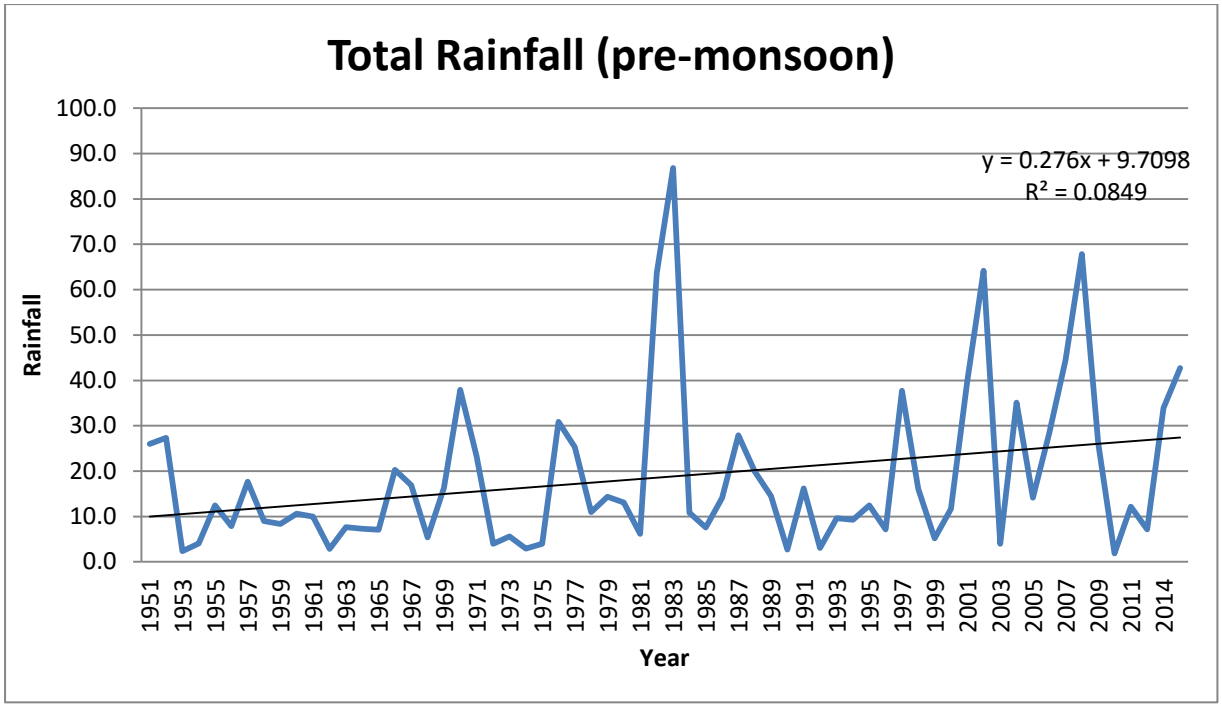


Figure 6: Graph showing increasing trend of rainfall in premonsoon

The analysis of climate data has been presented and accepted in international conferences

"Rainfall trend analysis over past 100 years (1915-2015) in Delhi"

- Presented at 3rd International Conference on Environment Management 2017 at JNTU, Hyderabad. Paper attached in Annexure III

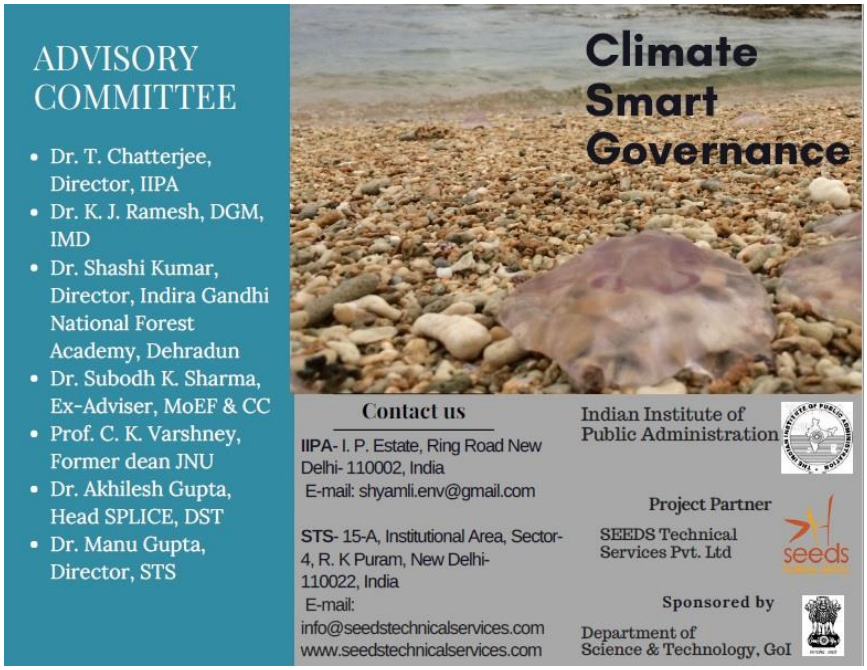
"Trend Analysis of Rainfall: A Climate Change Paradigm"

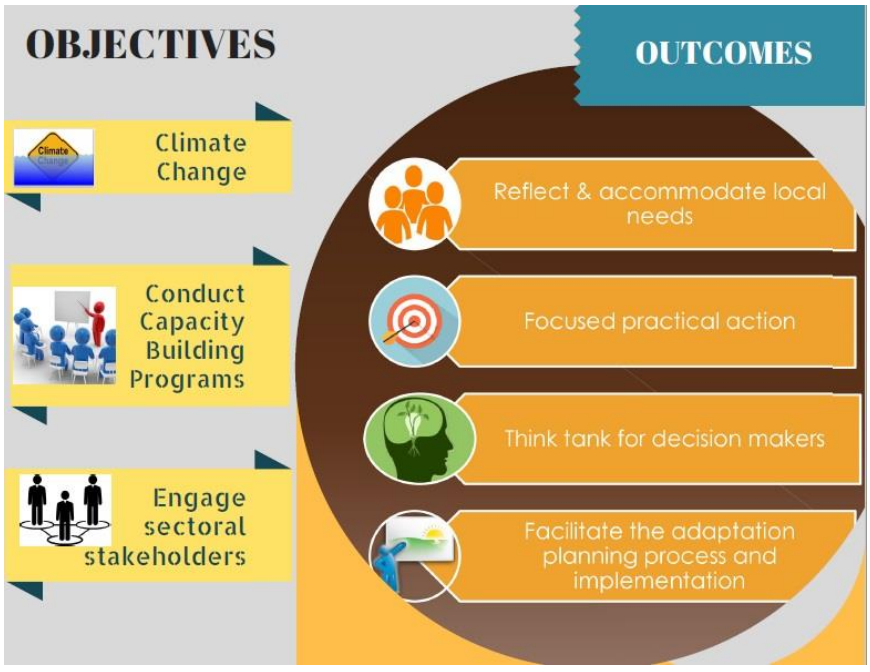
- Accepted for "ICCCGW 2018: International Conference on Climate Change and Global Warming" to be held on Oct 29-30, 2018 in Paris, France

7.4 Knowledge Dissemination

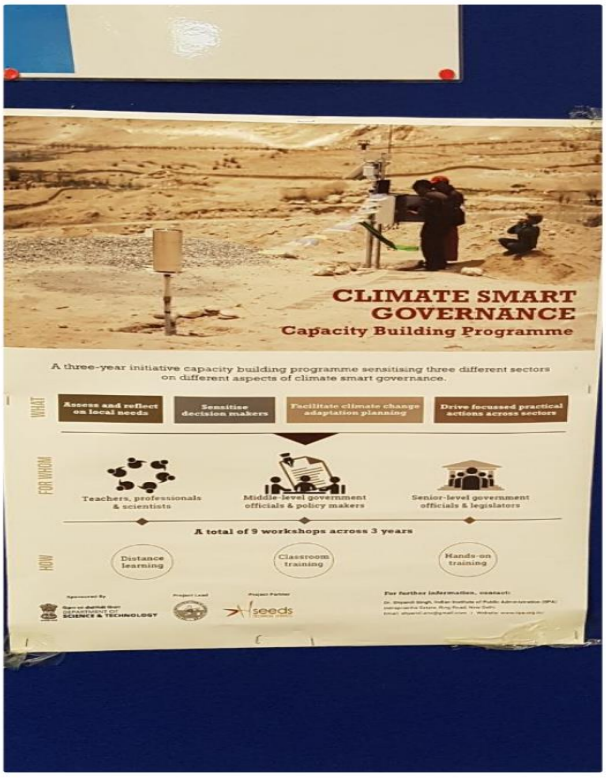
Climate change is a global issue of concern, and its consequences will impact each one of us in one or the other way. The various platforms have been used to promote this project for different stakeholders and also engage them for further course of actions.

❖ Project Flyer

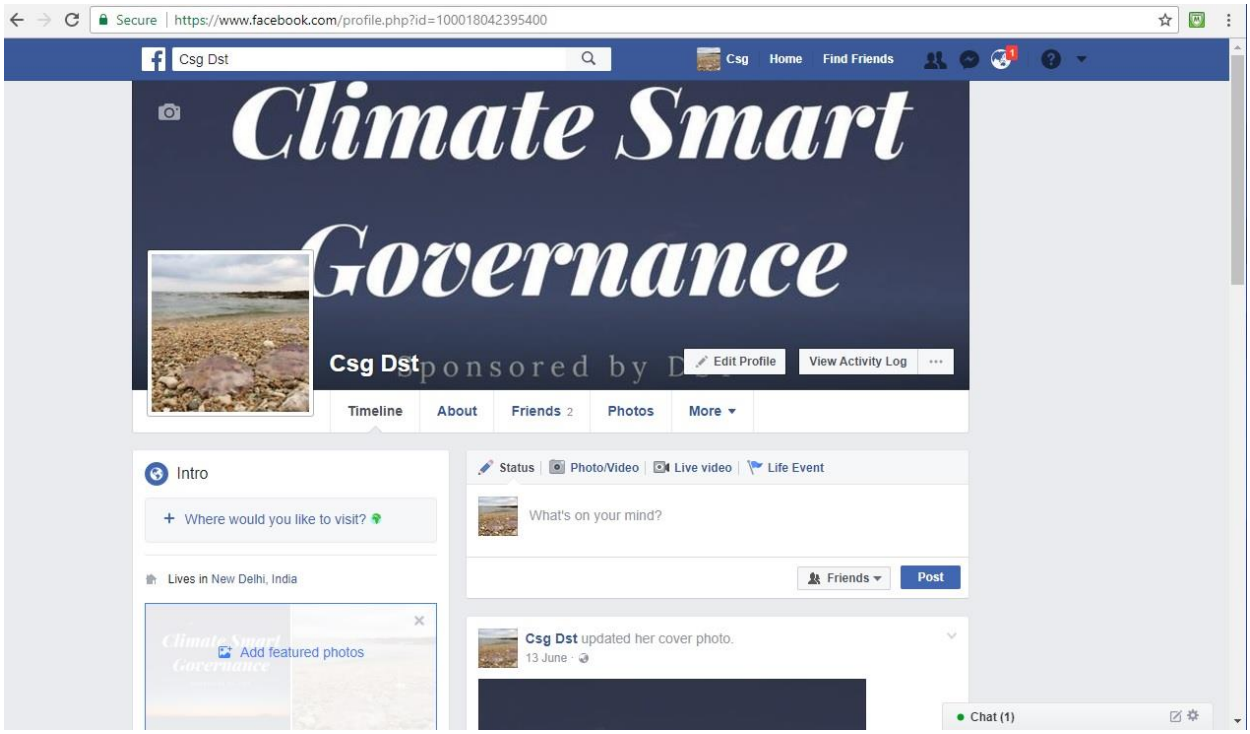




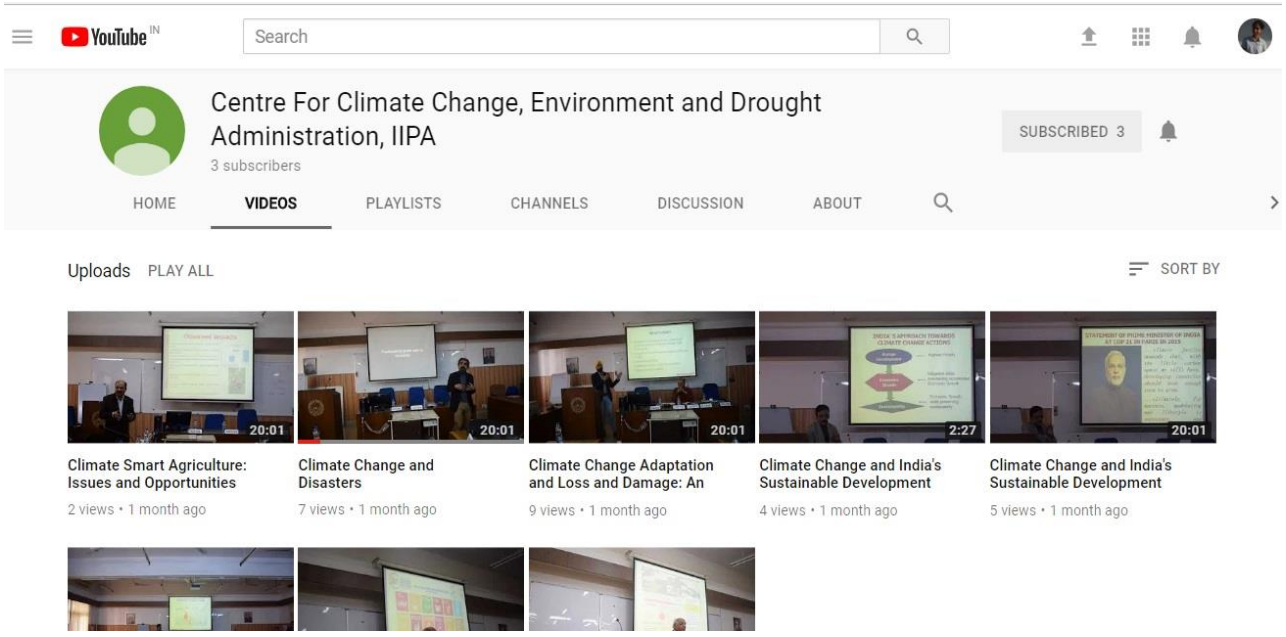
❖ Poster showcased at COP 23 Bonn, Germany, 2017



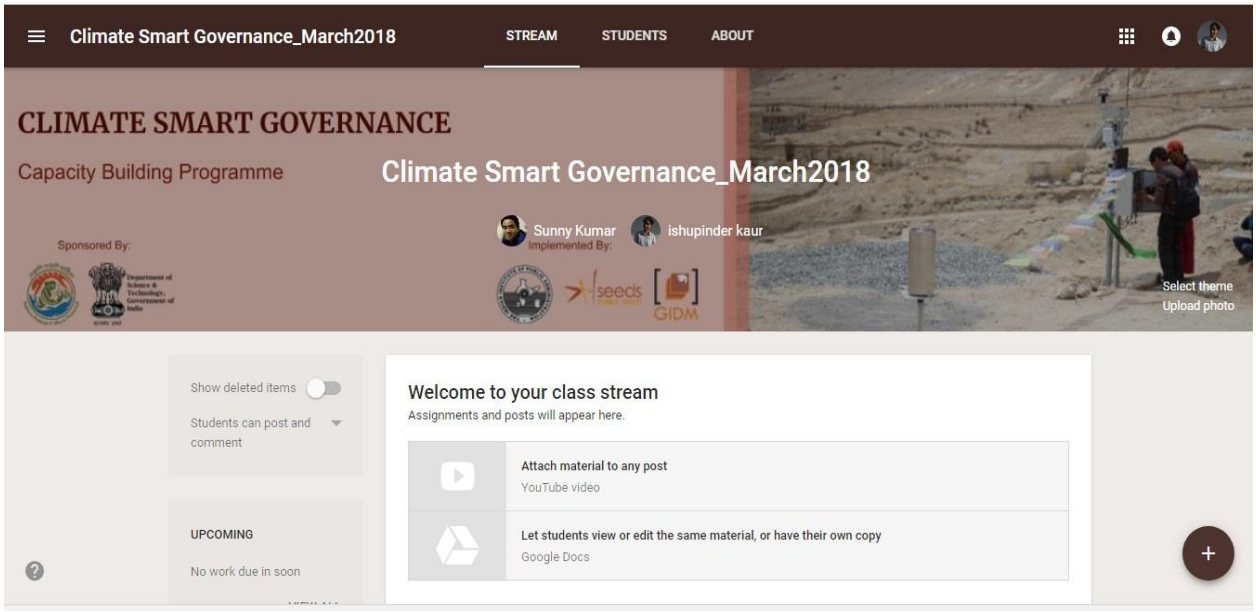
❖ Facebook Page



❖ Youtube page



❖ Online Classroom- Blended learning



ANNEXURE

Annexure I: Minutes of the first Advisory Committee Meeting for the project "Climate Smart Governance" sponsored by DST

The First Advisory committee meeting was conducted on 19th July 2017 at 11:30 am at Director's Meeting room IIPA, New Delhi. The agenda of the meeting was to discuss the start-up activities including desktop review, review of inception planning and decide the further course of action.

The following members attended the meeting:

Dr. T. Chatterjee (Chairman), Director, IIPA
Dr. K. J. Ramesh (Member), DGM, IMD
Dr. Akhilesh Gupta (Member), Head SPLICE, DST
Dr. Manu Gupta (Member), Director STS
Prof. Vinod K. Sharma, Project Investigator, IIPA
Dr. Shyamli Singh, Project Investigator, IIPA
Dr. Anshu Sharma, Project Investigator, STS
Mr. Mihir Joshi, Nodal Officer, STS
Ishupinder Kaur, Research Officer, IIPA

Leave of absence was granted to the following members: Dr. Subodh K. Sharma, Dr. Shashi Kumar and Prof. A. K. Nema (PAC members).

Director IIPA and Chair Advisory Committee welcomed all the members. The meeting was initiated with a conceptual briefing of the project by Dr. Shyamli Singh, followed by a presentation on its various aspects including objectives, methodology, *ongoing* tasks and deliverables.

It was emphasized to include experts in the subject area who could contribute to the Capacity Building Programmes. DST offered help in terms of building upon the list of organization/experts, which would help in strengthening the future work. A long term association between IIPA and DST in the field of Climate Change was also an agreed course of action.

It was suggested to broaden the project horizon in future and to conduct awareness generation programmes even for Parliamentarians regarding Climate Change issues and its mitigation/adaptation strategies. DST may write to IIPA in this regard separately.

It was agreed that as climate effects are locally relevant in terms of its damage potential, a landscape followed by micro-watershed approach should be

adopted in developing our strategies. To begin with, India's 12 bio-geographical zones should form the framework for the 12 generic modules of training and strategy development. Within these zones high-populated landscapes, watersheds, air-sheds and micro-basins should be targeted to commence data collection and preparing training modules and strategies.

Climate data analysis have to be on globally accepted parameters including relative humidity, wind-rose, eco-flows of water etc. A dialogue to be opened for better communication and visibility *via.* Elsevier, Knowledge Resource groups, knowledge base and web of science. It was also suggested to involve Eco Clubs, an initiative of Department of Environment, Delhi Government. This will be helpful in sustaining the programme in future, post project.

Success indicators have to be developed immediately and get approved by DST prior to commencing as this would confirm the deliverables in time.

It was suggested by members from DST and IMD that the IIPA should select target groups to sustain this project. They also suggested that state Climate Change Centres, State Meteorological Centres and ATIs can be made responsible for ToTs so that they may take ownership and their local resource persons can be used in the later phases of the project.

The deliverables for 2017-2018 includes:

1. Flyer
2. Preparation of training modules
3. Develop pedagogical tools
4. Three human capacity building programs
5. Reports

The meeting concluded with a vote of thanks.

Annexure II: Minutes of the second Advisory Committee Meeting for the project "Climate Smart Governance" sponsored by DST

The Second Advisory committee meeting was held on 14th November 2017 at 12:30 pm at Multi-purpose hall IIPA, New Delhi.

Agenda

- To discuss the follow up action of first PAC meeting
- To discuss current project progress
- To discuss further course of action.

The following members attended the meeting:

Dr. T. Chatterjee (Chairman), Director, IIPA
Prof. C. K. Varshney (Member), Former Dean, JNU
Dr. Shashi Kumar (Member), Director, Indira Gandhi National Forest Academy, Dehradun
Dr. Manu Gupta (Member), Director STS
Prof. Vinod K. Sharma, Project Investigator, IIPA
Dr. Shyamli Singh, Project Investigator, IIPA
Dr. Anshu Sharma, Project Investigator, STS
Mr. Sunny Kumar, Manager, STS
Ishupinder Kaur, Research Officer, IIPA

Leave of absence was granted to the following members: Dr. Subodh K. Sharma, Dr. Akhilesh Gupta and Dr. K. J. Ramesh (PAC members).

Director IIPA and Chair Advisory Committee welcomed all the members. The meeting was initiated with a presentation on the follow-up action of first PAC meeting, project progress and planned activities.

It was suggested by the Director Dr. Chatterjee that climate data should be taken from all data sources and not from any simple source no matter how reliable. For example, along with IMD, central and state continuous monitoring systems, State Pollution Control Boards and agriculture data to facilitate more robust data analysis at micro level and for inputs into training modules.

It was emphasised that the training techniques, pedagogy and ToT modules should be customised for target areas and groups. The participants should be

sensitized on Climate Change in such a way that they can relate to its local impact on their livelihoods rather than be subjected to mere theory and concepts at the macro level. Training pedagogy should have forward and backward integration and locally relevant case studies should be included in the modules. Training modules must be dis-aggregated for the twelve biogeographic regions of South Asia and should also should have a common generic module.

It was agreed that a standard module should be prepared covering all the major aspects of Climate Change, economics and scientific perspectives with a scope of further customization according to the target groups and target areas.

It was suggested to contact the "National Green Corps" and other NGOs with appropriate specialization to train school and college teachers in managing local impacts.

The project advisory committee members were also of the view that a concept paper should be developed for proposing a Centre for Excellence on "Climate Smart Governance" at IIPA to be submitted to DST.

The online course via formal and social network channels for content dissemination was floated by the members. However there were concerns that frivolous material may get propagated.

Major emphasis was laid on sensitization for parliamentarians. Bureau of Parliamentary Studies and Training (BPST) may be helpful for capacity building programme for parliamentarians. It was suggested to hold exhibitions in the Parliament annexe. It was also discussed to develop course capsule exclusively for them.

The meeting concluded with vote of thanks.

Annexure III: Paper titled "Rainfall trend analysis over past 100 years (1915-2015) in Delhi"

Rainfall trend analysis over past 100 years (1915-2015) in Delhi

Shyamli Singh*, Ishupinder Kaur, Vinod K. Sharma

Indian Institute of Public Administration, New Delhi, India

ABSTRACT

Anthropogenic activities have altered the natural greenhouse mechanism on earth and the impact will continue to last for several decades to come. Water is a very vital natural resource needed for the existence of all life forms but the plight is, it is not equally distributed over earth. Climate Change is projected to alter hydrological processes such as precipitation and evapo-transpiration. Climate Change in most likelihood will impact the available water resources and may have a direct impact on stream flow and groundwater recharge. Increasing urbanization and unplanned development upsurges the vulnerability impacts of Climate Change. The present paper focuses on analysis of annual rainfall trend in Delhi, one of the busiest and the most polluted metropolitan cities of India. Monthly rainfall data of 100 years (1915-2015) from Safdarjung station in Delhi has been analyzed for rainfall trend analysis. Standard deviation and linear trend line were used to analyze the trend over time. Statistical tool such as Mann- Kendall test along with Sen's Slope Estimator were used for analysis. Mann-Kendall test analyses the trend in the data set and Sen's slope Estimator determines the slope magnitude of trend line. Yearly variations in the rainfall pattern are observed. An overall positive trend is observed which is denoted by Sen's slope value 2.3.

Keywords Climate Change, precipitation, standard deviation, Mann- Kendall test, Sen's Slope estimator, Rainfall trend

INTRODUCTION

Water is a vital natural resource for the existence of life on earth. Since its distribution over the earth's surface is unequal therefore there is a need of proper water management to meet need posterity. Global warming, due to the enhanced greenhouse effect, is likely to have significant effects on the hydrological cycle (IPCC, 1996). The Second Assessment Report of the Intergovernmental Panel on Climate (IPPC) warned that global warming would lead to increase in both floods and droughts. Alarming rate of greenhouse gas concentration in atmosphere, rising temperature and rise in sea level are some of the direct impacts of Climate Change which will have negative environmental implications over the water resources. Over the past several decades global warming is consistently associated with changes in hydrological cycle.

Rising temperature will alter rainfall patterns, making them intense in some regions and weaker in others and may cause storms more frequent and severe in some areas. Global averaged precipitation is projected to increase, but both increases and decreases are expected at the regional and continental scales (IPCC 2001). In India southwest monsoon brings about 80% of the total precipitation and is critical for the availability of freshwater for drinking and irrigation. The heavy concentration of rainfall in the monsoon results in scarcity of water in many parts of the country during the non-monsoon period (Jain and Kumar, 2012).

In view of the above, a number of studies have been conducted to analyze long term trends of rainfall and other parameters of India. Rainfall trend analysis of 135 years (1871- 2005) indicated no significant trend for annual, seasonal and monthly rainfall over the country (Kumar, Jain and Singh, 2010). Parthasarathy and Dhar found that the annual rainfall for the period 1901- 1960 had a positive trend over Central India and the adjoining parts of the peninsula, and a decreasing trend over some parts of eastern India (Parthasarathy and Dhar, 1974). Long term southwest monsoon trends over India as a whole were studies by Pramanik and Jagannathan (1954), a pioneer work in organizing series of annual rainfalls over 80-100 years, found systematic variations over certain regions in addition to random fluctuations. Sub Himalayan West Bengal and Sikkim and the Bihar plains showed decreasing trends in monsoon rainfall (Parthasarathy, 1984), whereas Punjab, Konkan and Goa, West Madhya Pradesh and Telangana showed increasing trends (Chhabra et al., 1997). Goswami et al. (2006) indicated significant positive trends in the frequency and the magnitude of extreme rain events and a significant negative trend in the frequency of moderate events over

central India during the monsoon seasons from 1951 to 200. Over the year 1951- 2004) there is insignificant decrease in long term southwest monsoon rainfall over Delhi and it was found directly related to Scandinavian Pattern and East Atlantic/West Russia and inversely related to Pacific Decadal Oscillation (Rana et al., 2012).

The present research is aimed at analyzing the rainfall trends over past 100 years over Delhi.

STUDY AREA

Delhi is located at 28°37' N 77°14' E in Northern India. The climate of the area is monsoon- influenced subtropical with large variation in temperature and precipitation in different seasons. The prevailing winds are mainly easterly, northerly and northwesterly during the summer season (Singh et al. 2005).

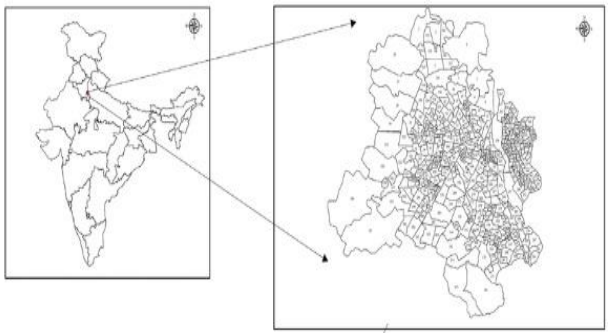


Figure 1: Location map of Delhi
(Source: www.researchgate.net)

DATA USED AND METHODOLOGY

Annual and monthly climatic data was obtained from Indian Meteorological Department (IMD). From the rainfall data mean, median and standard deviation were computed annually.

Rainfall trend analysis has been done using Man-Kendall test. This is a time series analysis statistical method which is being used to study the spatial variation and temporal trends in the data. Mann- Kendall test had been formulated by Mann (1945) as non-parametric test for trend detection and the test statistic distribution had been given by Kendall (1975) for testing non- linear trend and turning point. It is taken into consideration over the parametric one since it can evade the problem roused by data skew (Smith, 2000). Mann- Kendall was used to test Null hypothesis, i.e H_0 there is no trend exist in the given data set, against the alternative hypothesis, H_1 that is an increasing and decreasing trend in the series. The significance of trend can be evaluated on the basis of Kendall's tau value. Positive value of Kendal's Tau signifies positive trend in the series and vice-versa.

Mann- Kendall test tells us about that whether or not trend exist in the series. Sen's slope estimator is useful to find out magnitude of the slope i.e change per unit time. It represents the true slope of the linear trend present in the data set. Positive value of slope magnitude indicates an upward trend and negative value indicates downward trend.

RESULT AND DISCUSSION

Rainfall trend analysis has been done in the present study for 100 years of data 1915-2015, collected from IMD, Pune. Monthly data for each year were added for annual rainfall data set. Mann- Kendall and Sen's Slope Estimator has been used for the determination of the trend. Figure 2 represents the annual rainfall for the determination of the annual trend.

The graph shows maximum rainfall occurrence in the year 1933 with the total precipitation of 1532.7 mm and minimum rainfall has occurred in the year 1929 with the total of 173 mm. Average rainfall for 100 years is 734.7 mm with standard deviation 240 mm. Regression equation and R^2 value of liner trend line is as follows:

$y= 2.1443x + 626.38$
$R^2= 0.0677$

In Mann Kendall test for time series analysis, if Null hypothesis stands true that is $p>\alpha$, holds true resulting in inference that no trend exists in the series. Similarly if alternate hypothesis stands true that is $p<\alpha$, that is trend exists. It can be represented in the equation as

If H_0 (Null Hypothesis) is true = No trend exists

If H_1 (Alternate Hypothesis) is true = Trend exists

Results of Mann Kendall Test are as follows

Kendall's tau: 0.182
p-value: 0.008
Alpha (Significance level): 0.05
Sen's slope: 2.3

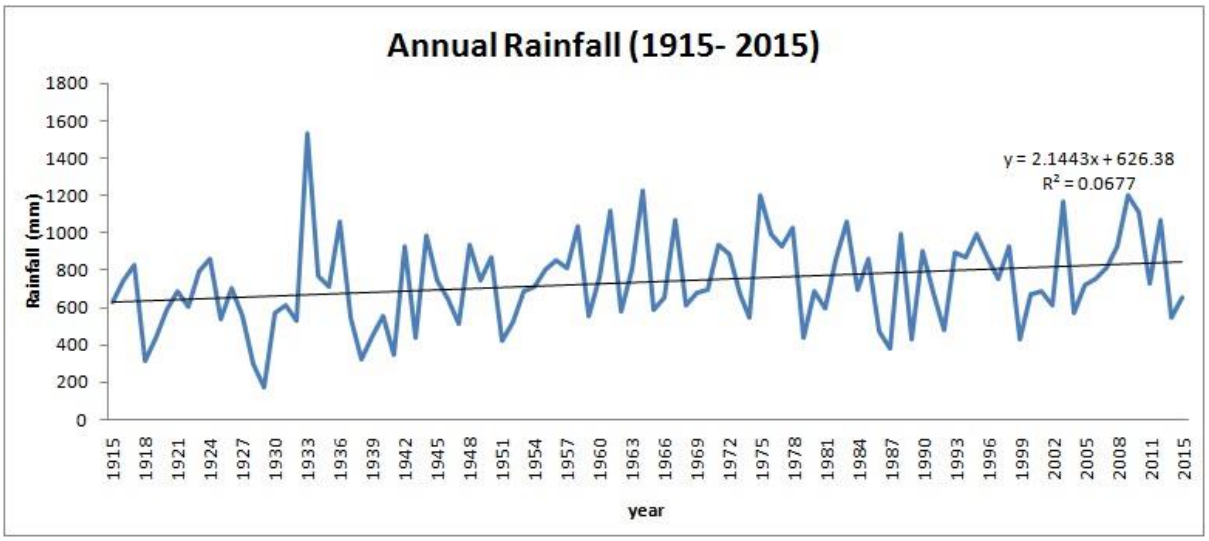


Figure 2: Annual Rainfall of 100 years

Since p-value is lower than the significance level alpha which is 0.05 as $p<\alpha$, thus the Null hypothesis stands rejected. The overall influence of the analysis of 100 year data comes out as acceptance of the alternative hypothesis H_1. Trend exists in the rainfall data series with Sen's slope 2.3.

CONCLUSION

It is concluded from the analysis of the past 100 years rainfall data that a positive trend exists. Findings of the analysis may be related to the impacts of Climate Change. Such relationship may be useful in predicting long term rainfall patterns and its impacts. The result and its analysis may be helpful for informed decision making and to dwell upon a policy which may include adaptation strategies in the wake of growing extreme hydro-meteorological events for proactive planning.

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