URBAN CLIMATE CHANGE RESILIENCE

Training Modules
for

Regional Training Institutions

February, 2015

ACCCRN
Asian Cities Climate Change Resilience Network
SUPPORTED BY
THE ROCKEFELLER FOUNDATION

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Module I

Concepts of Climate Change and UCCR

Introduction

This module focuses on conceptual understanding about climate change and its causes. It also brings clarity around the terms related to weather and climate change. The module also introduces the participants to the effect of climate change on our cities and the Intergovernmental Panel on Climate Change (IPCC) projections for urban areas (latest assessment report – AR5). The concluding part of module briefly deals with the concepts of adaptation and resilience and why they are important in combating the problems posed by climate change.

Key Messages

- Climate system is highly dynamic; even a small disturbance can trigger dangerous climatic events and cause adverse impacts on human society and the environment
- Climate change will happen on a global scale, but the effects will differ locally
- Urban areas are highly vulnerable to effects of climate change as they have dense population and are highly resource dependent
- Urban areas need immediate attention for adapting and mitigating towards climate change

Learning Objectives

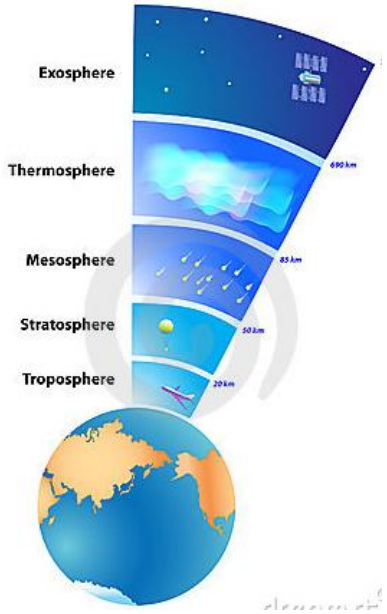
- Understand and appreciate the terms and concepts used in climate change and urban climate resilience
- Understand the causes of climate change and its impacts
- To create an understanding on the available scientific evidence on climate change

Session 1: Basic concepts and terminologies in climate change and UCCR

General terms and concepts

Atmosphere

The gaseous envelope surrounding the earth is called atmosphere. It has five layers which has different temperatures and composition: troposphere, stratosphere, mesosphere, thermosphere and exosphere. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases, such as argon (0.93% volume mixing ratio), helium and radiatively active greenhouse gases such as carbon dioxide (0.035%volume mixing ratio) and ozone. In addition, the atmosphere contains the greenhouse gas water vapour, whose amounts are highly variable but typically around 1% volume mixing ratio. The atmosphere also contains clouds and aerosols.[1]



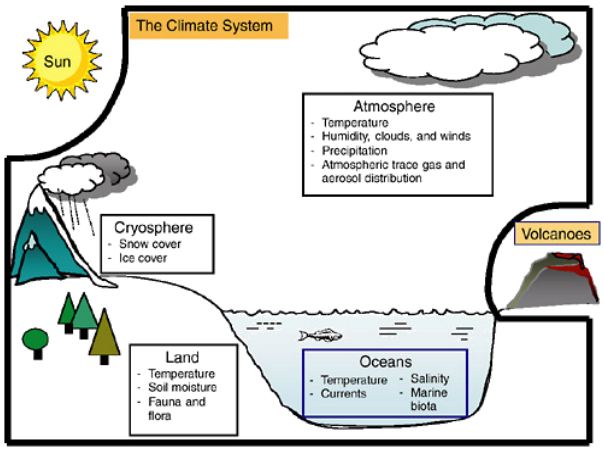


Figure 1: Atmospheric layers of the earth[2]; Figure 2: Climatic system[3]

Climate, Climatic system

Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time rang- ing from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind.

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[1] *IPCC, 2013: Annex III: Glossary [Planton, S. (ed.)]. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.)*

[2] http://www.dreamstime.com/stock-images-earth-s-atmosphere-layers-image22603834

[3] http://www.climateemergencyinstitute.com/state_of_climate.html

The climate system is the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations and anthropogenic forcings such as the changing composition of the atmosphere and land use change.[1]

Greenhouse gases and greenhouse gas effect

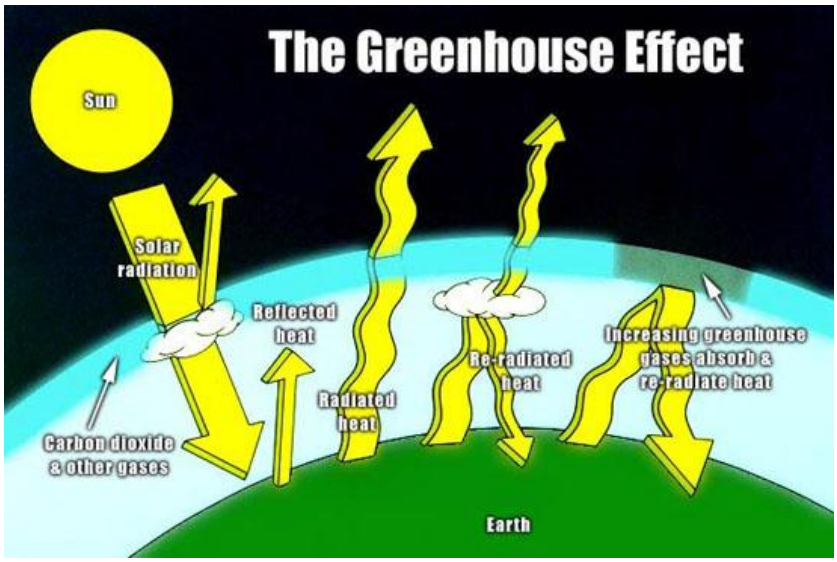


Figure 3: Greenhouse gas effect[4]

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Greenhouse gas effect: The infrared radiative effect of all infrared-absorbing constituents in the atmosphere. Greenhouse gases, clouds, and (to a small extent) aerosols absorb terrestrial radiation emitted by the Earth's surface and elsewhere in the atmosphere. These substances emit infra- red radiation in all directions, but, everything else being equal, the net amount emitted to space is normally less than would have been emitted in the absence of these absorbers because of the decline of temperature with altitude in the troposphere and the consequent weakening of emission. An increase in the concentration of greenhouse gases increases the magnitude of this effect; the difference is sometimes called the enhanced greenhouse effect. The change in a greenhouse gas concentration because of anthropogenic emissions contributes to an instantaneous radiative forcing.

[4] https://energyefficiencyinmotorsport.wordpress.com/about/home/

Surface temperature and troposphere warm in response to this forcing, gradually restoring the radiative balance at the top of the atmosphere.

Global carbon cycle

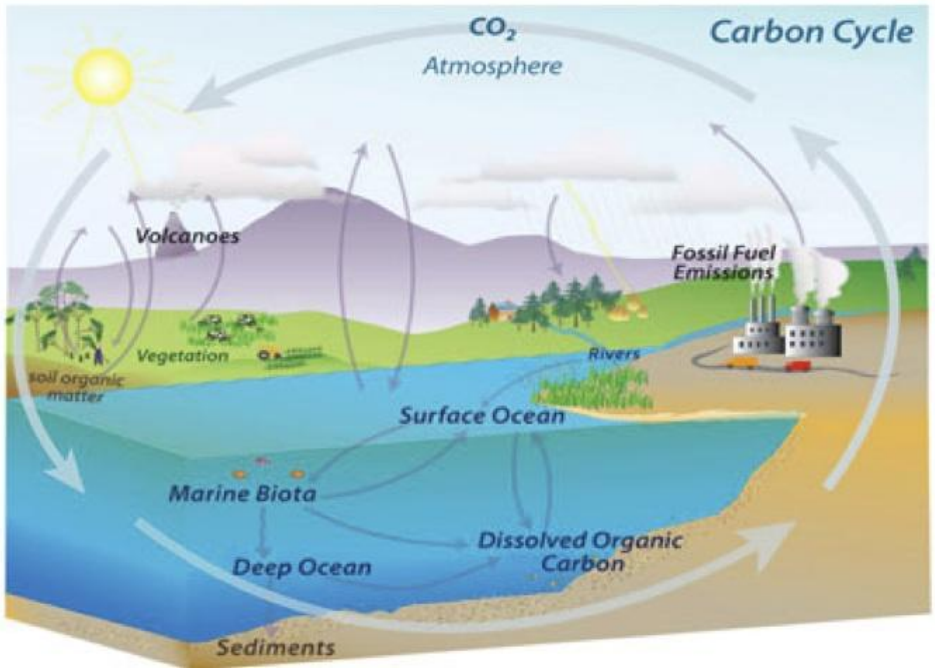


Figure 4: Carbon cycle[5]

The term used to describe the flow of carbon (in various forms, e.g., as carbon dioxide (CO_2)) through the atmosphere, ocean, terrestrial and marine biosphere and lithosphere.

Radiative forcing

Radiative forcing is the change in the net, down- ward minus upward, radiative flux (expressed in W m^{-2}) at the tropopause (the first atmospheric layer) due to a change in an external driver of climate change, such as, a change in the concentration of carbon dioxide or the output of the Sun. Sometimes internal drivers are still treated as forcings even though they result from the alteration in climate, for example aerosol or greenhouse gas changes in paleoclimates. The traditional radiative forcing is computed with all tropospheric properties held fixed at their unperturbed values, and after allowing for stratospheric temperatures, if perturbed, readjusting to radiative-dynamical equilibrium. Radiative forcing is called instantaneous if no change in stratospheric temperature is accounted for. The radiative forcing once rapid adjustments are accounted for is termed the effective radiative forcing. For the purposes of this report, radiative forcing is further defined as the change relative to the year 1750 and, unless otherwise noted, refers to a global and annual average value. Radiative forcing is not to be confused with cloud radiative forcing, which describes an unrelated measure of the impact of clouds on the radiative flux at the top of the atmosphere.[1]

[5] http://www.esrl.noaa.gov/gmd/outreach/carbon_toolkit/basics.html

Climate Change

Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate 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.' The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes[6].

Vulnerability

It is the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.[2]

Vulnerability means the characteristics of a person, group of persons (community) or their resources (property, infrastructure, environment or ecosystems) and the concerned situation that influences their capacity to anticipate, cope with, resist and recover from the impact of a natural or anthropogenic hazard. It involves a combination of factors that determine the degree to which someone's life, livelihood, property, ecosystems and other assets are put at risk by a discrete and identifiable event in nature and in society.[3]

Exposure

The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Climate Change Adaptation

The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Climate Change Mitigation

Mitigation refers to a sum of human interventions taken for reducing the risk (by preventing or containing the hazard, avoiding or reducing exposure, enhancing tolerance and reducing sensitivity, and inducing resilience and capacity), minimizing impact or effects of a hazard or threatening disaster situation, towards achieving objective of 'sustainable development'. Mitigation is generally categorized into two main types of activities, i.e., Structural and Non- Structural mitigation.

Structural mitigation refers to engineering measures or any physical construction to reduce or avoid possible impacts of hazards, through construction or modification activity for

[6] *IPCC WGII AR5 Summary for Policymakers*

hazard- resistant structures and infrastructure. Non-structural mitigation refers to policies, awareness generation, knowledge development, public commitment, legal interventions, methods and operating practices, including participatory mechanisms and the provision of information etc., which can reduce risk with related impacts.[7]

Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. [8]

Risk

The combination of the probability of an event and its negative consequences.[4]

Hazard

A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.[4]

Disaster

A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources [4]

Impacts

The term 'impacts' is used here primarily to refer to the effects of extreme weather, climate events and climate change on natural and human systems. Impacts refers to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate change or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes of climate change on geophysical systems, including floods, droughts, and sea-level rise, are a subset of impacts called 'physical impacts'.[2]

Forecasting[9]

- *Nowcasting*: A short range forecast having a lead time/validity of less than 24 hours
- *Short range forecasts*: Forecasts having a lead time/validity period of 1 to 3 days
- *Medium range forecasts*: Forecasts having a lead time/validity period of 4 to 10 days

[7] *Training Module Mainstreaming Climate Change Adaptation and Disaster Risk Reduction Into District Level Development Plans; National Institute of Disaster Management (NIDM) Ministry of Home Affairs (Govt. of India), New Delhi, India Gorakhpur Environmental Action Group (GEAG) Gorakhpur (Uttar Pradesh), India Institute for Social and Environmental Transition (ISET) Colorado, Boulder, USA*

[8] UNISDR Terminology, available on http://www.unisdr.org/we/inform/terminology, accessed on 14 October 2014

[9] Glossary, India Meteorological Department

- *Long range/Extended range forecasts*: Forecasts having a lead time /validity period beyond 10 days. Usually this is being issued for a season. IMD issues Long Range Forecast for southwest Monsoon rainfall and onset date for Kerala, Northeast Monsoon Rainfall and winter precipitation over Northwest India.
- *Local forecast*: In local forecast, whenever any weather phenomenon is expected, its intensity, frequency and time of occurrence is indicated. In the absence of a weather phenomenon, the local forecast describes anticipated sky conditions. The other parameters for which the local forecast issued include maximum temperature and/or minimum temperature, rainfall, wind and special phenomenon. It is valid for a radius of 50 km around the station and is updated 4 times in a day.

Winds

Atmospheric motion characterized by direction and speed. The direction of the wind is the direction from which the wind approaches the station (Example Northerly wind – Wind approaching the station from North)

- **Gales:** A gale is a very strong wind (34 to 47 knots)
- **Squall:** A sudden increase of wind speed by at least 3 stages on the Beaufort Scale, the speed rising to force 6 or more, and lasting for at least one minute is called a squall
- **Gust:** A rapid increase in the strength of the wind relative to the mean strength at the time

Weather phenomena:

One or two spells of rain	In a 24 hrs time, rainfall occurring with a frequency of 1-2 spells
A few spells of rain	In a 24 hrs time, rainfall occurring with a frequency of more than 2 spells but with well defined dry spells in between.
Intermittent rain	In a 24 hrs time, rainfall occurring with a frequency more than that defined in “A Few Spells” but is discontinuous and without presenting the character of a shower.
Drizzle	Liquid precipitation in the form of water drops of very small size (by convention, with radius of water drops between about 100 and 500 μm).
Rain	Liquid precipitation in the form of water drops of radius between about 500 and 2500 μm.
Shower	Solid or liquid precipitation from a vertically developed cloud is designated a shower and is distinguished from the precipitation, intermittent or continuous, from layer clouds. Showers are often characterized by short duration and rapid fluctuations of intensity.(by convention, with radius of water drops more than 2500 μm).
Hail	Solid precipitation in the form of balls or pieces of ice (hailstones) with diameters ranging from 5 to 50 mm or even more.

Thunderstorm	One or more sudden electrical discharges manifested by a flash of light (Lightning) and a sharp rumbling sound (thunder).
Duststorm	An ensemble of particles of dust or sand energetically lifted to great heights by a strong and turbulent wind. Surface visibility is reduced to low limits; the qualification for a synoptic report is visibility below 1000 m.
Mist	Mist is a phenomenon of small droplets suspended in air
Dew	Condensation of water vapour on a surface whose temperature is reduced by radiational cooling to below the DEW-POINT of the air in contact with it
Fog	Fog is a phenomenon of small droplets suspended in air and the visibility is one kilometer or less
Frost	Frost occurs when the temperature of the air in contact with the ground, or at thermometer-screen level, is below the freezing-point of water ('ground frost' or 'air frost', respectively). The term is also used of the icy deposits which may form on the ground and on objects in such temperature conditions (glaze, hoar-frost).
Haze	Haze is traditionally an atmospheric phenomenon where dust, smoke and other dry particles obscure the clarity of the sky.
Smog	A mixture of smoke and fog. It reduces the visibility.
Squally weather	Squally weather is meant to cover occasional or frequent squalls with rain or persistent type of strong gusty winds (mean wind speed not less than 20 knot) accompanied by rain. Such conditions are associated with low pressure systems or onset and strengthening of monsoon.

Terms used in sea area bulletins:

- **Tidal waves:** Tides are the rising and falling of Earth's ocean surface caused by the tidal forces of the Moon and the Sun acting on the oceans. Tidal phenomena can occur in any object that is subjected to a gravitational field that varies in time and space, such as the Earth's land masses.
- **Storm surges:** A storm surge or tidal surge is an offshore rise of water associated with a low pressure weather system, typically a tropical cyclone. Storm surge is caused primarily by high winds pushing on the ocean's surface. The wind causes the water to pile up higher than the ordinary sea level.
- **Swell waves:** Swell is wave motion in the ocean caused by a disturbance which may be at some distance away; the swell may persist after the originating cause of the wave motion has ceased or passed away. If often continues for a considerable time with unchanged direction, as long as the waves travel in deep water. The height of the waves rapidly diminishes but the length and velocity remain the same, so that the long, low, regular undulations characteristic of swell are formed.

State of sea:

Wave height in metres /Wind speed (kts)	
Calm (glassy)	0/0
Calm (ripped)	0-0.1/0
Smooth (waveless)	0.1-0.5/5-10
Slight	0.5-1.25/11-16
Moderate	1.25-2.5/17-21
Rough	2.5-4/22-27
Very Rough	4-6/28-33
High	6-9/34-47
Very high	9-14/38-63
Phenomenal over	14/>64

Monsoon

The seasonal reversal of winds and the associated rainfall with it is known as monsoon. This word is derived from the Arabic word "Mausim". The annual oscillation in the apparent position of the Sun between the Tropics of Cancer and Capricorn causes the annual oscillation in the position of the thermal equator (region of maximum heating) on the Earth's surface. This is associated with the annual oscillation of temperature, pressure, wind, cloudiness, rain etc. and is the cause of the monsoons. On the Earth's surface, there are asymmetries of land and Ocean. The differential heating of land and Ocean cause variations in the intensity of the annual oscillation of the thermal equator and hence regional variations in the intensity of monsoon. Prominent monsoon region includes Africa, South Asia and north Australia.

- **Southwest monsoon:** The south westerly wind flow occurring over most parts of India and Indian Seas gives rise to southwest monsoon over India from June to September.
- **Onset of southwest monsoon:** Commencement of rainy season with the establishment of monsoon flow pattern Normal date for Onset of southwest monsoon south Andaman Sea: 20 May, Kerala: 1 June, Mumbai: 10 June, New Delhi: 29 June, Entire country: 15 July
- **Withdrawal of southwest monsoon:** Cessation of southwest monsoon rainfall Normal date of withdrawal from extreme west Rajasthan is 15 September.
- **Northeast monsoon**: With the withdrawal of the southwest monsoon from the northern and central India and the northern parts of the Peninsula by the first half of the October, the wind pattern rapidly changes from south westerly to north easterly and hence the term "Northeast Monsoon" is used to describe the period October to December. This is

the major period of rainfall in south peninsula. In Tamil Nadu, this is the main rainy season, accounting for nearly 60 % of annual rainfall in the coastal districts.

Precipitation:

Precipitation whether it is rain or snow is expressed as the depth to which it would cover a horizontal projection of the earth's surface, if there is no loss by evaporation, run–off or infiltration and if any part of the precipitation falling as snow or ice were melted. It is expressed in the units of mm or cm.

- **Rainfall:** Liquid rainfall is expressed as the depth to which it would cover a horizontal projection of the earth's surface, if there is no loss by evaporation, run–off or infiltration. It is expressed in terms of mm or cm. It is assumed that the amount of precipitation collected in the gauge is representative of a certain area around the point where the measurement is made. The choice of the instrument and the site itself, the form and exposure of the measuring gauge, the prevention of loss of precipitation by evaporation and the effects of wind and splashing are some of the important points to be considered in the correct measurement of precipitation.

Weekly/Seasonal Rainfall Distribution:

Excess	**Percentage departure of realised rainfall from normal rainfall is + 20% or more.**
Normal	Percentage departure of realised rainfall from normal rainfall is between - 19 % to + 19 %.
Deficient	Percentage departure of realised rainfall from normal rainfall is between – 20 % to - 59 %
Scanty	Percentage departure of realised rainfall from normal rainfall is between – 60 % to - 99 %.
No rain	Percentage departure of realised rainfall from normal rainfall is– 100 %

Rainfall distribution on all India scale:

Normal	**Percentage departure of realised rainfall is within ± 10 % of the Long Period Average**
Below normal	Percentage departure of realised rainfall is < 10% of the Long Period Average
Above normal	Percentage departure of realised rainfall is > 10% of the Long Period Average
All India Drought year	When the rainfall deficiency is more than 10% and when 20 to 40% of the country is under drought conditions, then the year is termed as All India Drought Year
All India Severe Drought Year	When the rainfall deficiency is more than 10% and when the spatial coverage of drought is more than 40% it is called as All India Severe Drought Year

Spatial distribution of rainfall:

Widespread (most places)	75 % or more number of stations of a region (usually a meteorological sub-division) reporting at least 2.5 mm rainfall.
Fairly widespread (many places)	51% to 74 % number of stations of a region (usually a meteorological sub-division); reporting at least 2.5 mm rainfall.
Scattered (at a few places)	26 % to 50% number of stations of a region (usually a meteorological sub-division) reporting at least 2.5 mm rainfall.
Isolated (at isolated places)	25% or less number of stations of a region (usually a meteorological sub-division) reporting at least 2.5 mm rainfall.
Mainly dry	No station of a region reported rainfall

Intensity of Rainfall:

No rain	Rainfall amount realised in a day is 0.0 mm
Trace	Rainfall amount realised in a day is between 0.01 to 0.04 mm
Very light rain	Rainfall amount realised in a day is between 0.1 to 2.4 mm
Light rain	Rainfall amount realised in a day is between 2.5 to 7.5 mm
Moderate rain	Rainfall amount realised in a day is between 7.6 to 35.5 mm
Rather heavy rain	Rainfall amount realised in a day is between 35.6 to 64.4 mm
Heavy rain	Rainfall amount realised in a day is between 64.5 to 124.4 mm
Very heavy rain	Rainfall amount realised in a day is between 124.5 to 244.4 mm
Extremely heavy rain	Rainfall amount realised in a day is more than or equal to 244.5 mm
Exceptionally heavy rainfall	This term is used when the amount realised in a day is a value near about the highest recorded rainfall at or near the station for the month or season. However, this term will be used only when the actual rainfall amount exceeds 12 cm.
Rainy day	Rainfall amount realised in a day is 2.5 mm or more.

- **Snowfall:** Snowfall is measured either as the depth of snow which has fallen in a stated period, or melted and measured as water. The depth of snow is usually measured in millimetres and its water equivalent in millimetres and tenths obtained by dividing the snow depth by 10, assuming the density of snow as 0.1.

Temperature:

Normal	Departure of minimum/maximum temperature from normal is + 1°C to -1°C
Above normal	Departure of minimum/maximum temperature from normal is + 2°C
Appreciably above normal	Departure of minimum/maximum temperature from normal is +3° C to +4° C. The normal maximum temperature should be 40° C or less
Markedly above normal	Departure of minimum/ maximum temperature from normal is from + 5°C to+ 6°C. The normal maximum temperature should be 40° C or less
Hot day	Whenever the maximum temperature remains 40° C or more and minimum remains 5° C or more above normal, provided, it is not satisfying the heat wave criteria.
Heat wave	Departure of maximum temperature from normal is + 4°C to + 5°C or more for the regions where the normal maximum temperature is more than 40°C and departure of maximum temperature from normal is + 5°C to + 6°C for regions where the normal maximum temperature is 40°C or less (Heat Wave is declared only when the maximum temperature of a station reaches at least 40°C for plains and at least 30°C for Hilly regions). When actual maximum temperature remains 45°C or more irrespective of normal maximum temperature, heat wave is declared.
Severe heat wave conditions	Departure of maximum temperature from normal is +6 °C or more for the regions were the normal maximum temperature is more than 40 °C and +7 °C or more for regions were the normal maximum temperature is 40 °C or less. (Heat Wave is declared only when the maximum temperature of a station reaches at least 40° C for plains and at least 30° C for Hilly regions)
Cold day	In the plains of north India, foggy conditions prevail during winter for several days or weeks. The minimum temperature on these days remains above normal, while maximum temperature remains much below normal. This creates cold conditions for prolonged period. When maximum temperature is less than or equal to 16°C in Plains, it will be declared "Cold Day".
Cold wave	Wind chill factor is taken into account while declaring the cold wave situation. The wind chill effective minimum temperature (WCTn) is defined as the effective minimum temperature due to wind flow. For example, when the minimum temperature is 15°C and the wind speed is 10 mph, WCTn will be 10.5 °C. Departure of WCTn from normal minimum temperature is from –5°C to–6°C where normal minimum temperature > 10°C and from –4°C to –5°C elsewhere, Cold Wave is declared. For declaring cold wave etc. WCTn only is used and when it is < 10°C only, cold wave is considered (this criteria does not hold for coastal stations). Also cold wave is declared when WCTn is < 0°C irrespective of the normal minimum temperature for those stations.

Severe cold wave	Departure of WCTn from normal minimum temperature is –7°C or less for the regions where normal minimum temperature is > 10°C and –6°C or less elsewhere. (departure of WCTn from normal minimum temperature is from –5°C to –6°C where normal minimum temperature > 10°C and from – 4°C to –5°C elsewhere)

Synoptic systems:

- **Low pressure area**: Area in the atmosphere in which the pressures are lower than those of the surrounding region at the same level and is represented on a synoptic chart by a system of one closed isobar (wind speed on the surface < 17 Kts when the system is at sea or one closed isobar in the radius of 3 Deg. from the centre over land)
- **Depression**: Intense low pressure system represented on a synoptic chart by two or three closed isobars at 2 hPa interval and wind speed from 17 to 27 Kts at sea and two closed isobars in the radius of 3 Deg. from the centre over land.
- **Deep depression**: Intense low pressure system represented on a synoptic chart by two or three closed isobars at 2 hPa interval and wind speed from 28 to 33 Kts at sea and three to four closed isobars in the radius of 3 Deg. from the centre over land
- **Cyclonic storm**: Intense low pressure system represented on a synoptic chart by more than four closed isobars at 2 hPa interval and in which the wind speed on surface level is in between 34 – 47 Kts.

Other terms:

- **El-nino and La-nina:** The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. It has since become identified with a basin-wide warming of the tropical Pacific Ocean east of the dateline. This oceanic event is associated with a fluctuation of a global- scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere–ocean phenomenon, with preferred time scales of two to about seven years, is known as the El Niño-Southern Oscillation (ENSO). It is often measured by the surface pressure anomaly difference between Tahiti and Darwin or the sea surface temperatures in the central and eastern equatorial Pacific. During an ENSO event, the prevailing trade winds weaken, reducing upwelling and altering ocean cur- rents such that the sea surface temperatures warm, further weakening the trade winds. This event has a great impact on the wind, sea surface temperature and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and in many other parts of the world, through global teleconnections. The cold phase of ENSO is called La Niña.[1]
- **Critical Infrastructure:** The assets, systems and networks, whether physical or virtual that are extremely vital, that their destruction will have a debilitating effect on the national economic security, national public health and safety or a combination of thereof.[10]

[10] http://www.dhs.gov/what-critical-infrastructure, accessed on 7 November 2014

The term critical infrastructure is typically used by governments to describe assets that are essential for the functioning of the society, such as telecommunication, transportation, water supply, public health services etc.

- **Climate extremes (Extreme weather or climate event):** The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as 'climate extremes' [11]

Session 2: Overview of Climate Variability and Climate Change

What is climate change and climate variability?

Climate, in a narrow sense, can be defined as the average weather conditions for a particular location and period of time. In a wider sense, it is the state of the climate system. Climate can be described in terms of statistical descriptions of elements such as temperature, precipitation, atmospheric pressure, humidity and winds or through combinations of elements, such as weather types and phenomena that are typical to a location, region or the world for any period of time.[12] Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time.[13] Seasons are characterized by particular weather patterns over particular periods in the year. It is mainly caused by the earth's changing position with respect to the sun.

The difference between three is also depicted in the figure below:

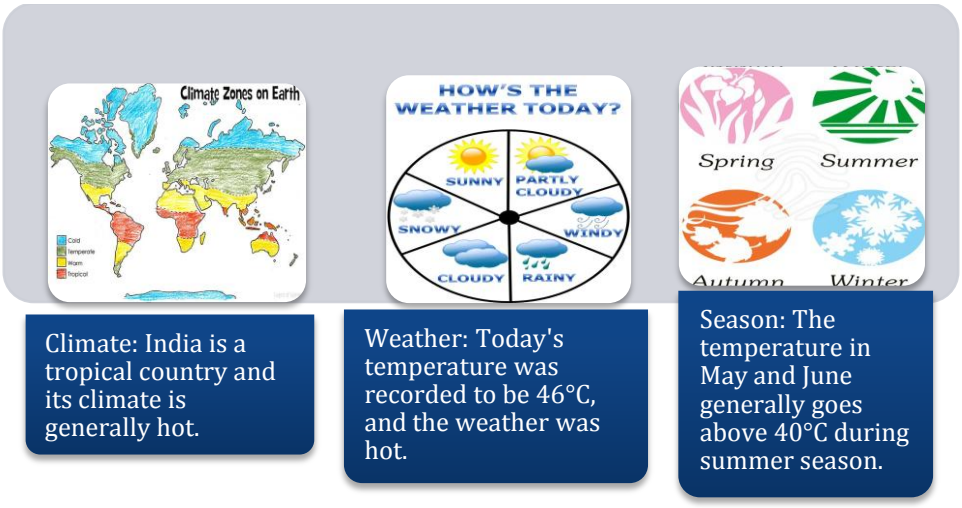


Figure 5: Climate, Season and Weather

Variability in the climate system is present at all times. Large systems in climate such as the atmosphere, oceans, ice sheets etc. are dynamic and have variability of their own. *"Distinguishing between the effects of external influences and internal climate variability*

[11] https://www.ipcc.ch/pdf/special-reports/srex/SREX_FD_SPM_final.pdf, accessed on 7 November 2014
[12] http://www.imd.gov.in/section/nhac/dynamic/FAQ_monsoon.htm, accessed on 7 November 2014
[13] http://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html, accessed on 7 November 2014

requires careful comparison between observed changes and those that are expected to result from external forcing".[14]

Keeping in mind the dynamism of the Indian sub-continent, it is necessary to understand the basic principles which govern our climate. India is a tropical country with landscapes ranging from mountainous, coastal, desert to plateaus. It also experiences varied seasons which makes it vulnerable to climate change. Risk reduction and adaptation measures that would help us in combating the effects of climate change are needed.

To help us better understanding of the vulnerability of the Indian sub-continent, we delve into some details about the dynamism of the Indian seasons. Later in this section we talk about the Intergovernmental Panel on Climate Change (IPCC) and how climate change specifically affects urban areas.

Dynamism of Indian Seasons

India is home to diverse climatic regions and is strongly influenced by the Himalayas and the Thar Desert. The Himalayas act a barrier to the strong wind currents from Central Asia, keeping most of the Indian subcontinent warmer than many locations at a similar altitude. The land-locked regions experience both hot and cold seasons. Whereas the coastal regions experience frequent rains and more or less uniform warm temperature throughout the year. Rains are the most important feature controlling the Indian climate because about 75% of the rainfall is received during the short span of 4 months (June to September).[15]

Table 1 gives a brief description of the four main seasons experienced in India[6]:

[14] Climate Change 2007, Working Group I, The Physical Science Basis, http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch9s9-1.html, accessed on 12 August 2014

[15] *Climate Profile of India, S.D. Attri and Ajit Tyagi, IMD, MoES, 2010*

Table 1: Seasons and their description

Season	Months	Characteristics	Temperature range	Rainfall pattern	Other features
Winter/Cold weather season	December, January and February (for north-western part of the country) January and February for rest of India.	Clear skies, low humidity and temperature, large day time variations of temperature.	Mean temperature 14°C to 27°C. Mean daily minimum temperature ranges from 22 °C in the extreme south, to 10 °C in northern plains.	Rains occur over the western Himalayas, the extreme north-eastern parts, Tamil Nadu and Kerala.	Western disturbances and associated trough in westerlies are main rain bearing system in northern and eastern parts of the country.
Pre-monsoon/Summer/Hot weather/Thunder storm season	March, April and May	Cyclonic storms are common.	Peninsular India records daily mean temperatures of 30 - 35°C. Central India records daytime maximum temperatures to about 40 °C. North and north-west regions record 45 °C.	Thunderstorms associated with rain and hails are experienced.	Hot and dry winds accompanied with dust winds (*andhis*) blow frequently over the plains of north-west India.
South-west/Summer Monsoon season	June, July, August and September	Most significant feature of Indian climate	Temperatures are generally below 40 °C	Rainfall varies from less than 75 days over West Rajasthan, to more than 120 days over the south-western regions of the country contributing about 75% of the annual rainfall.	Rainfall patterns observe inter-annual and intrannaul variations. Rains are also affected by global phenomena such as El-nino, sea surface temperature and snow cover etc.
Post-monsoon/Northeast/Retreating south west monsoon	October, November, December	Day temperatures start falling rapidly. Coastal areas are also affected by storm surges.	Temperature declines from about 38°C in October to 28°C in November	Coastal Andhra Pradesh, Rayalaseema, Tamil Nadu, Kerala and south interior Karnataka receive 35% of their annual total in these months.	Humidity levels are low with generally clear skies

Understanding the causes of Climate Change

The earth's temperature depends on the amount of energy entering and leaving the system. The earth absorbs the incoming solar radiation – which warms the earth. Some of the energy is retained within the earth and some is reflected back. This balance is maintained naturally; when this balance gets disturbed it leads to changes in the earth's climate system.

Changes in atmospheric concentrations of greenhouse gases (GHGs) and aerosols, land cover and solar radiation alter the energy balance of the climate system. Carbon dioxide is the major GHG that influences the earth's warming balance along with methane (CH_4) and nitrous oxide (N_2O).

As the concentration of GHGs increases, more heat is retained by the earth's surface than what is normally required which leads to warming of the earth. The IPCC has identified five major areas of concern as the temperature rises[16] [17]:

- Unique and threatened systems: As economies we are growing but we are highly dependent on natural systems for it. Increase in urban areas with concentrated populations and a fragile natural environment leaves us more vulnerable to effects of a changing climate.
- Extreme weather events: Increase in incidences of floods, droughts, heat waves have been reported throughout the country.
- Distribution of impacts: the impacts of any changes in the climate are seen on fragile areas and populations first.
- Global aggregate impacts: the earth on the whole is warming, and there is no escaping this fact.
- Disasters: Increased losses due to the disasters have been seen due to excessive interference with the natural systems.

Did you know?

"Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. In the Northern hemisphere, 1983 – 2012 was likely the warmest 30 – year period of the last 1400 years."

IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The

The impacts of these areas of concern will increase the risk of death, injury, health crisis and/or loss and disruption of livelihood in low lying coastal zones due to storm surges, coastal flooding and sea level rise and, in large urban populations due to inland flooding. Risks due to extreme weather events leading to breakdown of infrastructure networks and

[16]The IPCC's Fifth Assessment Report, What's in it for South Asia? – Executive Summary, published by Climate and Development Knowledge Network (CDKN), 2014

[17] IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability – Summary for Policymakers.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

critical services such as electricity, water supply and health and emergency services are also linked to impacts across these areas of concern.

The diagram in the next page elaborates the complex interlinkages climate change process has with human activities, climatic characteristics and disasters.

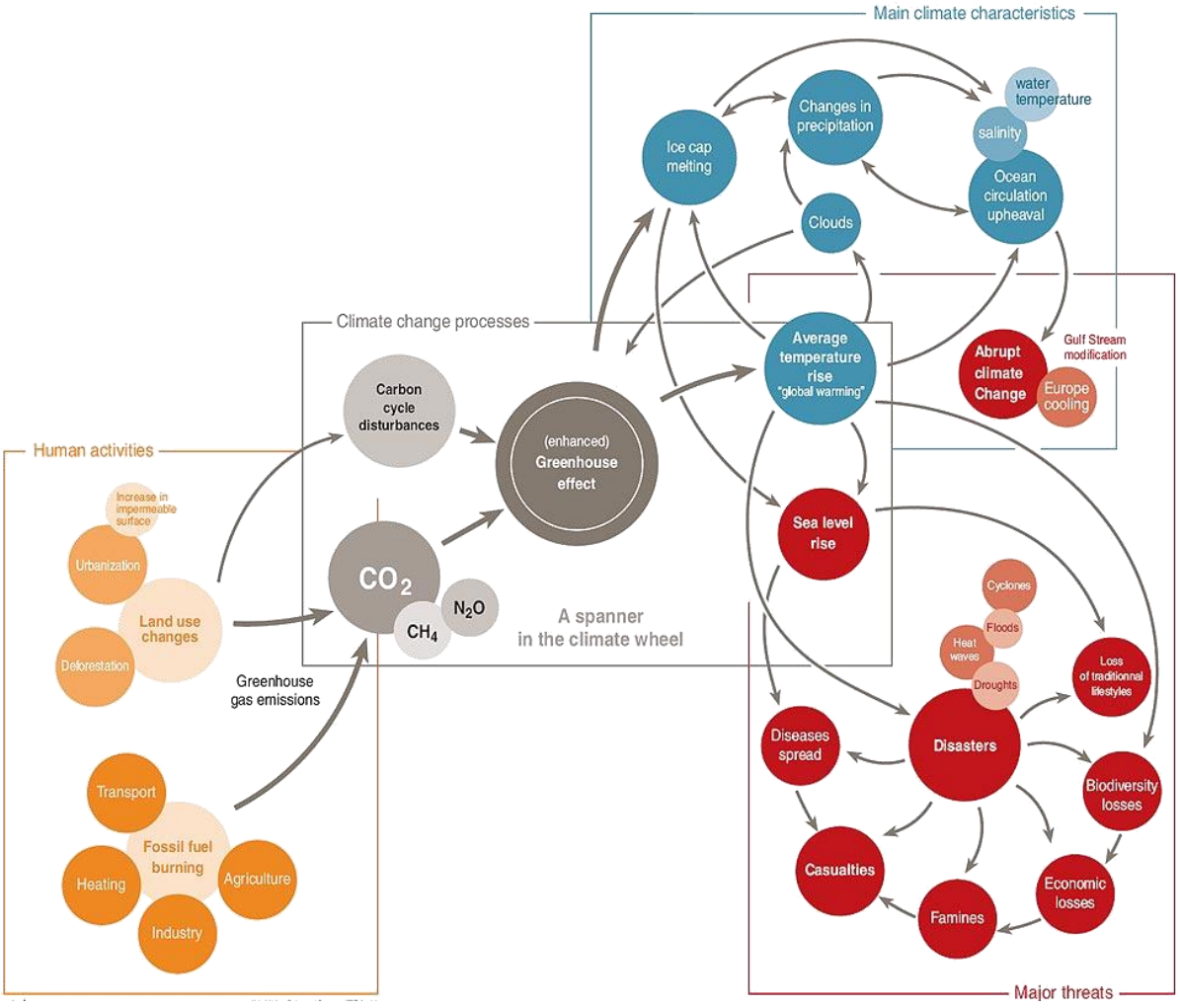


Figure 6: Interlinkages between climate change process, disasters and human activities[18]

What is the Intergovernmental Panel on Climate Change (IPCC) all about?

The IPCC is the leading international body for assessment of climate under the patronage of the United Nations (UN). It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It is an intergovernmental body and membership is open to all member countries of the UN and WMO. Currently there are 195 members of the IPCC.

[18] http://www.grida.no/graphicslib/detail/climate-change-processes-characteristics-and-threats_15a8

The main notable points are:

- Scientists from all over the world contribute to the work of the IPCC, voluntarily
- Review is the most important part of the panel's functioning and ensures complete assessment of the information available
- Member nations governments participate in the review process
- The IPCCs findings are rigorous and contain balanced scientific information, because of its intergovernmental nature
- The work of the organization is *"policy-relevant and yet policy neutral, never policy prescriptive"*[19]

The IPCC is currently organized in three working groups and a Task force. Working Group I deals with "The Physical Science Basis of Climate Change", Working Group II with "Climate Change Impacts, Adaptation and Vulnerability" and Working Group III with "Mitigation of Climate Change". The main objective of the Task Force on National Greenhouse Gas Inventories is to develop and refine a methodology for the calculation and reporting of national greenhouse gas emissions and removals. The diagram in the next page depicts the working structure of the IPCC.

Figure 7: The IPCC working structure[20]

The IPCC releases its review in the form of assessment reports, and its latest report – Fifth Assessment Report (AR 5) has been released in 2013. The AR5 provides a clear and up to date view of the current state of scientific knowledge relevant to climate change. It consists of three Working Group (WG) reports and a Synthesis Report (SYR) which integrates and synthesizes material in the WG reports for policymakers. The SYR is likely to be released in October 2014. The WG reports have been released.

[19] http://www.ipcc.ch/organization/organization.shtml , viewed on 11 August 2014
[20] http://www.ipcc.ch/organization/organization_structure.shtml

In assessing the future climate change, the AR5 presents four scenarios, known as the Representative Concentration Pathways (RCPs).The scenarios are[12]:

- RCP 2.6 – This is the low-emission scenario and assumes substantial and sustained reductions in greenhouse gas emissions
- RCP 8.5 – This is the high-emission scenario and assumes continued high rates of emissions
- RCP 4.5 and RCP 6.0 – Both these scenarios are intermediate ones and assume some stabilization in emissions

The IPCC however has not indicated whether a particular policy or behavioural choices would lead to a particular scenario. The scenarios show the result of different levels of emissions of greenhouse gases, from the present day to 2100, on global warming. All the scenarios have considered the concentration of carbon dioxide higher in 2100, than they are today.[12] However, irrespective of the future emissions the world is continuously warming due to the emissions that are already in the atmosphere. The combined effect of current GHGs in atmosphere and future emissions the climate is expected to change, creating risks both for humans and nature.

Climate Change in Urban Context

The IPCC AR5 reiterates the fact that urban areas are vulnerable to climate change and many risks are concentrated in these areas. Factors that pose risks in urban areas are heat stress, extreme precipitation, inland and coastal flooding, landslides, air pollution and drought. These risks will affect people at large, assets, economies and ecosystems. These risks are amplified for those lacking essential infrastructure and services or living in poor quality housing and exposed areas.

70 Indian cities are expected to have more than 1 million inhabitants, by 2025"

UCCR policy brief, IRADE, 2013-14

Threats posed by climate change in urban areas

Increasing population and expanding urban areas increases the vulnerability of urban areas to natural disasters. The location of many urban areas with large population and critical economic assets in high-risk zones contributes to the increased attention given to impacts in urban areas of disasters induced or enhanced by climate change (Table 2).

In case of fast paced developing countries such as India; the size and vulnerability of informal settlements, generally built in unstable areas such as coastal zones, flood-prone planes and ravines, and geologically unstable slopes, greatly increases their vulnerability.[21]

[21] Cities and Climate Change, Anthony G. Bigio, available at http://unfccc.int/files/cooperation_and_support/capacity_building/application/pdf/wbcitiescc.pdf, accessed on 13 August 2014

Table 2: The main threats to the urban areas due to climate change

Sea Level Rise    This is the most fundamental challenge that urban settlements face from global warming. The threat will likely increase due to the ongoing influx of people and economic assets into coastal zones. At risk are entire sections of coastal cities and their infrastructure, beaches subject to erosion, river floors in estuarine zones subject to sedimentation, and wetlands and tidal flats subject to flooding. Furthermore, groundwater risks increased salinization, and coastal aquifers risk diminishing, affecting fresh water supplies and peri-urban agriculture.
Tropical cyclones    Increasingly frequent and intense tropical and extra-tropical cyclones will likely cause severe wind damage and storm surges which, compounded with a rise in sea level, are expected to become a severe problem for low-lying coastal regions and cities. Ports and other coastal infrastructure are especially at risk.
Flooding and Landslides    Expected increases in the scale, intensity and frequency of rainfall in most developing countries will severely strain or overwhelm the storm drainage systems of many urban centers. This could lead to periodic flooding of low-lying areas as well as landslides and mud-slips on geologically unstable slopes, often subject to informal settlements. Cities built next to rivers and on reclaimed lands in riverbed planes will be prone to additional inundations.
Water quality and shortage    Urban flooding damages water treatment works and flood wells, pit latrines and septic tanks. Sewage treatment systems and solid waste disposal areas can also be affected, contaminating water supplies. Where overall rainfall decreases, droughts will likely compromise the replenishment of the water tables, the normal sources of water supply.
Heat and cold waves    Intense episodes of thermal variability could severely strain urban systems by adding an environmental health risk for more vulnerable segments of the population, imposing extraordinary consumption of energy for heating and air conditioning where available, and disrupting ordinary urban activities.

Drought

Dourhgt conditions appear when there is scanty or no rainfall over a long period and there is severe shortage of water. It can have serious health, impacts, shoratge of food supplies – even famine, social conflicts and also migration.

Why is India at risk?

Figure 8 Vulnerability of India's urban areas (Policy Brief TERI, March 2014)

India is urbanizing rapidly and is accelerating at a never seen pace before. However its cities are exposed to various natural hazards due to its diverse physiographic and meteorological conditions. Indian cities are facing additional risk due to climate induced extreme events such as floods, droughts, heat and cold waves. An increasing concentration of population coupled with extreme events, results in high damages to assets, interruptions in business continuity opportunity losses, loss of lives, displacement of populations, which is further enhanced by economic and social vulnerability. [22]

Over 40 million hectares of the country's area is prone to floods; and the average area affected by floods annually is about 8 million hectares, where as 68% of area is susceptible to drought Climate change also influences the micro-climate of cities, leading to extreme weather conditions such as heat waves, cold waves etc. apart from floods and droughts, which could cause health problems and other issues related to the quality of life. Cities such as Mumbai, Kolkata, Chennai, Surat and Thiruvananthapuram, which are low-lying and densely populated are vulnerable to cyclones and associated hazards such as storm surges, high winds and heavy rainfall.[12]

The riverine cities like Allahabad, Surat, Gorakhpur and many alike are highly exposed to floods. River deltas are among the world's most valuable and heavily populated areas. With large populations, living in the coastal areas and flood plains, Indian cities need particular attention as millions become simultaneously vulnerable. The accelerated development of

[22] Urban Climate Change Resilience, Policy Brief, 2013 – 14, published by Integrated Research for Action and Development (IRADE), accessed online at http://www.irade.org/Policy%20Brief%202%20IRADe_Urban%20Vulnerability%20&%20Risk-1.pdf , on 12 August 2014

Indian cities have neglected the adequate planning on natural drainage, ecology and environment; resulting in a crisis situation.[14] The urban poor too face increased risks, especially slum and squatter settlements dwellers, partly due to their increased exposure to natural hazards and partly due to lower adaptive capacity. Permanent changes to local ecosystems induced by climate change such as the salinization of ground-water and river estuaries might also alter the local economic base. If the cities are to make progress in paving the way for climate resilient urban development, they must improve their understanding of the natural hazards and climate change induced risks and the factors that influence vulnerability.

It is critical for the cities to better understand these risks and how they vary across time scales and spatially across geographical location It is has become necessary for urban areas to adopt adaptation approaches in view of likely future climate change impacts.

Ringing alarm bells

Recent large scale natural disasters, for example the two large cyclones - Phailin and Helen – which hit the states of Andhra Pradesh and Odisha within a period of two months and the flash floods that hit Uttarakhand in June 2013 call for immediate attention towards making our cities climate proof.

Even though these events cannot be attributed completely to impacts of global climate change, their severity and the volume of damage that they have caused demonstrate that actions for resilience and climate-proofing settlements are immensely important. These events call for better planning and preparedness to deal with new and unforeseen climatic changes in the future. [23]

Session 3: Understanding adaptation and resilience for urban centres in India in relation to Climate Change

Adaptation and Resilience – the key drivers

Adaptation as we have noted is the *process of adjustment to actual or expected climate and its effects*[12]

Resilience is the capacity of the system to cope with changes in climate or hazardous events in such a manner that it maintains its essential functions.

The ultimate goal of the city is to ensure the continuity and advancement of economic prosperity, business success, environmental quality and human well-being despite the threats it faces. In a globalized world only the most resilient cities will remain economically competitive and capable of adapting to continuously changing conditions.[24]

Resilience is the capacity of individuals and institutions to survive and grow within a city despite the chronic stresses and acute shocks it faces. Chronic

[23] Climate Proofing Indian Cities: A policy perspective, The Energy and Resources Institute, March 2014, accessed online at http://www.teriin.org/policybrief/docs/Urban.pdf , on 12 August 2014

[24] Toolkit for Resilient Cities, Executive Summary, available online at http://w3.siemens.com/topics/global/en/sustainable-cities/resilience/Documents/pdf/Toolkit_for_Resilient_Cities_Summary.pdf , accessed on 12 November 2014

stresses include chronic food and water shortages, an inefficient public transport system etc. Acute shocks are sudden stresses such as floods, earthquakes, landslides etc. Resilience enables cities to evaluate their exposure to specific shocks and stresses and develop a plan to address those challenges, and to respond to them effectively. It is about making cities better, for both short and long-term, for everyone. [25]

Developing resilience framework for a city requires a complete understanding of the city and the drivers that contribute to its resilience. There are four essential dimensions of urban resilience:

1. **Health and well-being:**

- The city should be equipped to meet basic needs of its people especially in times of crisis, and ensure that they have access to basic resources necessary to survive – food, water and sanitation, energy and shelter etc.
- Provide access to effective public healthcare and emergency services

2. **Economy and society:**

- Adequate financial resources and an ability to attract business investment makes the economy vibrant, and makes the city self sufficient in the time of a crisis
- A sense of collective identity and mutual support is important for a community

3. **Infrastructure and environment:**

- Natural systems like wetlands, mangroves and sand dunes or built infrastructure like sea walls or levees should be protected as they reduce the physical vulnerability of the systems
- Physical infrastructure such as roads and bridges, communication networks etc. should be designed in a way that they can withstand floods and other natural disasters

4. **Leadership and strategy**

- Access to information to all stakeholders, and ensure that everybody is well informed, capable, and involved in their city.
- City plans and projects should address the city's needs

Conclusion

Cities play a key role as generators of economic wealth. It is important that they have the capacity to create well-being, especially for the urban poor who are the most vulnerable. There exists a strong link between urban poverty, vulnerability and climate change. The

[25] 100 resilient cities, available online at http://www.100resilientcities.org/resilience, accessed on 18th November 2014

poor are affected more due to their increased exposure to hazards and limitations in their ability to respond due to limited resources.[26]

Making our cities resilient to the effects of climate change will require sustained efforts from all sectors. It can only be achieved through collective contribution of multiple interventions and actions over time, and the ability of individuals and institutions to imbibe learning and experience for future.

Are adaptation and resilience linked?

"Adaptation and resilience are two concepts originally developed in dissimilar problem contexts but which are of significant importance for our ability to respond to a changing climate. While both concepts encompass processes of change they differ in several important areas. First, although adaptation responses can help to build resilience, they just as easily can undermine resilience. Second, the magnitude of change may be outside our abilities to adapt, and thus it is not always possible to maintain system resilience. Finally, resilience will differ from case to case basis and is not normative. The desirability of a resilient system, or community, must be considered in light of social goals and how benefits and risks are distributed. Better appreciation of the relationship between the concepts of adaptation and resilience will provide more effective tools to plan for, and respond to, current and future change."

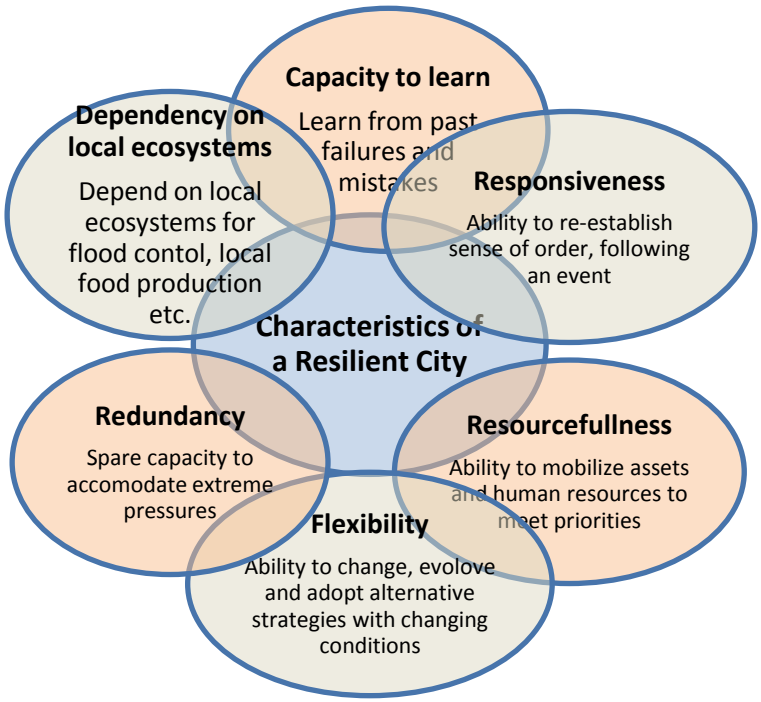


Figure 9: Characteristics of a resilient city
(Adapted from Jo da Silva, Sam Kernaghan and Andres Luque, 2012[20])

[26] Jo da Silva, Sam Kernaghan and Andres Luque, 2012, A systems approach to meeting the challenges of urban climate change, International Journal of Urban Sustainable Development, 4:2, 125 – 145, DOI: 10.1080/19463138.2012.718279, accessed online on 27 October 2014

Module II

Urbanization process, climate change risks, vulnerabilities & impacts

Introduction

The module reviews the trends of urbanisation at global, national and city levels. It then highlights the two way connect between the process of urbanisation and climate change – causes, risks, impacts, vulnerability and exposure at local, regional and global scales. Impacts will be discussed as direct and indirect in terms of increased temperatures, drought, water scarcity, sea level rise, storm surge, inland flooding and human health. So far, we have discussed vulnerability as a term, which will be further detailed out as a concept in this module; at system, community and sectoral levels. The module also introduces tools to assess vulnerability and risks. It also talks about the sensitivity and exposure in various urban sectors: Water supply, waste water & sanitation; Energy supply; Transportation & Telecommunications; Built environment, recreation & heritage sites; Green infrastructure and Health & social services.

Key Messages

1. As human race has entered the *Anthropocene*, urbanisation has become the truth of present and future.
2. Changes associated with urbanisation (deforestation and GHG emission) are driving changes in climate system.
3. Changing climate system is adversely impacting human lives, society, economy and environment.
4. Cities being the centre where populations and resources concentrate are all the more susceptible to such adverse impacts and thus need to prepare for future climate change.

Learning Objectives

- To understand the bidirectional relationship of urbanisation and climate change
- To develop an understanding of direct and indirect impacts of climate change in urban areas and hence, different urban sectors
- To know and comprehend the risks of climate change in urban areas and their mapping
- To be able to assess climate change vulnerabilities in different urban sectors
- To be aware of various exposures and sensitivity of different urban sectors

Urbanisation

Urban Age

The current era is often termed as ***Urban Age*** as we are witnessing the largest wave of urbanisation in human history. 54 % of world's total population currently resides in urban areas. This percentage was 30% in 1950 and is expected to be 66% by 2050. North America is today the most urbanised region with 82% people living in urban areas, followed by Latin America and the Caribbean (80% each), and finally Europe (73%). Asia and Africa are predominantly rural with 48% and 40% urban population. Though, in future these continents are expected to urbanise faster than other regions of the world and are projected to be 64% and 54% urban by 2050. Despite its lower levels of urbanisation, Asia houses 53% of world's urban population which is expected to be 90% by 2050[27]. Globally mega cities are capturing much of public attention, though new growth is more expected in the smaller yet faster growing towns and cities. This is in spite the fact that such cities have a general dearth of resources to the magnitude of the changes taking place.

India may not be a highly urbanized country (31% as per 2011 census) like most of the developed countries, but in absolute terms India's urban population is 37,71,05,760 which is more than the total population of US. The picture will change as six hundred million new urban citizens are expected to be added by 2050[28], which will require India to address simultaneous and complex needs for effective governance, good infrastructure, social protection and environmental management. As per research by McKinsey Global Institute (MGI), cities in India could generate 70 percent of net new jobs by 2030, produce more than 70 percent of Indian GDP, and drive a near fourfold increase in per capita incomes in the country[29].

- ✓ **Tokyo** is the world's largest city with 38 million inhabitants, followed by **Delhi** with 25 million, **Shanghai** with 23 million, and **Mexico City**, **Mumbai** and **São Paulo**, each with around 21 million inhabitants.
- ✓ By **2030**, the world is projected to have 41 mega-cities with more than 10 million inhabitants. **Tokyo** is projected to remain the world's largest city in 2030 with 37 million inhabitants, followed closely by **Delhi** where the population is projected to rise swiftly to 36 million.
- ✓ The **fastest growing urban agglomerations** are medium-sized cities and cities with less than 1 million inhabitants located in Asia and Africa.

Process of Urbanisation

Urbanisation is often described as increase in proportion of people living in urban areas (town and/cities). In principle, there are a number of factors that are driving urbanisation at such huge scales and swift pace. Cities generate jobs and income opportunities. They provide more encouraging backdrop and resources for resolving social and environmental issues. Cities can efficiently deliver education, health care and other services owing to their sheer scale and proximity. They also propound prospects for social mobilization and

[27] World Urbanisation Prospects, 2014
[28] http://iihs.co.in/tui/
[29] India's urban awakening: Building inclusive cities, sustaining economic growth, by McKinsey Global institute.

women's empowerment. The density of urban life helps reduce pressure on natural habitats and areas of biodiversity. Urban areas also offer improved standards of living as compared to their rural counterparts. Apart from such ***pull*** factors, some ***push*** factors are also responsible for increase in urbanisation. Population pressure along with lack of services and opportunities in rural areas often results in large scale migration serving as the push factor for growth of urban areas.

Urban area usually represents the geographic territory within or close to a city. However, different countries define urban in different ways (Figure 10).[30,31]

HOW DO YOU DEFINE URBAN?

Census of India, 2011

Towns (places with municipal corporation, municipal area committee, town committee, notified area committee or cantonment board); also, all places having 5 000 or more inhabitants, a density of not less than 1 000 persons per square mile or 400 per square kilometre, pronounced urban characteristics and at least three fourths of the adult male population employed in pursuits other than agriculture.

UNICEF, 2010

An urban area can be defined by one or more of the following; administrative criteria or political boundaries (e.g. area within the jurisdiction of a municipality or town committee), a threshold population size (where the minimum for an urban settlement is typically in the region of 2000 people, although this varies globally between 200 and 50000), population density, economic function (e.g. where a significant majority of the population is not primarily engaged in agriculture, or where there is surplus employment) or the presence of urban characteristics (e.g. paved streets, electric lighting, sewerage).

Figure 10: Definitions of urban by Census of India and UNICEF

[30] Census of India, 2011
[31] UNICEF, 2014

Urbanisation and climate change

Urbanisation as a driver of climate change

Urbanisation is a dynamic set of interrelated processes, which involve an increase in population in urban areas due to natural increase as well as due to migration. This increase is thus both relative and absolute. This, results in simultaneous expansion in urban area called '*Urban Sprawl*' at regional as well as local levels. Rapid urban population growth means an increasing demand for urban land, particularly for housing, but also for various other urban uses such as transport, industry, commercial activities etc.

The rising demand for land compels conversion of rural lands to urban. Such urbanisation led land use land cover changes across the world are considered to be one of the two most important anthropogenic changes impacting climate[32]. Other important human led change affecting climate is emission of Green House Gases (GHGs) which is again largely related to urbanisation through increased industrial and vehicular emissions and urban lifestyle issues. More importantly these are irreversible in nature which further increases the complexity of such changes.

Consequently there is loss of green cover, depletion of water sources such as lakes, ponds etc., and also encroachment of open areas takes place. This disturbs the ecological balance (destruction of habitats, landscape fragmentation, and loss of biodiversity, loss of vegetation) and climatology of the area (buildings obstructing the wind flow, fall in ground water recharge due to construction of various structures, pavements and roads, increased runoff, increased absorption of heat by building materials, increased air pollutants which absorb more heat).

Such massive and drastic changes in land use patterns thus gradually modify the local climate and at larger scales impact the overall climate and weather patterns of global reach. This whole process has been diagrammatically presented in Figure 11**Error! Reference source not found.**. Links between urbanisation and climate are complex. Cities drive changes in land use and land cover patterns (decreasing carbon sinks) and cause increased emissions of green house gases (GHGs) (increasing carbon sources); the most important factors that bring about changes in climate (Figure 12).[33] [34]**,**

[32] Kalnay & Cai, 2003 (Nature)
[33] Angel et al, 2005 (https://www.citiesalliance.org/sites/citiesalliance.org/files/CA_Docs/resources/upgrading/urban-expansion/1.pdf)
[34] International Resource Panel, 2014 (http://www.unep.org/resourcepanel/Portals/24102/PDFs/Summary-English.pdf)

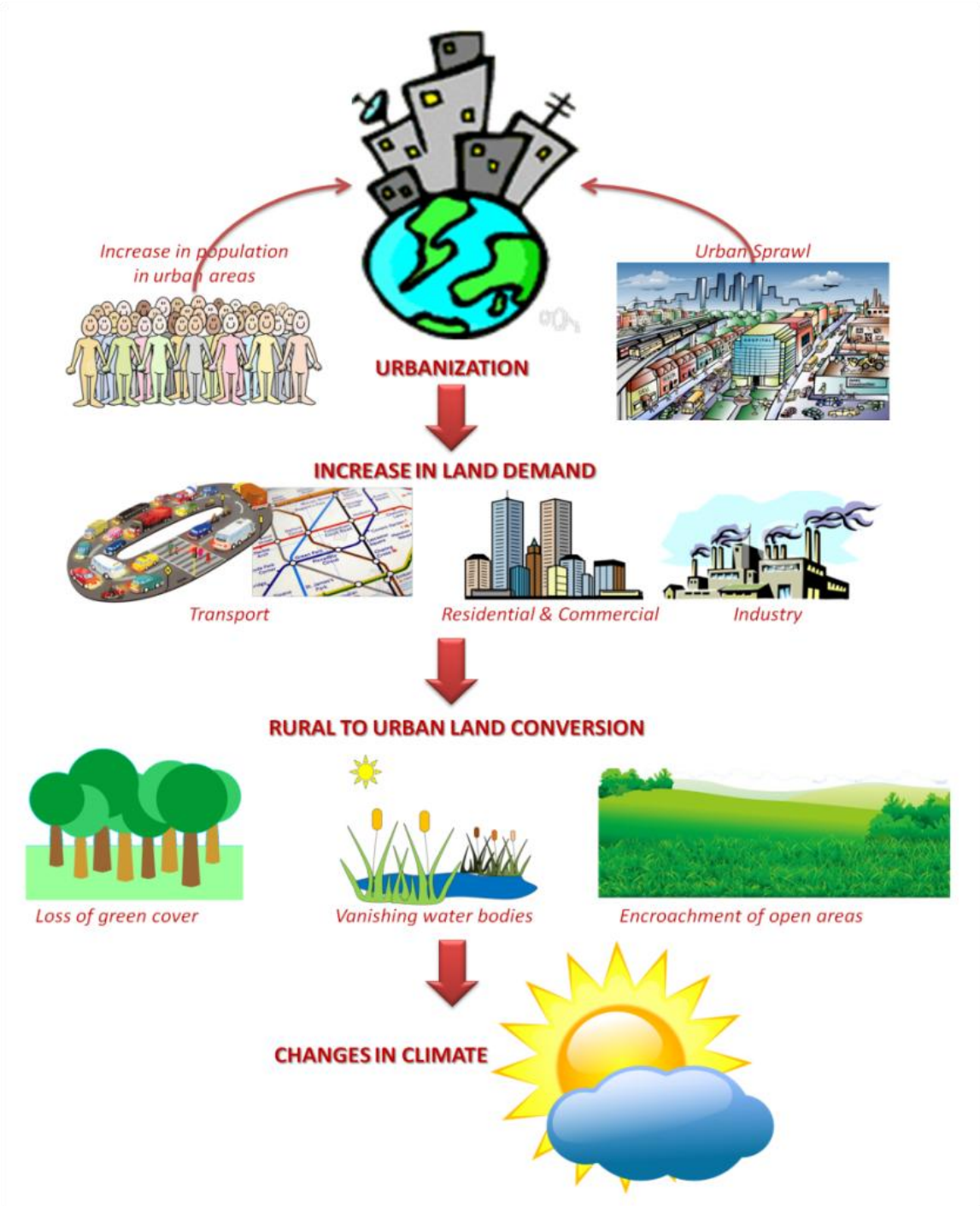


Figure 11: Process of urbanisation and changing climate

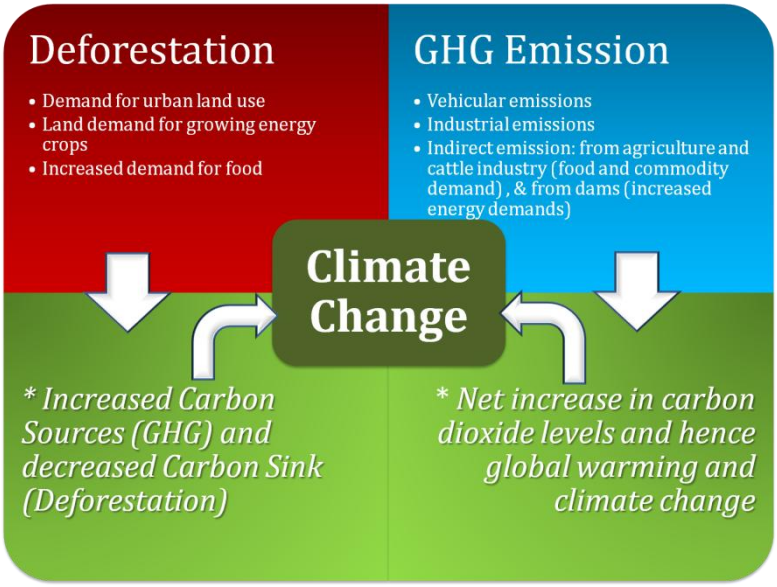


Figure 12: Urbanisation and physics of climate change

Causal-Impact relationship of urbanisation, climate and climate change

Urbanization as discussed above impacts climate resulting in climate change. Such changes in climate in turn impacts urban areas, thus exhibiting a two-way relationship between urban areas and climate change. Climate related impacts of urbanisation vary in form from local to regional to global scales.

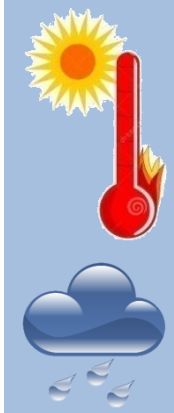
At local scale, urbanisation impacts all the three pillars of sustainable development; environment, economy and social. Urban land use drives land conversions from rural landscape affecting the local *environment*; drives *economic* growth; and transforms *societal* organizations and affects the demography as well (differing fertility rates, mortality and migration). The environmental impacts in particular affect the climate manifesting results in form of different phenomenon such as Urban Heat Island (UHI) or localised urban floods. Moving from local to regional level, the impacts scale up from micro to regional climate. The effects gradually spread far beyond the regional space triggering complex mechanisms (such as disturbance in carbon cycle) that finally show effects at the global scales.

Table 33 identifies various urbanisation related activities (e.g. alteration in land use and land cover) as causes for climate change related impacts and phenomenon (e.g. UHI). It also describes the how these phenomenon have their extended impacts (e.g. heat related mortality). All the causes and impacts have been classified under local, regional and global scales. Climate change is believed to exacerbate the impacts given that climate change will increase extreme events and will result in increase in temperature in general. Extreme events such as excessive precipitation might result in more frequent urban flooding instances. Drought on other hand will exacerbate the water supply problems in urban areas. Increasing temperatures are expected to further intensify the UHI problems. The interplay between urbanisation, climate change and its impacts may further complicate the issues giving rise to more complex and unfamiliar problems in urban areas affecting a wide range of sectors.

Table 3: Urbanisation related causes of climate change and their impacts

Scale	Climate drivers	Impacts	Causes	Possible effects
Local		Urban Heat Island (UHI)[35],[36],[37],[38]	✓ Urban areas tend to absorb more heat and retain it for longer time periods due to the thermal properties of materials used for construction. ✓ Tall buildings obstruct the wind movement and do not allow heat to escape. ✓ Decreased vegetation cover and lack of water bodies resulting in decreased cooling ✓ Air pollutants and emissions from vehicles and industries trap heat and retain it for longer durations. ✓ Heat emissions from cooling appliances	✓ Increased energy demands ✓ Impacts on health (heat stroke, respiratory diseases etc.) ✓ Air quality deterioration: Smog formation
		Flooding	✓ Impervious pavements ✓ Concretisation of land	✓ Increased water & vector borne diseases ✓ Loss of property & infrastructure

[35] Mirzaei *et al.*, 2010
[36] Tomlinson *et al.*, 2010
[37] Shahmohamadi *et al.*, 2011
[38] Memon *et al.*, 2008

Scale	Climate drivers	Impacts	Causes	Possible effects
Regional		Impact on regional climate[39, 40, 41]	✓ Anthropogenic Heat Release (AHR) ✓ Changes in surface temperatures ✓ Influence regional precipitation (changes in surface convergence, aerosol effects) ✓ Changes in diurnal temperature range	✓ Impacts on regional biodiversity ✓ Impacts on human health ✓ Increase in extreme events (flooding and drought for instance)
Global		Ecological imbalance[12, 42]	✓ Loss of habitats ✓ Deforestation: Loss of biomass and carbon stock	✓ Impacts on biodiversity ✓ Increased extreme events ✓ Increased global temperatures ✓ Increased species extinction ✓ Impacts on availability of carbon pool

[39] Jinming *et al.*, 2014
[40] Zhang *et al.*, 2013
[41] Wang *et al.*, 2014
[42] Seto *et al.*, 2012

Scale	Climate drivers	Impacts	Causes	Possible effects
		Warming of oceans[12]	✓ Impacts on carbon pool ✓ Increased GHG emissions ✓ Global warming	✓ Sea level rise - Threat to coastal habitats ✓ Loss of habitats and hence impact on biodiversity ✓ Impacts on flora phenology ✓ Ocean acidification
		Threat to food security[43]	✓ Increased threats to crop; pests attacks, vector borne diseases, invasive species etc. ✓ Changes in temperature and precipitation regimes (huge impacts on phenology) ✓ Urbanisation led land use land cover changes; • Direct – for urban land use such as housing, industries, etc. • Indirect – demand for energy crops to meet the elevated energy demands.	✓ Malnutrition among poor especially children ✓ Inflation in food and commodity prices

LEGEND

 Increase in temperature

 Changes in precipitation patterns

 Sea level rise & Ocean warming

[43] Stones, 2011

Urbanisation – Spatial & Temporal dimensions

Spatial patterns of settlements in urban areas are crucial elements determining the scale and intensity of damage due to climate change related impacts. Climate impacts on urban areas get magnified as these are the point of concentration of human lives and resources. Concentrated population in urban areas increases the risk of damage to these areas due to the climate change driven disastrous impacts.

The temporal dimension of urbanisation-climate change relationship is defined by migration and material flow (both inter and intra-city). High rates of immigration in a city, exposes more people to climate change impacts and may also accelerate the pressure on existing resources further complicating and intensifying the impacts. On the other hand, city under impacts of climate change may witness a rise in emigration rates.

Climate Change and Variability – Risks & Impacts (Indian Context)

Climate Variability

Climate variability is the natural variations (due to internal processes) in yearly climate above or below a long-term average value[44]. This is often measured on long-term climate data using various statistical parameters, such as average, range, standard deviation or simple trend detection. Climate variability may occur due to natural processes such as El Nino, La Nina, volcanic eruptions, sunspots etc. However, a long-term continuous change (increase or decrease) to average weather conditions (e.g. average temperature) or the range of weather (e.g. more frequent and severe extreme storms) due to intervention from external processes (such as anthropogenic activities) is termed as climate change.

Sources of Climate Data

- ✓ Berkley Earth Data

http://berkeleyearth.org/data

- ✓ TuTiempo.net

http://www.tutiempo.net/en/Climate/

- ✓ India Meteorological Department

http://www.imd.gov.in/

- ✓ PSMSL

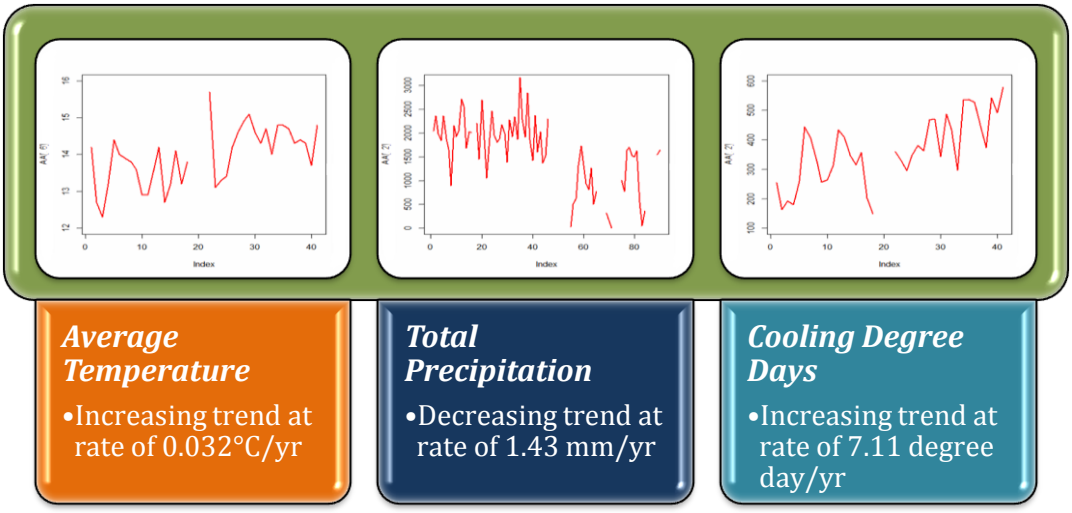
http://www.psmsl.org/data/obtaining/map.html

[44] IPCC WG-I, 2014

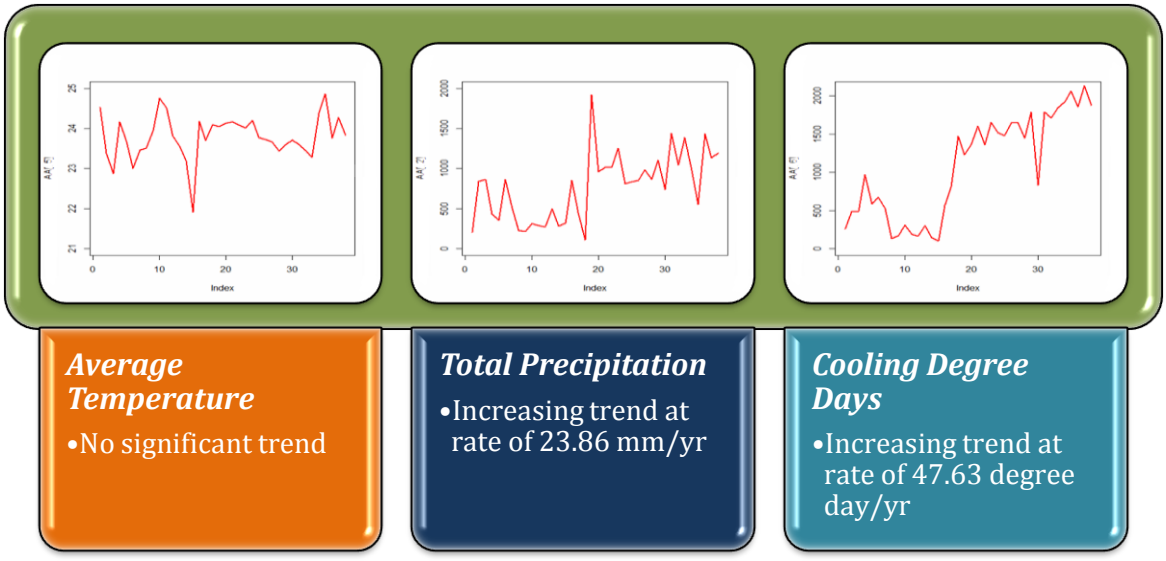
✓ ***Cooling Degree Day (CDD)*** = Each degree that a day's mean temperature is above a reference temperature is counted as one CDD. A cooling degree day is a unit used to relate the day's temperature to the energy demands of air conditioning. The higher the average daily temperature, the more will be CDD and the greater will be energy demand for cooling.

✓ ***Heating Degree Day (HDD)*** = Each degree that a day's mean temperature is below a reference temperature is counted as one degree-day. A HDD is a unit used to relate the day's temperature to the energy demands of heating. The lower the average daily temperature, the more will be HDD and the greater the will be energy demand for heating.

Climate Variability in four cities – Trends in average temperature, total precipitation and Cooling Degree Days (CDD) based on past 40 years' data[45]

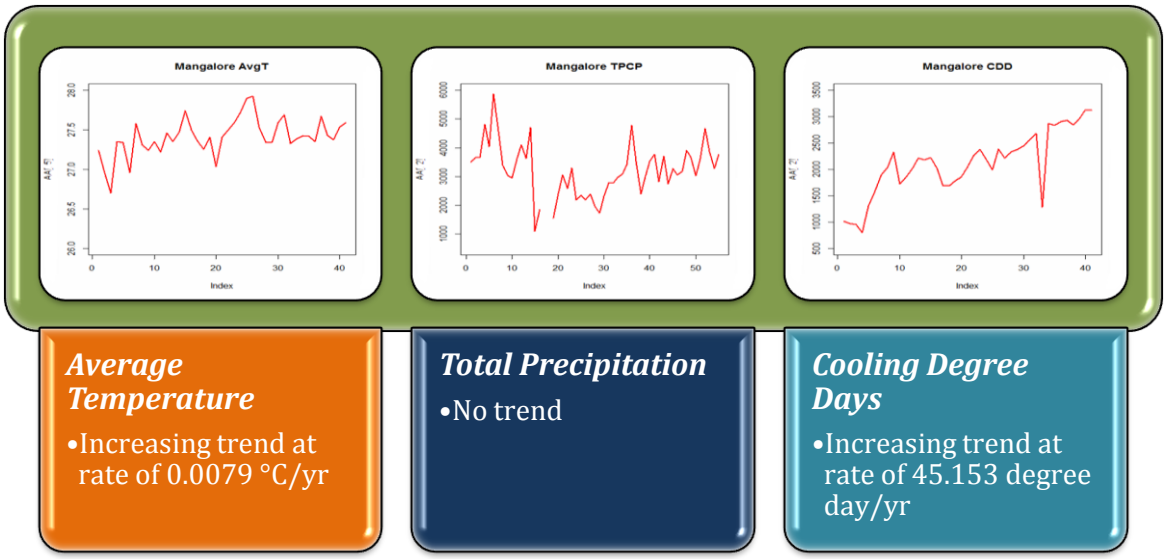


Case Study 1: Srinagar

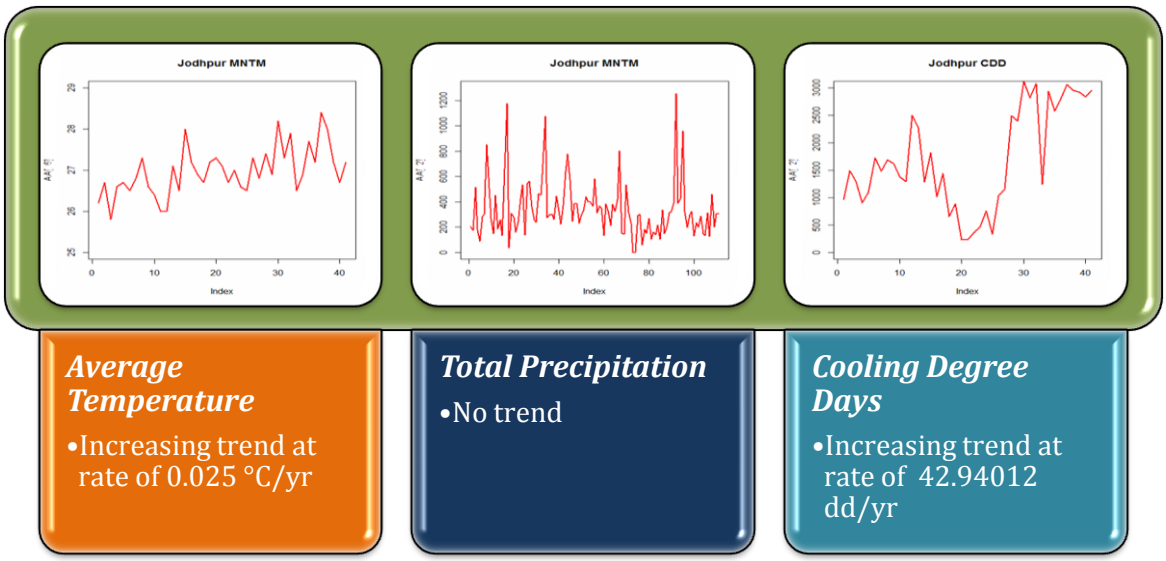


Case Study 2: Ranchi

[45] NCDC NOAA, 2014



Case Study 3: Mangalore



Case Study 4: Jodhpur

Risks

IPCC defines 'Risk' as the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. It is the probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. The interaction of vulnerability, exposure, and hazard results in risk. Climate change poses risks for humans and natural systems, and also it causes shifts in the patterns of risks.

A number of climate change risks are concentrated in urban areas. Heat stress, extreme (low and/or high) precipitation, flooding, landslides (hill cities), flash floods and water scarcity pose risks in cities for lives, property, infrastructure, and ecosystem as well. These risks get amplified in lack of essential infrastructure and basic facilities or setting up habitation in more vulnerable areas (high exposure and low adaptive capacity). Thus reinforcing basic services, improving housing quality and location (low exposure areas) and building resilient structures can markedly reduce the exposure and vulnerability (IPCC, WG-II2014).

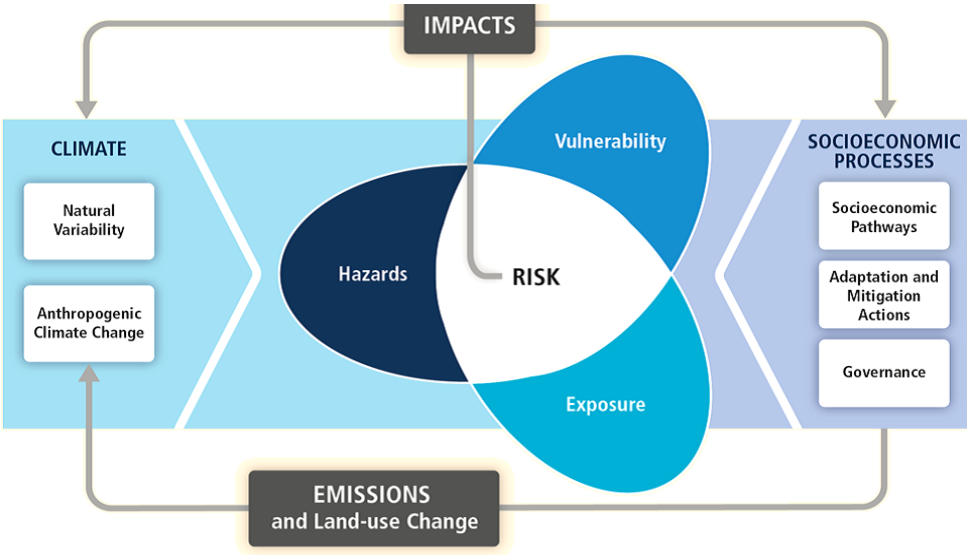


Figure 13: The linkage between risk and vulnerability[46]

Impacts

General

As mentioned in previous module, IPCC makes predictions for future climate scenarios. And their latest report Assessment Report-5 (AR-5), has predicted; an increase in Earth's average temperature, modification in the patterns and amounts of precipitation, reduction in ice and snow cover, as well as permafrost, rise in sea level and increase in the acidity of the oceans.

[46] http://www.ipcc.ch/report/srex/

Figure 14 represents such climate trends predicted by IPCC for Indian subcontinent by 2100.

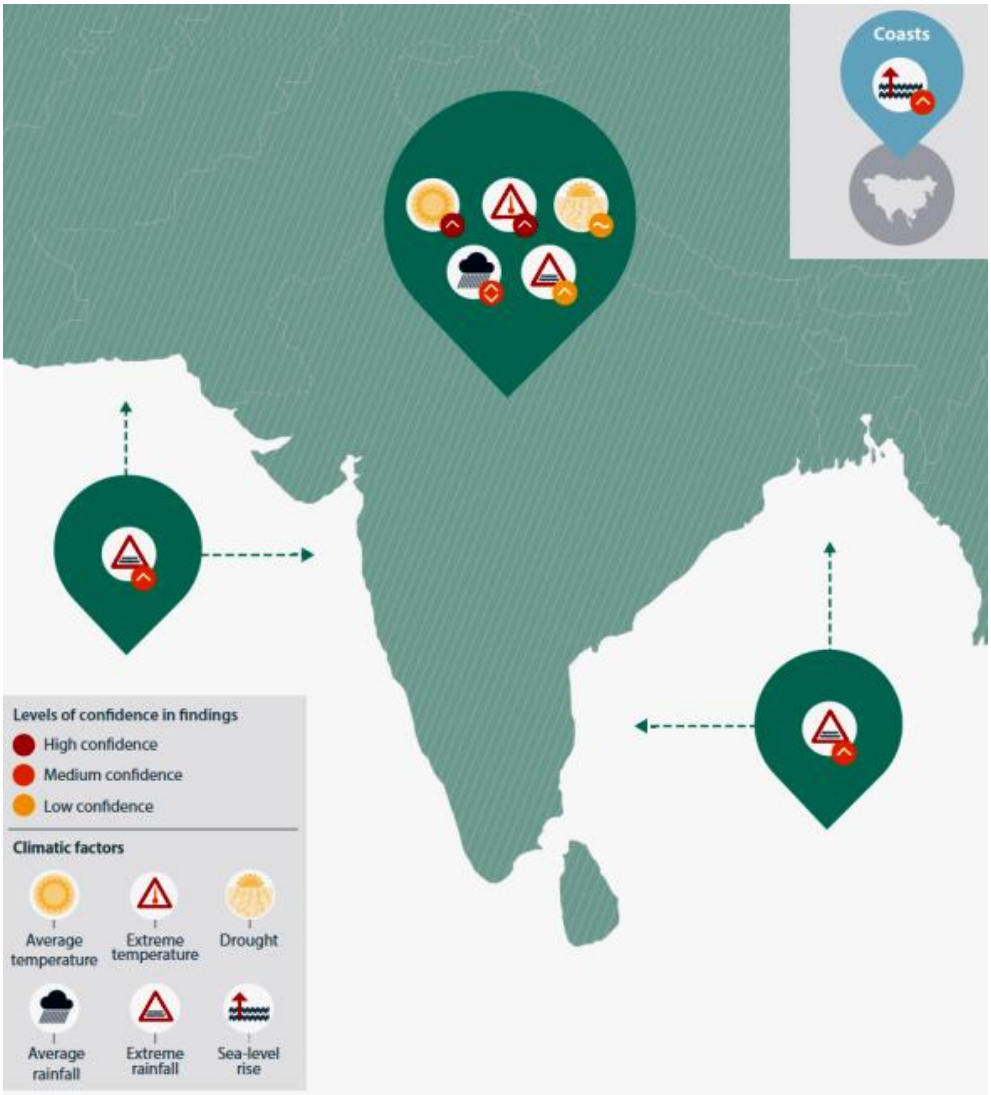
City-specific

Of the various impacts of climate mentioned above, this section will focus upon the climate change impacts in context with cities and how their physiography may be shaping up these risks for them. The impacts will be discussed under two broad headings, Direct and Indirect.

Direct impacts of:

1.1. Increased temperatures

As discussed in previous sections, cities tend to have air and surface temperatures higher as compared to their rural vicinities. This manifestation of micro climate change is termed as UHI. As the climate change is expected to further raise the Earth's average temperature, the problem of UHI will be further exacerbated. This will shoot up the energy demands for cooling which might not be only limited to peak summer season. For tropical country like India, where summers are usually harsh, this can have serious implications. Apart from increasing the energy demands, UHI also impacts the city's biodiversity and can adversely affect human health and comfort by bringing a rise in heat related morbidity and heat mortality cases.



Symbol	Rainfall	Temperature	Extreme rainfall, extreme temperature, sea-level rise
	up to 30% increasing trend	1–5 °C increasing trend	increasing trend
	both increasing and decreasing trends	–	both increasing and decreasing trends
	up to 30% decreasing trend	–	decreasing trend
	inconsistent trend	inconsistent trend	inconsistent trend
	no or only slight change	no or only slight change	no or only slight change

Figure 14: Future climate trends (Indian subcontinent)[47]

Heat waves occurrence and duration is on rise across the world[48]. Heat waves could be high-humidity or low humidity. High humidity heat waves often make deadly combination of heat and humidity posing threat to medically vulnerable population (elderly, infants, patients etc.). Extreme heat events take more lives annually than hurricanes, lightning, tornadoes, floods, and

[47] CDKN, 2014
[48] Luber & McGeehin, 2008

earthquakes combined. In contrast, low-humidity heat waves are often associated with droughts and in some cases are responsible for wild fires[49, 50].

1.2. Changes in precipitation pattern –

(a) Inland Flooding

Increased flooding is expected to be one of the most serious impacts of climate change in urban areas. As the sewage system in most of Indian cities the drainage and sewage systems cannot cope with the amount of water during rains which often results in water logging and flooding in some cases. Extreme precipitation events (with heavy rainfalls) are expected in future which are likely to increase the risk of urban flooding in Indian cities. Urban structures often aggravate the flooding by restricting water flow due to lack of open spaces. As cities are crowded with people, this increase the vulnerability of damage due to flooding especially in high exposure areas such as low lying areas, poor quality housing, settlements along the river banks, to mention a few. Thus even moderate storms can create havoc in urban areas. Urban areas also tend to augment the thunderstorm activity by modifying the local air circulation patterns owing to UHI effect. Apart from UHI, the aerosols are also believed to trigger the convectional rainfall in some urban areas [51].

(b) Drought and water scarcity

Across the globe, since 1970s, droughts have become longer and more extreme particularly in tropical countries like India[52]. India has already been facing the hydrological variability for past few years owing to changing precipitation patterns, and climate change is expected to further threaten the water security and make it costlier to achieve[53].

1.3. Sea level rise and storm surge –

With changing climate, the ice sheets and glaciers are melting which is adding more water to oceans. Simultaneously the increasing temperatures are warming up the oceans, which then increase the volume of ocean/sea waters. Both the factors jointly contribute in increasing the sea levels[54]. Thus, as the climate changes and sea level rises, coastal flooding is expected along the coastlines of the nations. Coastal flooding is particularly expected to be worsened during storms due to increased storm surges. This poses great risks to numerous coastal cities in India threatening the lives, properties, infrastructure and livelihood in these urban areas[55].

[49] Trenberth, K. E., 2011
[50] Lau, W. K. M. and K-M Kim, 2012
[51] Huong & Pathirana, 2013
[52] EPA, 2014 (http://www.epa.gov/climatestudents/impacts/signs/droughts.html)
[53] World Bank Group, 2014 (http://water.worldbank.org/topics/water-resources-management/water-and-climate-change)
[54] Climate Institute, 2010 (http://www.climate.org/topics/sea-level/)
[55] EPA, 2014 (http://www.epa.gov/climatechange/impacts-adaptation/coasts.html#impactssea)

Figure 15: New Moore island submergence due to sea level rise

Indirect impacts of:

1.1. Increased temperatures –

Rising temperatures are giving rise to another climate change issue which is sea level rise. Elevating temperatures worsen the smog conditions and often result in 'bad air days'. This poses threat to human health in numerous ways; irritation in eyes, respiratory diseases such as asthma, and skin diseases. Thus with climate change air pollution problem is expected to get worsened. Increasing temperatures are known to pace up the ozone smog formation[56].

1.2. Changes in precipitation pattern –

(a) Drought and water scarcity –

Droughts will not only pose direct threat to water supplies of the cities, but will indirectly affect the hydroelectric dam projects that serve as electricity sources for a number of urban areas. Droughts also pressurize the food production that ultimately threatens the food security resulting in inflation in food and commodity prices[26].

(b) Inland flooding –

Inland flooding affects people and property at risk. It damages the urban utilities such as transport systems (rail and road), electricity network and other critical infrastructure and services such as hospitals and schools. It affects health directly and indirectly. Direct health impacts could be through injuries due to debris and stress. While indirect health impacts could be due to infections from contaminated water and food, vector-borne diseases (such as dengue, encephalitis, malaria, chikungunya)[57].

[56] NRDC, 2010 (http://www.nrdc.org/health/climate/airpollution.asp)
[57] NHP, 2013 (http://www.metoffice.gov.uk/nhp/media.jsp?mediaid=15112&filetype=pdf)

1.3. Sea level rise and storm surge –

Rising sea levels are expected to increase the ground water salinity and are also found to be pushing salt water further up the streams. This can have major implications for water supplies by increasing the cost in terms of desalination[58].

Urban Vulnerability to Climate Change

As per IPCC, 'Vulnerability' is the propensity or predisposition to be adversely affected. It largely depends on the sensitivity or susceptibility to harm, and lack of capacity to cope and/or adapt[20]. In other words, vulnerability to climate change is a 'measure of possible future harm'[59].

For each of the direct and indirect impacts of climate change, there is a group of urban dwellers that face higher risks and are often classified as vulnerable groups. These can be identified based on a number of factors; age (e.g. infants and elderly are more sensitive to heat hazards), health status (e.g. asthma patients are more sensitive to bad air days), site and location (e.g. settlements along river banks are more prone to flooding), coping capacity (e.g. poorer sections of society lacking coping capacity are at greater risks), and gender in some cases if they face discrimination in access to resources etc[60].

Exposure and sensitivity

Two important concepts that help in shaping up the vulnerability are exposure and sensitivity. Exposure is defined as 'the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economical, social, or cultural assets in places and settings that could be adversely affected[61]. The two main elements to be considered in exposure are; things that can be affected by climate change (populations, resources, property, etc.) and the change in climate itself (sea level rise, precipitation and temperature changes, etc.). Thus, more is the exposure, more will be the vulnerability.

Sensitivity is the degree to which a system will be affected by, or responsive to climate stimuli[62]. Sensitivity is by and large the biophysical effect of climate change; however it can be altered by socio-economic changes. For example, drought resistant crop varieties would be less sensitive to climate change, hence reducing the vulnerability.

Levels of Vulnerability

Climate vulnerability can exist at three levels; Individual/Community level, Sectoral level and Systems level[34]. Figure 16 depicts the climate variability at different levels in urban areas as identified by IPCC.

[58] EPA, 2014 (http://www.epa.gov/climatechange/impacts-adaptation/coasts.html#impactssea)
[59] Hinkel, 2011
[60] IPCC AR5, Chapter-8, 2014
[61] IPCC AR 5, 2014
[62] Smith et al., 2001

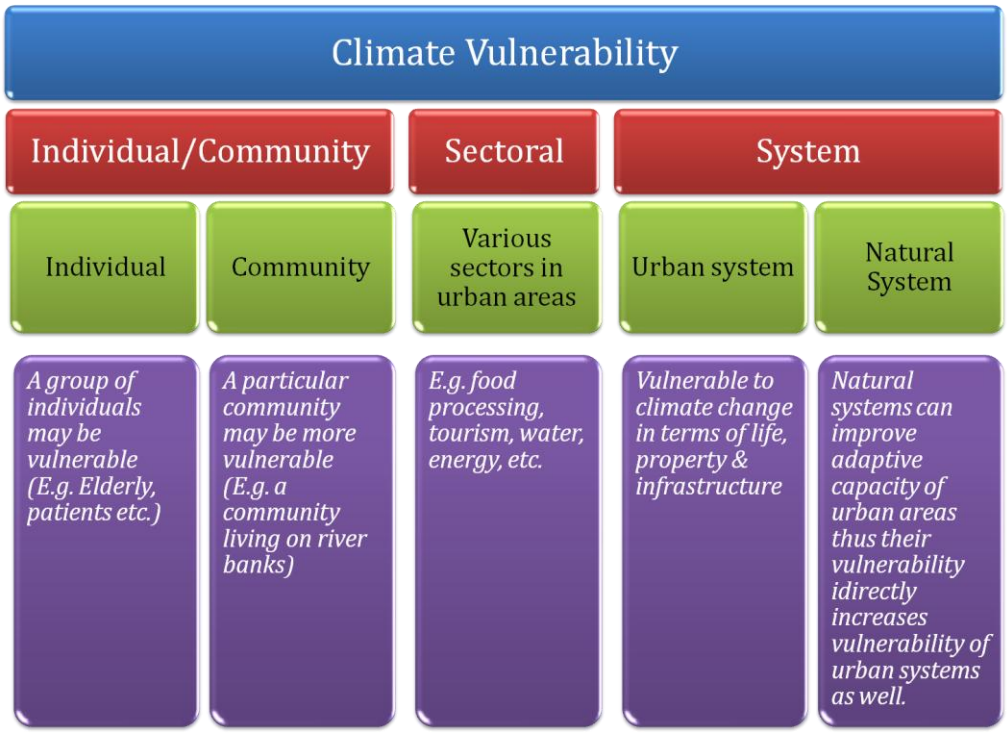


Figure 16: Climate variability in urban areas

Vulnerability Assessment

Identifying vulnerability

There could be several criteria regarding impacts, based on which key vulnerabilities can be identified[63]. These are;

(a) Magnitude of impacts - Determined by the *scale* (e.g., the area or number of people affected) and the *intensity* (e.g., the degree of damage caused). Different aggregate metrics can be used to describe the magnitude of climate impacts, e.g. monetary units such as welfare, income or revenue losses, and non-monetary indicator such as the number of people affected by certain impacts.

(b) Timing of impacts - A harmful impact is considered 'key' if it is expected to happen soon rather than in the distant future. Another important aspect of timing is the rate at which impacts occur. The adverse impacts occurring suddenly would be more significant than the same impacts occurring gradually, as the potential for adaptation would be much more limited in the former case.

(c) Persistence and reversibility of impacts – impacts that are irreversible and/or persistent are in general considered as key impacts. E.g. extinction of species is irreversible and considered as a key impacts of climate change.

(d) Likelihood and confidence of impacts and vulnerabilities - These two define the uncertainty of the impacts to take place. *Likelihood* is the probability of an outcome having occurred or occurring in the future; *confidence* is the subjective assessment that any statement about an outcome will prove correct. Thus an impact with high likelihood will have higher risk and would be hence considered as key impact.

[63] IPCC AR4, 2007

(e) Potential for adaptation – Vulnerability inversely varies with potential to adapt. The higher the potential to adapt an individual or a community or a system has, less will the vulnerability.
(f) Distribution - Heterogeneous impacts and vulnerabilities having significant distributional consequences are likely to be more salient, and therefore considered as 'key'.
(g) Importance of the system(s) at risk – the more important a system is, more are the chances that its climate vulnerabilities would be considered as key.

Vulnerability Assessment Tools

Researchers use various kinds of tools to assess vulnerability. These may vary depending upon the sectors, regions, and hazards. Vulnerability (V) is a function of potential impact (I), minus adaptive capacity (AC). Quantitative assessment of vulnerability is usually done by constructing some kind of 'vulnerability index'. Index construction is usually a multi-step process. First of which is selection of study area, followed by selection of a set of indicators for the hazard, risk, exposure and adaptive capacity. IRADe for instance, has conducted matrix based vulnerability assessment for 20 cities in India. Based on which it prepared HIGS (H=Hazard, I=Infrastructure, G=Governance, S=Socio-economic) framework for climate responsive development[64].

Note: We will have a detailed exercise on vulnerability and risk assessment.

S.No.	Classification	City Name	Hazards					Infrastructure					
			Drought	Flooding	Landslides	Cyclones	Heat / cold waves	Water supply	Sewerage	Drainage	MSW	Population (million) base in 2011	Categorization of cities on basis of population
1	Coastal	Kolkata	Y	Y		Y	Y	Y		Y	Y	141	A
2		Mumbai		Y	Y	Y				Y		184	A
3		Chennai	Y	Y		Y	Y					8.6	A
4		Surat	Y	Y		Y				Y		4.5	A
5		Visakhapatnam	Y	Y		Y	Y		Y	Y		1.7	B
6		Thiruvananthpuram		Y		Y				Y	Y	1.6	B
7		Kochi	Y	Y		Y	Y		Y	Y	Y	2.1	B
8		Puri	Y	Y		Y		Y	Y	Y	Y	0.2	C

Figure 17: A part of IRADe's vulnerability matrix

[64] Parikh, J.K., 2013 (IRADe)

Module III

Mainstreaming Climate Change Adaptation & Resilience into City Planning and Development

The present module is aimed at getting participants to understand and mainstream climate change adaptation/ resilience into urban development and planning. The module addresses policy issues and sector specific climate change impacts and adaptation measures.

Learning Objectives

- To understand how climate change adaptation and resilience can be mainstreamed
- To enhance the capacity of participants to understand the linkage of key sectors to climate change, climate variability and associated risks. To integrate climate change adaptation/resilience aspects in city planning and development strategies
- To build climate change adaptation/resilience aspects into projects in key sectors

Climate change is a growing reality and understanding its impact on cities is crucial to managing urbanization. The uncertainties associated with climate variability poses great risk for economic development and social well being of citizens. Cities in India are already under stress and unable to provide minimum level of basic services to its population and climate change related risks will create further pressure on infrastructure and services in cities . Most of the climate change impacts are likely to be experienced through floods, droughts, and unpredictable levels of rainfall and these will put at risk water and sanitation services affecting the health of millions of people, especially the poor who are most vulnerable. The challenge is to prepare Indian cities for sustainable growth (in economic, social and environmental terms) that can withstand climate induced risks. Mainstreaming climate change adaptation and resilience in urban development and planning is therefore required. The process of mainstreaming allows integration of climate change concerns and adaptation measures into relevant policies, plans, programmes and projects. The adaptation strategies can be effectively implemented when all the stakeholders participate in decision making. This also helps in addressing and integrating socio-economic differences that exist in different urban centres.

Mainstreaming Climate Change Resilience and Adaptation

In India, the federal structure of policy making and planning makes it possible to mainstream Climate Change Adaptation and Resilience (CCAR) at all three levels of government viz. national, state and city, as indicated in the Table4.

Table 4 : Entry Points for Mainstreaming Resilience at Various Levels of Government

National Level	Subnational/State Level	City Level
1. National Missions as part of the National Action Plan on Climate Change (NAPCC) 2. Sectoral policies (water, transport, buildings, energy, etc.) 3. Five Year Plans	1. State Agendas and Action Plans on Climate Change 2. Sectoral Policies 3. State Five Year Plans	1. Master Plans 2. City Development Plans 3. Disaster Management and Resilience Plans 4. City Mobility Plans 5. City Sanitation Plans

Source: Mainstreaming Urban Resilience Planning in Indian Cities: A Policy Perspective, TERI, May 2011

Mainstreaming CCAR also requires policy framework, institutional framework, and financial framework to be put in place.

Policy Framework in the Indian context is defined by the Central and State Governments. There are national policies such as the NAPCC and sectoral policies for different sectors such as National Water Policy, National Sanitation Policy, National Urban Transport Policy, etc. (TableTable 5).

Table 5: National Action Plan on Climate Change (NAPCC)

Mission	Description
National Solar Mission	The NAPCC aims to promote the development and use of solar energy for power generation and other uses with the ultimate objective of making solar competitive with fossil-based energy options. The plan includes: • Specific goals for increasing use of solar thermal technologies in urban areas, industry, and commercial establishments; • A goal of increasing production of photovoltaics to 1000 MW/year; and • A goal of deploying at least 1000 MW of solar thermal power generation. Other objectives include the establishment of a solar research center, increased international collaboration on technology development, strengthening of domestic manufacturing

Mission	Description
	capacity, and increased government funding and international support.
National Mission for Enhanced Energy Efficiency	Current initiatives are expected to yield savings of 10,000 MW by 2012. Building on the Energy Conservation Act 2001, the plan recommends: • Mandating specific energy consumption decreases in large energy-consuming industries, with a system for companies to trade energy-savings certificates; • Energy incentives, including reduced taxes on energy-efficient appliances; and • Financing for public-private partnerships to reduce energy consumption through demand-side management programs in the municipal, buildings and agricultural sectors.
National Mission on Sustainable Habitat	To promote energy efficiency as a core component of urban planning, the plan calls for: • Extending the existing Energy Conservation Building Code; • A greater emphasis on urban waste management and recycling, including power production from waste; • Strengthening the enforcement of automotive fuel economy standards and using pricing measures to encourage the purchase of efficient vehicles; and • Incentives for the use of public transportation.
National Water Mission	With water scarcity projected to worsen as a result of climate change, the plan sets a goal of a 20% improvement in water use efficiency through pricing and other measures.
National Mission for Sustaining the Himalayan Ecosystem	The plan aims to conserve biodiversity, forest cover, and other ecological values in the Himalayan region, where glaciers that are a major source of India's water supply are projected to recede as a result of global warming.
National Mission for a "Green India"	Goals include the afforestation of 6 million hectares of degraded forest lands and expanding forest cover

Mission	Description
	from 23% to 33% of India's territory.
National Mission for Sustainable Agriculture	The plan aims to support climate adaptation in agriculture through the development of climate-resilient crops, expansion of weather insurance mechanisms, and agricultural practices.
National Mission on Strategic Knowledge for Climate Change	To gain a better understanding of climate science, impacts and challenges, the plan envisions a new Climate Science Research Fund, improved climate modeling, and increased international collaboration. It also encourages private sector initiatives to develop adaptation and mitigation technologies through venture capital funds.

The States have their own plans such as the State Action Plans on Climate Change, and sectoral policies (Table 6).

Table 6: State Action Plans on Climate Change (SAPCC)

State Action Plans on CC	Urban & CCA Components
Assam's Strategy and Action Plan on Climate Change (Draft)	The strategy focuses on promoting roof top rain water harvesting for urban areas, water audits in industrial houses, tea gardens, public buildings and housing complexes for preparation and promotion of water conservation measures and development of low cost water purification technology to remove contaminants like iron, arsenic. On a regional level it promotes restoration of wetlands, water literacy campaign, and restoration and revamping of traditional rain water harvesting systems. The strategy also focuses on mitigating natural disasters and crisis management through the establishment of a State Disaster Response Force, and disaster management wings in each district with dedicated human resource and infrastructure.
State Action Plan on Climate Change: Karnataka	The state action plan has a strong focus on climate change mitigation actions which will reduce emissions, but adaptive components are also present in the plan. The plan promotes sustainable urban development, with emphasis on public transport, integration of land use and transport, improved walkability, green rating of buildings, assessment of water resources, water conservation, water audits, regulation of ground water use, installation of water savers, development and use of

State Action Plans on CC	Urban & CCA Components
	solar water heaters and bio-fuels, integrated solid waste management, life cycle assessments of critical materials, rain water harvesting and water recharge, creation of lung spaces in urban areas. Updation of the SAPCC is also part of the plan.
Orissa Climate Change Action Plan	The action plan focuses on priority actions to be taken under different sectors such as urban planning, energy, transport, water, etc. The plan promotes assessment and downscaling of global climate models to local and regional levels, increasing water efficiency, water harvesting, improving drainage, climate friendly designs of urban water supply and sewerage, MSW management plan, public transport, energy efficient lighting, undertaking measures to manage vector borne and water borne diseases, and management of coastal biodiversity impacts. It also supports capacity building of ULBs for climate change adaptation.
West Bengal State Action Plan on Climate Change	The action plan focuses on sectors like habitats, energy, water, biodiversity, health and agriculture. It promotes water management through rainwater harvesting, enhancing artificial recharge activities of ground water, restoration of existing water bodies, recycling and reuse of waste water, as well as through assessment of weather patterns, water demand and vulnerability. It also promotes disaster management through assessment of vulnerability and weather forecasting and development of adaptation plans for disaster risk reduction. Protection of mangroves features high in priority in the plan. Managing vector borne diseases through increased surveillance, improved infrastructure and disaster preparedness is also part of the plan to address human health impacts of climate change. The plan supports alternative and decentralized renewable energy development in the state.
Climate Change Agenda for Rajasthan 2010- 2014	The agenda focuses on water, health, sustainable habitats and energy. It promotes basic water and sanitation services for all areas and localities, water audits to encourage efficiency in use, integrated water resources management, leak detection studies, rainwater harvesting, artificial recharge of water, integrated SWM with recycling of waste, and use of informal sector in waste management, conservation of biodiversity and forest cover, improved information on health and diseases and enhanced

State Action Plans on CC	Urban & CCA Components
	public health care system, energy efficiency and conservation, use of renewable energy, public transport and clean fuels and urban planning. It makes specific reference to urban governance and acknowledges the increased demands placed by urban centers and the need for integrating climate risks and responses into urban planning and development processes. The Rajasthan plan also identifies specific urban policies and programs that could be leveraged to undertake climate adaptation initiatives in its urban areas
Action Plan on Climate Change for Union Territory of Puducherry (Draft)	The action plan promotes climate mitigation and adaptation actions to address the challenges of increasing demands of urbanization, industrialization, changes in land use, increased waste, depletion of ground water, sea water ingression, and health hazards. It advocates use of renewable energy, the setting up of a state solar plant, energy efficiency in appliances, implementing ECBC codes, energy conservation in lighting, waste to energy, promotes sustainable habitat through promoting clean fuels, coastal protection, disaster management through hazard mapping and vulnerability assessment, solid waste management, waste treatment, encouraging plantation and conservation of wetlands, rain water harvesting, and water metering, and supports capacity building on climate change.
Madhya Pradesh State Action Plan on Climate Change	The Plan focuses on key climate challenges through policy reforms, resource mobilization, capacity building and implementation. For water management, it promotes water and soil conservation, water recharge, integrated water shed management. It promotes assessment of health vulnerabilities capacity building and disaster preparedness to tackle health impacts. It promotes energy efficiency in buildings and street lighting, coverage of water supply, reuse and recycling of water, improvement of storm water drainage and solid waste management, developing norms for improvement in transportation, promoting public transport and non motorized transport, integrating climate adaptation in city planning. The plan also provides a monitoring and evaluation mechanism.
State Action Plan on Climate Change for	The plan focuses on sustainable development by protecting vulnerable sections of society from adverse effects of climate

State Action Plans on CC	Urban & CCA Components
Andhra Pradesh	change and provides a framework for climate mitigation and adaptation, with strong focus on increasing adaptive capacity. For disaster management in coastal areas, it promotes early warning systems, good prediction systems, effective policies, restoration of mangroves, and increasing cyclone shelters. It advocates strengthening of public health systems for tackling health impacts. It promotes creation of biodiversity registers and community based management of forests. For sustainable urban development, it promotes efficient sanitation and sewerage system and integrated waste management and utilization system, promotion of public and non motorized transport and use of cleaner technologies and renewable energy.

Source: Climate Change Adaptation in Urban India, ICLEI-GIZ, January 2012

At the city level climate change adaptation and resilience can be mainstreamed in:

- Town and Country Planning Act and zoning regulations
- Development control rules and building bye-laws
- District planning manual
- National Building Codes
- Urban and Regional Development Plan Formulation and Implementation (URDPFI) Guidelines
- City Master Plans

Source: Mainstreaming Urban Resilience Planning in Indian Cities: A Policy Perspective, TERI, May 2011

The **Institutional Framework** for mainstreaming climate change adaptation and resilience (CCAR) includes institutions at the National, State and Local levels.

At the National level the main ministries that are involved in urban climate change adaptation and resilience include the Ministry of Urban Development, Ministry of Housing and Urban Poverty Alleviation, and the Ministry of Environment, Forests and Climate Change. At the state level, the departmental equivalents of these Ministries, and the Town and Country Planning Department would play an important role. At the local level, the urban local bodies, the line departments and the urban development authorities would be the institutions that would be able to incorporate climate change concerns in their plans and activities.

The **Financial Framework** for including climate change adaptation and resilience at the national and level includes funds available under various programmes of the government including NAPCC and JNNURM. At the state level the funds are linked to state programmes under SAPCC and sectoral programmes. However, at the local level, funding climate change adaptation and resilience has to be built into the projects. The only example of climate change

financing being mainstreamed is in Surat where the Surat Municipal Corporation has added a new head of 'Climate Change' in their municipal budget.

Sectoral Climate Change Adaptation and Resilience Planning

This section of the module will cover the following sectors:

A. **Urban Water Supply and Sanitation**
B. **Urban Drainage**
C. **Built Environment / Human Settlement**

Urban Water Supply and Sanitation

Water supply and sanitation are basic to public health and they also impact the economy and development of cities. Productivity in urban areas is also impacted by the availability of clean drinking water in households and access to safe sanitation. Water security is important for not only survival but also for flora and fauna and for the eco-system as a whole. Climate change is likely to have significant impact on water resources, which have already been adversely affected by pollution (Table 7). The challenge of climate change comes from variability in rainfall patterns, high intensity rainfall, rise in temperature and extreme events, flooding, salt water intrusion, sea level rise, contamination of ground water, droughts, glacial melt – affecting water supply to urban areas. Rapid urbanization requires local authorities and utilities in urban areas to address the challenges posed by climate change and take measures now to make cities resilient and protect the vulnerable groups from suffering disproportionately.

Learning Objectives

- To understand how climate change adaptation and resilience can be mainstreamed
- To enhance the capacity of participants to understand the linkage of key sectors to climate change, climate variability and associated risks. To integrate climate change adaptation/resilience aspects in city planning and development strategies
- To build climate change adaptation/resilience aspects into projects in key sectors

Policy and Water

Water is high on the agenda of Government of India. One of the eight sub-missions rolled out by the Government of India under the **National Action Plan for Climate Change (NAPCC)** is the National **Water Mission**[65] which addresses the threats posed by changing climate and global warming. The Mission will:

[65] http://www.pib.nic.in/newsite/erelease.aspx?relid=71513

1) Prepare a comprehensive water data base and put it in public domain and assess the impact of climate change on water resources.
2) Promote citizen and state actions for water conservation, augmentation and preservation.
3) Focus attention on vulnerable areas, including over-exploited areas.
4) Increase water use efficiency by 20%; and
5) Promote basin level integrated water resources management.

Box 1: Climate Change and water supply

In urban areas, resilience building activities in relation to water management have focused on:

- Repair and maintenance of water supply systems to reduce water theft and leaks;
- Green-scaping to improve natural drainage during periods of heavy rain and flooding
- Increasing the number of supply options to deal with changes in conditions or emergency situations, e.g. rainwater harvesting, introduction of private and/or informal vendors when local supplies are contaminated or energy failures result in suspension to pumped water
- Water recycling schemes
- Demand management, i.e. public education, industrial process changes to reduce water intensity
- Reducing heat-island effect through greening of buildings (excess heat from buildings and roads due to the urban heat-island effect can be transferred to storm water, thereby increasing the temperature of water that is released into streams, rivers, ponds and lakes which exacerbates water pollution).

Source: http://www.acccrn.org/uccr/key-issues-urban-resilience

Box 2: Climate change and sanitation

The effects of climate impacts on sanitation may be direct – where water is an essential part of the technology process (e.g. sewerage) – or indirect – where the capacity of the environment to absorb or reduce the adverse effects of wastes is changed.

Where precipitation levels decline, sewerage systems may become more difficult to operate and maintain. This will be a particular problem for conventional sewerage with its relatively high water requirements. Further problems may also arise from the reduced capacity of water resources to absorb and dilute pollution, which will increase the performance requirements, and hence the cost and potentially the carbon footprint, of wastewater treatment. Sewers are also at risk from flooding damage. Where sewers also carry stormwater, increased flooding will result in widespread contamination, overwhelm treatment facilities and increase public health risks.

Pit latrines as a group of technologies are resilient, because different designs allow adaptation to changing climate. Individual facilities may, however, not be resilient. Where groundwater levels rise, pollution from pit latrines may become more difficult to control.

Source: WHO-DFID (2009) - VISION 2030: Summary and Policy Implications - The Resilience of Water Supply and Sanitation in the Face of Climate Change

Table 7: Impact of climate change on urban water supply and sanitation, and adaptation measures

Climate Change Forecast:
Precipitation: More intense, with higher annual average rainfall as well as increased drought; urban flooding.
Temperature: Maximum and minimum temperatures will rise in most parts of India by 2°C to 4°C.

Sector and its components	Probable Impacts	Adaptation Measures
Water Supply	• **Variability in flow** of water in perennial and non-perennial rivers will affect water availability. • **Variability in rainfall** will affect ground water recharge. • **Reduction in water levels** in tanks and dams will be seen due to rise in temperature and variability of precipitation. • **Scarcity of water** will rise over the time and geographically. • **Water supply systems** such as jackwells, pumping stations, water treatment plants, will get affected due to floods	• **Water conservation** – promoting efficiency in water supply and consumption; demand management • **Reducing water leakages** to increase water availability • Promotion of **dual pipeline system** to separate drinking water supply from other. This will reduce treatment and energy costs and help set realistic tariff for water. • Improve **communication with citizens** to inform them of the changing water situation to prevent water conflicts and over use. • **Conjunctive water management** – optimal use of local resources such as rainwater, surface water, groundwater, treated wastewater and water from distant sources.
Water source	• Springs and rivers will be **more seasonal in nature** due to variability of rainfall and rise in extreme rainfall events. • Reservoirs/dams/lakes will **register sharp decline** due to high	• **Rainwater harvesting** - making it mandatory in Building Bye-laws. • Conservation and rejuvenation of water bodies

Sector and its components	Probable Impacts	Adaptation Measures
	temperatures and reduced catchment inflow of water. Storage in dams and reservoirs will dwindle. • **Ground water table will fall** rapidly in over exploited areas, as recharge of aquifers will reduce due to change in rainfall patterns (more extreme rainfall events leading to high run off). • Coastal cities will face additional problem of **salt water intrusion** that will affect ground water supply due to sea level rise and salt water ingress due to over exploitation of ground water.	to **check surface run off** and preserving fresh water. • **Basin level approach** to manage water resources. • Selecting multiple and decentralized sources of water.
Water Treatment	• **Sediment load will rise** in rivers/streams, especially during rainy season and extreme spells of rain, which will reduce treatment capacity, hampering water supply. • Seasonal deficit of water and reduced availability of ground water will **increase the pollutant load**, impacting treatment.	• Invest in augmentation of treatment capacity. • Innovations in engineering to settle silt and use the water for storage or percolation. • Locate **new pumping stations** in places which don't get flooded. • Augment storage by adding new water tanks
Water supply - Vulnerable sectors/section of society	• Change in rainfall patterns and rise in temperature could affect water level in dams which will **impact hydel power generation**, even thermal and nuclear power plants would be affected due to reduced availability water. • **Industrial output will be impacted** both due to water shortage and energy deficit. • **Biodiversity** in eco-sensitive zones like the Himalayan belt, western and Eastern Ghats **will be affected** by changes in the rainfall pattern and rise in temperature. This will impact the water	• Technologies to **reduce the intensity of water use** in industries. • **Re-use, Recycling** of grey water for peri-urban agriculture, landscaping. Peri-Urban agriculture can hold flood waters and can be a resilience measure. • **Industries to use recycled water** to the extent possible. • **Focus on mini hydel power projects** rather than

Sector and its components	Probable Impacts	Adaptation Measures
	holding capacity of these ecosystems. • The **urban poor**, who are the **most vulnerable** section of the society, will be affected due to rise in temperature and water scarcity.	large hydel power projects. • Choosing other options for power generation like **solar**, pine needle. • Identifying vulnerable people and providing relief to them
Sewerage system	• Infiltration of flood waters into sewers – creating pollution impacting health. • Pollution of water downstream. • Due to high temperature & reduced water supply reduced flow may choke sewers and early decomposition may take place resulting in **deposits in the network.** • Increase in harmful **sewer gases.** • Due to change in precipitation biological treatment process of STPs will be disturbed. • Open sewers may overflow due to heavy rains and threat of epidemic may increase. • The scouring velocity in the sewerage system may get disturbed due to change in rainfall.	• Separate sewerage and drainage systems. • Put up decentralized sewage treatment systems where possible. • Clean sewers regularly and especially before monsoons. • Regular operation and maintenance of the system. • Install STPs to treat all wastewater and prevent water pollution.

Climate Change over 21st Century is projected to reduce renewable surface and groundwater resources in most dry sub tropical regions, intensifying competition among different sectors. It is projected to reduce the raw water quality and pose risks to drinking water quality even with conventional treatments, due to interacting factors: increased temperature, increased sediments, nutrient and pollutant loadings from heavy rainfall; increased concentration of pollutants during droughts; and disruption of treatment facilities during floods. All models and all scenarios project an increase in both the mean and extreme precipitation in the Indian summer monsoon.

Other Initiatives

(a) An autonomous Authority, **National Bureau of Water Use Efficiency**[66] (NBWUE) is proposed to be set up in the XII Plan under Article 3(3) of the Environment (Protection) Act, 1986 to increase water use efficiency by 20% by March 2017. The Bureau will have the overall responsibility for improving water use efficiency across various sectors like irrigation, drinking water supply, power generation and industries in the entire country.

(b) The **National Mission on Sustainable Habitat** is a sub-mission under the National Action Plan for Climate Change, which will include a major R&D programme focusing on bio-chemical conversion, wastewater use, sewage utilization and recycling options wherever possible.

(c) In order to benchmark service levels and plan for their improvement, the Ministry of Urban Development started the Service Level Benchmark exercise. Under this the urban bodies measure the services – water supply, sanitation, solid waste and drainage on yearly basis. The Thirteenth Central Finance Commission has also endorsed this and made it a condition for releasing grants.

Box 3: 24x7 Water Supply in Nagpur – An Adaptation Measure

The Nagpur Municipal Corporation (NMC), which is responsible for water supply in Nagpur city, decided to undertake a pilot 24x7 water supply project in one zone of the city. This was in response to the very high level of non-revenue water assessed by the water audit done in the city. Improving leakages in the system is a measure that has helped conserve precious water, improve service level, and save energy.

Prior to the implementation of the 24x7 pilot project, the average duration of water supply in the city was 4 hours (with a range of 2 to 12 hours in different areas). The supply system covered about 80% of the population in the city.

A water audit conducted in the city in 2005 revealed that of the 625 MLD raw water available to the city, as much as 62% was assessed as non-revenue water. The physical loss in the system was 148 MLD while the unbilled consumption was 226 MLD.

This prompted NMC to improve its performance. It initiated a pilot project in 2007, in an area covering about 10 sq. kms, to reduce the losses and improve supply standards from intermittent to continuous. The project was implemented through a 7-year Performance Management Contract and with 9 months for preparatory work, 15 months for rehabilitation and 60 months of O&M.

An impact assessment has shown that the pilot project improved supply pressure and this eliminated the need for booster pumps used by households earlier to improve pressure. The project also extended the connections to slum households in the zone. The non-revenue water reduced considerably. The high density polyethylene pipes that have been used in the system reduce the need for joints, which are generally the points from where water leaks. By reducing water leakages NMC has not only improved its efficiency of operations, reduced energy costs, increased revenue but also helped conserve the natural resource that was brought to the city from a considerable distant source. Not wasting water also means more water available for distribution.

[66] http://pib.nic.in/newsite/erelease.aspx?relid=89125

Urban Drainage

Urban flooding is becoming more frequent in India and is one of the major causes of disaster in cities. Rapid urbanization in the country is leading to unplanned growth of urban areas, conversion of agricultural areas for non-agricultural use and usurping of wetlands, water bodies and natural drains for construction of buildings have all contributed to the phenomenon of urban flooding in the country. Floods are a seasonal phenomenon in India, and though devastating, they play an important environmental role of soil replenishment, ultimately helping agriculture and livelihoods. Encroachment on flood plains and natural drainage has made the phenomenon of flooding more destructive in nature.

What is Flooding?

As per NIDM, a **flood** is an excess of water (or mud) on land that is normally dry and is a **situation** where the inundation is caused by high flow, or overflow of water in an established water course, such as a river, stream, or drainage ditch; or pond of water at or near the point where rain fell[67].

Causes of Flooding

Flooding is caused due to both natural and anthropogenic reasons such as:

1) Heavy rainfall /cloud burst
2) Cyclones
3) Silting of river bed and other water bodies
4) Alteration of natural course of rivers/streams
5) Encroachment on water bodies - lakes, ponds, natural drainage
6) Poor management of drainage system
7) Deforestation
8) Lack of flood control measures

Urban drainage is a crucial component of urban infrastructure as it discharges excess water into natural systems like rivers, lakes, natural drains etc. With growing number of challenges, the role of urban drainage will further gain importance in future because of erratic nature of rainfall both in terms of time and quantum of rainfall, in order for city to come out of stresses posed by flooding. This interaction between climate and non-climate factors will be crucial and decisive.

Floods are one of the major climate related problems in cities as well in rural areas. Climate change is increasing the unpredictability of rainfall and this will have a major impact on the life, livelihoods and the economy of cities (Table 8).

[67] http://nidm.gov.in/idmc/Proceedings/Flood/B2%20-%2036.pdf

Table 8: Storm water drainage, flooding and adaptation measures

Climate Change Forecast:
Precipitation: Rainfall variability, more intense, with higher annual average rainfall, increased flooding

Sector	Probable Impacts	Adaptation Measures
Storm water drainage	• Floods damage life and property • Damage to roads, bridges; power and telecommunication, transport systems; water and sewerage systems etc. • Flooding of essential services (hospitals, power, telecommunication), paralysing of emergency response systems • Flood waters will recede at a slower pace if outfall points are encroached • Loss of business and assets; loss to economy • Riverine cities: Overflow of river due to breach in embankments due to heavy rainfall and silting; inundation of settlements and infrastructure especially in low lying areas. • Himalayan cities: incidence of landslides, mud and debris damage houses, buildings and infrastructure • Coastal cities: high tides could cause additional problems aggravating floods, reduce the rate of draining of water into the sea • Silt drying and stagnation in drainage line due to rise in temperature can loosen construction joints of storm water drains	• Separate sewerage and storm water drainage systems. • Ensure solid waste does not choke the drains. • Regular de-silting of drainage network and natural water bodies – rivers , lakes, ponds. • Preserve natural drainage while planning. • Make water permeable pavements. • Construct retention ponds and restore water bodies. • Riverine cities: Ban construction in high flood risk zones; construct bunds and dykes to prevent flooding; permit flood resistant agriculture on river banks and peri-urban areas. • Himalayan cities: Afforest steep slopes and do not allow construction in landslide prone zones; position key post disaster infrastructure on safer height. • Coastal cities: Construct houses on stilts in deltaic and other flood prone areas. • Removal of encroachment on natural drains. • City sanitation plan and drainage plan should be prepared • Procure de-watering equipments

Sector	Probable Impacts	Adaptation Measures
Unauthorised colonies / slums	• Flooding of low lying areas and poorly drained areas. • **Health risks** due to waste water and solid waste getting mixed with flood water. • Damage to immovable property in flood affected zones, especially those next to streams and rivers. • Drinking **water** scarcity due to flooding and **contamination** of sources.	• Early Warning System to prevent loss of movable assets and lives. • Mobile Urban Health Clinics in strategic locations for optimal outreach. • Insurance against losses due to floods. • Identifying flood risk areas and make climate proofing plans by involving community. • Public awareness on emergency action plan and evacuation routes.
Other sectors	• Stress on water treatment capacity due to excessive sediment load and contamination. • Longer commuting hours due to **traffic jams** caused by water logging. • Emergency services will be hit (esp. health and fire).	• Set up **Public Information System** to alert people about water logged and flooded roads, • Awareness campaign on dos and don'ts during floods by administration and municipality in high flood risk areas. • Construct boundary walls to protect water treatment plants, sewage treatment plants from getting flooded. • Procure generators for WTP and STP functioning. • Construct of innovative Green Infrastructure like swales and detention basins adjacent to critical flooding locations.

Increased riverine, coastal, and urban flooding leading to widespread damage to infrastructure, livelihoods, and settlements in Asia (medium confidence). IPCC AR5

Disruption of basic services has implications on local economies and strip people of assets and livelihoods, in some cases leading to migration. IPCC AR5

Importance of preserving natural drainage and wet lands:

Wetlands are not only bio diversity hotspots, but are also natural sponges which absorb sudden rush of water due to extreme rainfall, which man made drainage network are unable to channelize fully. What happened in July 2005 in **Mumbai** is an example which taught us a lesson in a very hard manner. Meethi river's course had been altered, its banks were encroached, even the width of its mouth was reduced. The treatment Mumbai gave to this rivulet was nothing more than of a drain, sadly its true even today! On 26th July 2005, unprecedented amount of rainfall happened. Even if the entire existing drainage network would have been ready, the amount of water which fell as rain could not have been drained out. And therefore the financial capital of India was flooded, loosing precious lives, assets, business days and not to forget the trauma which surviving people still have.

Gorakhpur, in Uttar Pradesh is another example, which needs to learn to respect the Ramgarh Taal and its catchment which is a being gradually encroached by settlement all around and solid waste being dumped into its periphery and catchment streams, which gradually has blocked the path of water flowing into the lake. On any extreme rainfall day, many of the low lying areas get flooded, because water simply cannot escape into the channels leading to the Ramgarh Taal. Conserving Ramgarh Taal is important not only for local ecology but also important for the health of the city.

Box 4: Low income households' adaption to flooding in Indore[68]

In many low-income communities in Indore, flooding is perceived as a natural, seasonal event, and households take steps to limit the damage it does. Those who live on land sites adjacent to small rivers that are also key storm drains are particularly at risk. But these sites have the advantage of a central city location. They have economic advantages because they are close to jobs or to markets for the goods these households produce or collect (many earn a living collecting waste). The land is cheap and because it is in public ownership residents are less likely to get evicted. These sites have social advantages because they are close to health services, schools, electricity and water. Most inhabitants have strong family, kinship and community ties with other inhabitants. Some residents have noted that the sites are considered safer for children because the narrow streets make them inaccessible to motor vehicles. Households and small enterprises have made both temporary and permanent adaptations to flooding. These include raising plinth levels and paving courtyards, using landfill, using materials which resist flooding, choosing furniture that is less likely to be washed away and ensuring that shelving and electric wiring are high up the walls, above expected water levels. Roofing may not be attached to a house so it can be quickly removed if the structure is in danger of being swept away. Many households also have suitcases ready, so valuables can be carried away. Residents have also developed flood-prediction and protection systems, and contingency plans for evacuating persons and possessions. In one settlement (Shekha Nagar), residents' first response to the threat of severe floods is to move the elderly, children and animals to

[68] Adapting to climate change in urban areas – by David Satterthwaite, Saleemul Huq, Mark Pelling, Hannah Reid and Patricia Romero Lankao, Page 48.

higher ground. Then they move electrical goods such as televisions and radios. Then other lighter valuables and cooking utensils are moved, with clothes being moved last as these are more easily replaced and not damaged by flooding. The more established residents have also learnt how to use the state system of compensation for flood damage, and this can provide a perverse incentive for residents to build houses in the most vulnerable and dangerous areas.

Built Environment and Settlement

As climate changes, the built environment, physical and social infrastructure will be impacted by extreme weather events more severely frequently (Table 9). Built environment is said to be man-made environment, which is more dense in case of cities and sparse for rural settlements. Built environment comprises of structures for residential, commercial, institutional use, network of roads, by-lanes and means of transit within a settlement, which varies depending upon size of population and morphology of the settlement. Events like heat waves, drought, high humidity and temperature, flooding due to heavy rainfall or cyclone etc. interact with the settlement type (dense/sparsely populated), infrastructure (planned/illegal colonies and slums) and construction material used and building design.

Population living in a congested area, which lacks motorable network, civic services and open spaces has a slim chance of surviving a sudden natural shock or climate change induced disaster like flood, fire due to short circuit on a hot day etc. A well planned settlement and its residents are much better equipped to cope and survive climate related disasters.

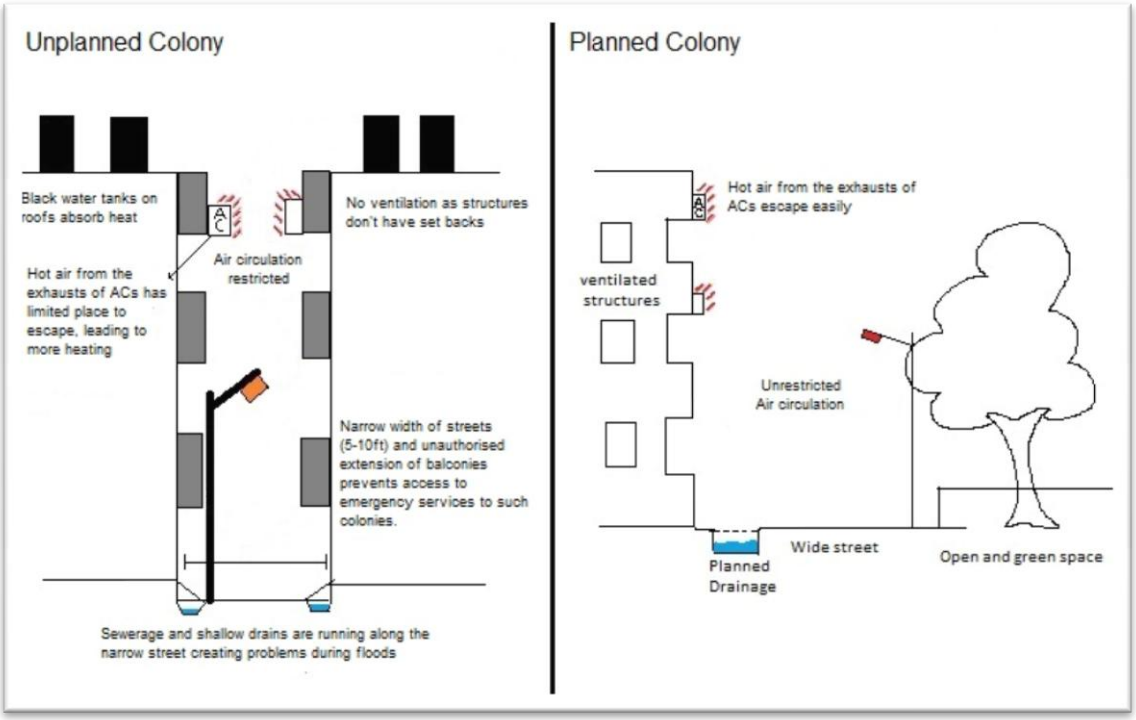


Figure 18: Built environment and its impact on micro climate (NIUA)

Table 9: Impact of climate change on urban built form and adaptation measures

Climate Change Forecast:
Precipitation: More intense, with higher annual average rainfall as well as increased urban flooding.
Temperature: Maximum and minimum temperatures will rise in most parts of India by 2°C to 4°C.

	Probable Impact	Adaptation Measures
Built Space	• Settlements on dangerous slopes susceptible to landslides. • Urban Heat Island along with humidity will add stress. • Roof materials like asbestos, tin, plastic etc. add to indoor air temperature. • High energy demand for cooling could lead to power outages and blackouts during extreme heat events. • Restricted air circulation in the streets/lanes due to high density of built structures. • Reduction of open areas in high density areas.	• Promoting vernacular / traditional construction methods. • Water permeable pavements. • Water harvesting systems. • Preserving natural drainage while planning. • GRIHA Certification for new public projects. • Discharge capacity of existing drains to be revamped. • Ventilated houses, built on stilts.
Residents	• Heat stress, especially for senior citizens and children. • Hazards – fire hazards due hanging wires, health risks due to stagnant water because of poor drainage or choked drainage. • Access to services limited in the interiors of the unauthorised / slum settlement. • Lack of toilets and absence of solid waste collection add to health risks in slum settlements. • Negative impact on productivity of working population. • Emergency services absent, excessive load on existing health functionaries in the area.	• **Early Warning System** to prevent losses of lives due to heat and flooding. • Identifying flood risk areas and make climate proofing plans by **involving community**. • **Evacuation routes** and emergency plans for communities in their consultation. • **Public information system and public awareness campaigns** to alert people on extreme heat event and floods. • **Insurance** of lives and assets against loss due to fire and floods. • **Mobile urban health clinics** in strategic locations for optimal outreach to needy people.

Box 5: Ahmedabad's Heat Action Plan

Extreme heat events already have significant impacts in India, which exacerbate in urban areas due to the Urban Heat Islands effect arising out of paved, cemented, less green environment in cities. After a deadly heat wave hit the city of Ahmedabad in 2010, when temperature reached 45°C (113°F), the Ahmedabad Municipal Corporation (AMC) has taken the initiative to develop a comprehensive heat action plans for extreme heat events, the first in India to do so.

This ground breaking project, created by AMC in partnership with an international coalition of health and academic groups, aims to implement three key strategies:

- Building public awareness and community outreach
- Initiating a simple Early Warning System
- Capacity building among health care professionals

2010 Heat wave was a wakeup call for that intergovernmental agency action, preparedness and community outreach is critical in saving lives. This plan directly targets those individuals and communities most at rise during heat waves – slum communities, outdoor workers, elderly and children and also individuals and organizations, such as Urban Health Centres (UHCs), NGOs and link workers who directly and frequently work with at-risk population.

Source: http://switchboard.nrdc.org/blogs/ajaiswal/HAP%202014_FINAL.pdf

Table 10: Changes in Temperature and Precipitation in different geographies of India ***(Temperature in degrees Celcius)***

	Himalayan	Riverine	Coastal	Desert and Plateau
Temperature	Over 3° rise in minimum and >4° rise in maximum temperature in higher Himalayas (J&K, HP,UK and Sikkim)	Less than 2° rise in max temperature in the Satluj-Ganga plains from Punjab to West Bengal & Brahmaputra plains except in Tarai belt in UP and Bihar and mouth of Hoogly river where the maximum temperature will rise between 2 to2.5°.	Over 2° rise in max temperature in the western and eastern coasts except Konkan stretch and Gujarat coast where temperature will rise by 2-2.5°	2-2.5° rise in max temperature in the western central parts of India, Vidarbha, Marathwada and south Maharasthra.
	3-4° rise in **max temperature** in *middle Himalayan* belt (J&K, HP,UK and Sikkim) and Manipur, southern Assam and eastern Meghalaya & 2-4° rise in **min temperature** in the *middle Himalayas* of J&K, HP and UK, < 2°in Sikkim and <2.5° in ArP	2-3° rise in min temperature in the entire Satluj-Ganga plains from Punjab to West Bengal & Brahmaputra plains.	< 2 ° rise in min tempera-ture along Konkan, Karnataka coast and Malabar and entire eastern coastal plains.	2.5° rise in min temperature in Rajasthan, western MP, Vidarbha and Marathwada

	Himalayan	Riverine	Coastal	Desert and Plateau
Precipitation	Negative changes to negligible rise in precipitation in higher Himalayas and trans Himalayan region (J&K, HP,UK, Sikkim and ArP); Negative changes to negligible rise in precipitation in *middle Himalayas* (-50mm to +50mm); Reduction in rainy days.	Rise in annual precipitation between 250-500mm in the Satluj Plains, Upper and Middle Ganga Plains in UP. 100mm-250mm in Lower Ganga Plains of Bihar, WB & Upper Brahmaputra plains. Decreasing trend in Lower Brahmaputra Plains.	Rise in annual precipitation between 500-1000mm: -Rise of 250-500 mm in northern Karnataka coast, entire eastern coast; Decrease in rainfall by 250mm in southern Karnataka coast and Kerala coast.	Negative changes to moderate rise in precipitation (-100mm to 150mm) in Madhya Pradesh, Rajasthan, North Gujarat and Kathiawad, Vidarbha, Marathwada and south Maharashtra

Note: *All the changes are based on RCP45 scenario (a medium scenario).*
Source: *atrisk.in developed by TARU Leading Edge Pvt Ltd.*

Planning framework for integrating climate change and associated risks with development planning

It is important that cities which face extreme events must embark on development which not only answers the question how to minimise the impacts, but also answers how to achieve our development goals while factoring in for current and future risks.

UNFCCC recently estimated that by 2030 the world will be spending and additional $36-$135 billion each year to address the impacts associated with climate change and that $23-$55 billion investment will be needed to fund adaptation in the developing world.

Cities can prepare themselves by both informal preparations like community engagement, awareness, knowledge dissemination among vulnerable sections, etc. as well as by formal planning activities, like zoning and conserving wetlands, regulating land use conversions in prohibited zones, pricing tools, promotion and expansion of public transportation modes and network, etc.

The United Nations Office for Disaster Risk Reduction (UNISDR) in 2010 launched the global campaign "Making Cities Resilient – My City is Getting Ready!"[69] to promote increased understanding and commitment from cities and urban local governments to build cities which are resilient to climate change and disasters. A ten point checklist was propagated, built from Hyogo Framework for Action. The *ten guiding principles* are:

- *Organization and coordination*: Putting in place organization and coordination among them, based on public participation, to reduce the risk of climate induced disasters. Ensure that all departments understand their role.
- *Assign a budget*: This element will help in risk reduction by providing incentives to low income groups, businesses at risks, public sector to invest in reducing the risk they face.
- *Vulnerability assessment*: Updated data and maps on vulnerable sections and the risks they face. Using these data while planning and related decision making.
- *Invest in infrastructure*: Investment should be done to strengthen the infrastructure, especially if it reduces risks, like dykes, barrages and flood gates, drainage, mobile health clinics for poor sections, etc.
- *Assess all schools and hospitals* for safety and upgrade them wherever necessary.
- Apply and Enforce building regulations and planning principles
- *Ensure education, campaigns, training* on risk reduction, in education institutions and local communities.
- *Protect ecosystems and natural buffers* to mitigate storm surge, floods, heat related hazards, and other risks to which the city may be vulnerable to.
- Install *early warning systems and emergency management* capacities in your cities and hold regular preparedness drills.
- After any disaster strikes, ensure that the needs of the survivors and those with least coping capacity are placed at the centre of reconstruction and rehabilitation

[69] Guide to Climate Change Adaptation – by The World Bank, box item 3.3, page 20

Urban planning and its approaches – current and future requirement

The climate change adaptation and mitigation strategies are best addressed and sustained through planning interventions, which is a holistic exercise and can deal issues at regional scale to local area scale.

It should be noted that developed countries have already started working on these strategies which are *integrated in nature and sustainable*, reducing the risks to extreme events not only today but also future.

The approach has started changing from visualising the near future needs of 10 – 20 years which is a popular practice today, to *long term planning* where needs for next 50-100 years, once in a 100 and once in a 500 year extreme events are factored in.

Planning exercise over decades has been more of technical exercise, where soft and non-technical aspects have been overlooked, which has resulted into non-acceptance of planning outputs in many instances. For example – informal settlements have sprung up in cities which attract population from rural areas for various purposes and they settle to reap benefits of economic opportunities. But planning to build affordable houses in cities has never been able to match this large inflow of population, resulting in people encroaching government land and living in slums, which are vulnerable, as mostly sites where slums come up are dangerous for some reason or the other. *Community participation and inputs are necessary so that people owns the plans* and the designated land use is respected by them.

Planning in India has been centralized in nature, having a top-down approach, however things have changed since 1992, when 73rd and 74th constitutional amendment act provided a more *decentralized and democratic planning process*. It is important that the urban local bodies have role to play in decision making, planning and allocating resources, within its notified area. Without having control over basic civic functions, city and its residents cannot handle and reduce the risks posed by different extreme events.

A major shift is required in planning process when we factor in the climate change, which is element of certainty. Nothing is certain in natural systems, and perfect projects for long term climate change do not exist. Therefore, an *element of uncertain and unforeseen events* should always be left in the plans so that it can be accordingly adjusted and modified, as and when need arises.

Planning is not confined to certain specific disciplines like engineering, rather it benefits from *inter-disciplinary* inputs. It connects economic, social, health, environment, demographic characters of place. If a plan for a place does not connect with any of these aspects it leads to unrest or disturbance. And when we factor in climate change all these aspects become even more crucial.

All the above elements, which are highlighted, are important for a planning process to be complete and holistic in nature. Plan cannot be rigid, short term and centralized in nature, when climate change induced variability and extreme events are factored in.

Table 2: Types of urban level plans and incorporation of potential climate change aspects

Type of Plan	General Purpose	Potential CC features
Town Plan / Physical Land use plans	• Identifies areas (zones) for different types of development (i.e., housing, commercial, industrial, etc.) • Identifies development hazard areas (steep slopes, flood plains, etc.) • Provides long-term direction on land use and development, transportation and overall community development	• Highlight development "hot spots" or "no development areas" where climate change impacts are likely to be most severe. • Set policy direction on "climate friendly" and/ or "climate resilient" infrastructure and services (i.e., storm water management). • Land capability, suitability, and the feasibility of different development alternatives are analyzed to determine appropriate spatial relation-ships that form the basis of the generalized future land use maps.
Storm water management plan	• Improves storm water management, including drainage and infrastructure	• Identifies climate change-related storm water/ flooding hazard areas. • Considers options for flood and coastal management, including prompting appropriate and sustainable defences and locating new development away from areas of highest risk. • Directs new infrastructure to "safer" areas not as exposed to climate change impacts (i.e., can attract or pull development to serviced areas). • Accelerates investment in existing coastal and river flood defence programs to protect existing development in flood prone areas. • Identifies options to increase permeability of paved areas in drought prone and flood affected areas.

Type of Plan	General Purpose	Potential CC features
Transportation Plan	• Improves road, pedestrian, transit and bicycle connections and infrastructure	• Identify and improve "weak links" in transportation networks that are threatened by climate change impacts (e.g., bridges threatened by storm surges, roads subject to flooding, etc.). • Identify and designate emergency transportation networks. • Prioritize transportation network improvements that improve transportation connections for climate vulnerable groups • Support climate change mitigation through reduced traffic congestion, prioritizing non-motorized transportation.
Local Economic Development Plan or Strategy	• Identifies and prioritizes economic sectors and opportunities (i.e., jobs, capacity, infrastructure, etc.)	• Reduces urban poverty levels for key climate change vulnerable groups (e.g., women, children, urban poor). • Promotes "climate friendly" and/or "green development" opportunities
Informal Settlement Upgrade Plans	• Develops policies and plans to improve services, infrastructure and sanitation • Formalizes property ownership	• Identifies potential climate change impact risks (e.g., storm water and flooding, slope failures, health) and responses to them (i.e., relocation, infrastructure improvement, etc.). • Identifies and relocates housing from high hazard areas and/ or develops "planned retreat" and/ or relocation strategy.
Solid Waste Management Plan	• Improves solid waste management, including collection, handling and infrastructure	• Supports climate change mitigation through improved materials recycling and/ or reuse and, where practical and feasible, landfill emissions capture
Energy Management Plan	• Improves energy generation options, distribution, and conservation	• Identifies climate change-related risks to energy generation and distribution facilities. • Supports climate change mitigation (i.e., green energy, conservation)

Type of Plan	General Purpose	Potential CC features
Water Management Plan	• Improves water supply, management and distribution • Improves water conservation	• Identifies climate change-related risks to municipal water supply, treatment and distribution and adaptive measures to counter them. • Identifies water conservation and water demand strategies and tools to better manage and adapt to future potential water shortages
Sewer / Liquid Waste Management Plan	• Improves waste water/ sewer management, including and infrastructure	• Identifies development and/ or construction guidelines for "climate proof" facilities (i.e., facilities that are located and built to withstand and function during climate change impact events). • Identifies and prioritizes high risk areas where new facilities are most needed to reduce climate change impacts amongst vulnerable groups. • Identifies options to reduce or reuse wastewater (grey water) for urban agriculture and horticulture.
Emergency Management Plan	• Improves disaster response preparedness • Identifies 'hot spots' (i.e., areas and groups vulnerable to disaster)	• Identifies climate change disaster risks, likelihoods and adaptive capacity. • Supports, facilitates and expedites infrastructure and planning improvements to reduce climate change-related disaster impacts
Public Health Plan	• Typically focuses on disease prevention and public safety improvements	• Identifies and prioritizes health risks (e.g., disease, accident, etc.) associated with climate change. • Supports, facilitates and expedites infrastructure and planning improvements to reduce climate change related public health impacts (e.g., supports improved storm water and waste treatment facilities, supports urban greening to reduce heat island effects, etc.)

Source: TARU Leading Edge Pvt Ltd.

Operationalising Planning Framework for developing Climate Resilience Strategy

A number of challenges arise when any plan or strategy is framed to address a certain sector or issue and its success depends upon how robust it is and whether or not the community for which that plan or strategy is framed has a sense of ownership to it.

Why Resilience Strategy?

We all know every city has its own existing challenges which will interact with variability in temperature and precipitation associated with changing climate. The need to build up the resilience of cities is especially important which are growing rapidly, high proportion of their population are poor or do not have access to sufficient resources and infrastructure, where urban local bodies have limited experience of adapting to extreme events, where funds are limited and need to be used judiciously .

Therefore a resilience strategy built around – ***systems*** (to develop flexibility, redundancy and element of safe failure), ***agents*** like government, private & civil society actors, various individuals and organizations etc. (to develop responsiveness, resourcefulness and capacity to learn), and ***institutions*** (to develop knowledge of institutions around rights and entitlements, decision making, flow of information and application of new knowledge) is important.

Process to be followed to build a resilience strategy

Framing a city resilience strategy is unique to every city since the character of city varies in terms of socio-economic and demography, location, existing capacity in terms of institutional structure, finance and infrastructure. A city begins to work on this exercise when it acknowledges the looming threat of climate change and associated extreme events and its impacts on the city dwellers and urban systems.

The following steps are suggested to frame a CRS.

STEP 1: Getting started - Each city is unique in terms of its planning context, capacity, governance, leadership, institutional base, current climate situation: threats, vulnerability and adaptive capacity. Therefore each city should start by acknowledging these variables and build a core team of experts. It may be necessary that such a team be formed under the umbrella body of municipality, having specific objectives. A formal agreement may be needed to plan and fund this process.

STEP 2: Stakeholders assessment and engagement – This is a stage when different stakeholders are to be identified and engaged, who can offer their perspective, views and knowledge to frame the climate resilience strategy. It should be ensured that stakeholders are from planning, health, finance, engineering background, so as to enrich the background behind the strategy or plan they will formulate.

STEP 3: Identify community issues – It is important to identify and note the current issues which bother different communities. This base information helps in framing the strategy which will eventually be owned and accepted by the communities readily. Without having

proper understanding of the problems and issues communities face today, a plan or strategy for future cannot be successfully framed and implemented.

STEP 4: Identify risks – Risks posed by changing climate need to be identified first which ultimately form the basis for which adaptation strategy is to be formulated. This will require climate data (current and projections) to be assessed and tools to assess it. It helps us understand whether risks are areal in nature or linear in nature. Zoning can be done based on such risks assessments.

STEP 5: Vulnerability assessment – Not everyone and everything is vulnerable to risks posed by climate change. Usually anyone or anything which is incapable to cope up with the risks and return to normal functioning post an extreme event is said to be vulnerable. With the help of correct data and tools vulnerability assessment can be done. Assessment can be done focusing on priority areas, economic sectors or population at risk.

STEP 6: Identify options – Stakeholders and state actors can brainstorm the different scenarios clubbing with the objectives and results intended to be achieved. The group can prioritise their options in terms of vulnerable communities, sectors, locations, costs for different options, options which will reap quick benefits, options which will be easy to implement and replicate, options acceptability to all stakeholders.

STEP 7: Evaluate the options – Decide strategies that best meet the local CC vulnerabilities, and identify them within current urban planning/development priorities and gaps. Assess consequences of options, action and strategies.

STEP 8: Implementation of Strategies – Identify and bridge the institutional gaps. Effort should be made to formally mainstream and link actions with existing schemes and established policy instruments. Actions should be durable, integrated and sustainable. Develop an action plan.

STEP 9: Monitor and Evaluate – An effective M&E is an integral part of planning process. M&E will sound an alarm in case the stakeholders are not carrying out their pre assigned tasks and are lagging behind, external and internal circumstances have changed, adaptation measure not effective, etc. For a non-biased monitoring and evaluation an external partner should be engaged in.

STEP 10: Modify and Adjust - A good strategy or plan is one which is flexible enough to adjust itself as per the changing needs over time. A need may arise when the strategy needs to be modified due to changes in factors arising out of changes in community's priorities, changes in risks associated with changing climate, changes in funds flow, or a complete redesign of the strategy as the intended results are not achieved or accepted.

Monitoring and Evaluation to assess progress

Monitoring is an on-going process through which the implementers of the project ensure that actual activities conform to the planned and intended ones. The outcome of such exercise gives us the discrepancies and deviation from the set task. Such information helps in taking corrective measures while such a deviation from the set task is taking place.

Monitoring helps in following ways:

a) Analysing the inputs in the projects are well utilized

b) Identifying problems faced while implementing the project

c) Ensuring all activities are carried out properly by right people and on time

d) Using lessons from the implementation to replicate in other projects

e) Determining whether the way project was planned and implemented was best or need revision

f) The exercise actually acts as a feedback to stakeholders, investors and implementers.

Elements of Monitoring exercise:

(a) *Establishing standards* – Without setting a benchmark, assessing whether a task performed is as intended or not, is not possible. Such benchmarks should be easily understood by everyone and accepted by everyone who is implementing.
(b) *Measuring performance* – Once standards are unanimously accepted and understood, next step is to measure the performance of implement project and determining the quality of actual performance. Measurement should not only restrict itself to what has happened but also predict and guide what might happen in future.
(c) *Feedback mechanism* – Without flow of information and feedback the effectiveness of monitoring exercise cannot be achieved. Therefore, a robust mechanism must be put in place to ensure the free flow of data, statistics, reports, returns etc. that will provide the basis for the regular availability of useful information on which action can be taken.
(d) *Taking corrective actions* - When significant deviations are noticed from the set quality standards, time schedules, physical targets or cost estimates, corrective actions need to be initiated. In such cases, actions like re-orientation and motivating implementers, strict supervision, supervision, engaging community, re-training staff may be required.

Evaluation is crucial step as it sums up how well a project/activity achieved its objective. Based on the evaluation implementers of project are able to take corrective measures, continue with or discard certain practices or change policies on implementing.

Evaluation can be of two types – ***Qualitative*** and ***Quantitative***. Qualitative evaluation is an assessment process which answers “How well did we do?”and Quantitative evaluation is an assessment which answers “How much did we do?”

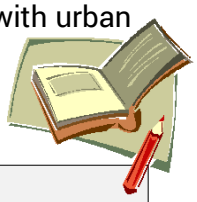
Evaluation helps in improving our learning about the end results and impacts of project on community and accordingly modify the strategy or plan while replicating in other areas.

Module IV

Putting UCCR into Practice

Introduction

This module will briefly discuss the concepts of urban vulnerability and risk assessment. It will give examples of action taken by ACCCRN cities to address vulnerability and risks. It will then introduce participants to the vulnerability and risks assessment tools and assist them in building scenarios for their cities. The module will enable participants to enlist partner agencies within and outside municipal departments for planning and implementing resilience strategies. The module will, through an exercise, help participants to identify projects that will address the vulnerability and risks identified in the scenarios. The module will also provide information to participants on the existing networks connected with urban climate change for continuous updation of knowledge.



Learning Objectives

- To recapitulate the concepts of urban vulnerability, risk assessment and related terminologies.
- To understand, through examples, how the ACCCRN cities have planned and implemented resilience strategies.
- To enable the use of tools for assessing vulnerability and risks and building scenarios.
- To appreciate the importance of forming partnerships for strengthening collaborative action.
- To identify appropriate adaptation and mitigation projects that will help cities reduce the impact of climate change.

Background

There is increasing awareness of climate change as well as requirement of coordinated, well aimed and executed measures to meet emerging challenges of climate change impacts. There is a strong need felt to support the urban local bodies, civil society and other stake holders to implement resilience strategies. Resilience requires building capacity of urban local bodies to effectively respond to changing climate and its impacts. This can be achieved by sharing knowledge on practices, tools, methodologies, and forging partnerships to devise long term sustainable solutions for cities. Such shared learning and co–production of knowledge, build both formal and informal networks cutting across sectors. These measures help in promoting inclusive climate resilience development.

Cities contribute to climate problems but proper planning of cities can also provide solution to these problems. Appropriate urban policies and programmes can promote infrastructure that can withstand climate hazards and limit the exposure and vulnerability of people to climate change threats. This could be achieved through an integrated planning approach addressing both adaptation and mitigation[70].

Under the ACCCRN project, Gorakhpur, Indore and Surat developed a plan for tackling climate change threats by preparing a city resilience strategy. A brief of the city profile, the climate change threats, and key points of the resilience strategy of these cities is given below.

Case Studies

GORAKHPUR

Profile

- Located in the north–eastern part of Uttar Pradesh in the Himalayan -Gangetic plains
- Area - 147 sq. km divided into 70 wards; average density of 4,559 per sq. km.
- Population (2011 census) - 671,048
- Topography of the city is largely plain with marginal gradient/slope from north to south.

Climate Change Threats

- Noticeable change in climate over the years in the city - Increasing problem of intense precipitation events and variations in temperature ; Analysis of climate models predicts increase in maximum temperature in all seasons.
- Thus, the city is vulnerable to flooding, water logging, sanitation problems and deterioration of eco system.
- Unplanned growth, poor coverage by sewerage network, encroachment on water bodies - 44% of the city affected and about 20% of the area suffers acute water logging; only 22% of the city has access to sewerage system - remaining 78% rely on other means or have no access to sanitation.
- Solid waste is disposed off in various informal dumping grounds. This waste clogs drains resulting in water logging, drinking water contamination and enhanced public health hazards.
- These, coupled with potential variability in precipitation, could have significant impact on local water availability, agriculture and incidence of water and vector borne diseases.

Key Actions

- Vulnerable points identified
- Gorakhpur Environment Action Group (GEAG), with support from ISET and ACCCRN, launched various campaigns to address these issues; ***Sanitation and waste*** – leaflet distributed to *educate* citizens, and *encouraging* them to change their habits regarding waste and recycling, and *participate* actively to demand better services from the city government; ***Ecosystem Management*** – Conservation of Ramgarh Lake raised *awareness* among the communities to understand the risk posed by water contamination and encroachment in the lake; ***Solid waste management*** – Decentralized and *cost–effective* SWM measures *involving* residents encouraged and promoted (helped in waste recycling to increase soil fertility through composting and reducing solid waste volume)

Outcomes

- The city prepared and implemented a resilience strategy through active engagement of stakeholders. Key outcomes: It deepened understanding of climate change threat to the city; led to implementation of ward level resilience project in one ward; combined and integrated drainage, urban agriculture and flood resistant housing, training and capacity building.
- Climate change threats acted as catalyst of engagement.

[70] J. Corfee-Morlot et. al, Cities, Climate Change and Multilevel Governance, OECD Environment Working Paper No. 14, 2009 http://www.oecd.org/dataoecd/10/1/44242293.pdf

INDORE

Profile

- Part of the Malwa plateau drained by two rivers; Khar and Saraswati
- Located on an elevated plain with Vindhyanchal range to the south.
- Population (2011 Census) - 1,960,631 with total slum population of 529,370 (about 27% of the total population)
- Density - 9,718 / sq. km
- City spread rapidly over an area of 3,898 sq km.
- Temperature rises sharply in the summer season and it drops sharply during the winter season.

Climate Change Threats

- City faces potential threat of climate change through precipitation changes and rise in average minimum temperature, which would add to urban heat island effect.
- Impacts: The impact of precipitation changes would increase flood risk and water logging. It would also create associated risk of health. The climate change factors are also going to impact water availability.
- Many parts of the city are low lying and have limited sewerage and storm water infrastructure. In such a scenario, the city will face risk of intense impact of climate change.

Key Actions

- Multi-pronged approach to address risk and vulnerability to climate change adopted; *Awareness* about climate change risks created and citizens *encouraged* to demand services and action from the urban local body; Generation of municipal information system to analyze gaps in infrastructure and its availability; Based on these mid-term and long term strategies were devised to create sustainable infrastructure to deal with challenges emerging from climate change.
- ***Water*** - Comprehensive water management plan was drawn; Inter linking and gridding of various water supply projects were undertaken; Improvement in water supply system including ground water recharge and waste water recycling introduced; Efficiency improvement measures such as metering, pressure monitoring, maintenance, helpline undertaken; Emphasis on rainwater harvesting and technological options in waste water recycling were stressed.
- ***Energy*** - Encouraging energy efficiency through Building codes under Energy Conservation Act 2001; Emphasis on building redundancies to meet demands and control prices, meet shifts in energy demand.
- ***Disaster Management*** - Efforts to reduce risk and exposure (especially for the poor) undertaken; For better disaster management devices for warning and forecasting of extreme weather events were put in place. Mapping of flood plains including flood plain risk zoning with advanced warning system were undertaken for better identification of water logging prone areas. Stress was laid on improving disaster response including evacuation of people from water logged zones.
- ***Sewerage, waste management and public health*** – An integrated approach was designed for waste management that included awareness campaigns, encouraging waste segregation, and waste processing on scientific principles for waste recycling. Cleaning of drains passing through the city and resettlement of habitations along them to reduce the impact of water logging planned.

Outcomes

- Created awareness about the impact of climate change on the city and generated bottom up demand.
- A municipal information data base on information about the city helped in identifying gaps and strategies to address them. This developed cross learning mechanisms.
- By analyzing risks and vulnerabilities, the city was able use the opportunity to address climate change impacts.

SURAT

Profile

- Surat is a port city and a major industrial hub located on the banks of river Tapi. It is also a coastal city.
- It is the second largest city of Gujarat with a population of 44,61,206 million (2011 census).
- Area - 326.5 sq km with total density of 3,662 persons/sq km .
- The city has recorded unprecedented growth and has spilt over peripheries.
- There are about 334 slums (2011 census) in the city, mostly located in hazardous locations.
- The city has a flat terrain. Being a coastal city it has a humid climate with extreme temperatures in summers and has moderate to high rainfall.

Climate Change Threats

- Analysis of climate in the region indicates increase in maximum and minimum temperatures. This together with high humidity and effects of urban heat island will result in variations in temperature and precipitation patterns during different seasons. This may cause increase in flood events due to extreme precipitation.
- Since it is a coastal city, the potential threat of sea level rise and prolonged high tides and an increase in the water yield in Tapi river basin can lead to inundation of many parts of the city. This would impact distribution and survival of aquatic species and algal blooms.
- Temperature increase is expected to lead to shrinking of water bodies and increase in pathogens.
- In case of any extreme climate change event like flood, storm water runoff might mix with sewage and discharge in the river. This will increase river pollution and result in water shortages. There is also potential threat of vector borne and water borne diseases. Silt brought by river Tapi to the creek may result in inundation of parts of the city.

Key Actions

- Based on vulnerability assessment, a resilient strategy for the city was prepared and short term, midterm and long term priorities were set out Key sectors were identified and potential strategies were suggested:
- ***Water*** - Robust water supply infrastructure and its expansion to deal with the emerging challenges of climate change; Water conservation practices such as water audits and expansion of metering introduced; Surat Municipal Corporation (SMC) introduced metering policy in 2008. A consumer sensitization campaign for saving water, monitoring of water quality from source to tap on a real-time basis, linking this to other departments for public health surveillance and recycling of waste water was undertaken.
- ***Sewerage and Drainage***- Four sewage treatment plants were built to treat and reuse wastewater - treated wastewater supplied to industries. Storm water drainage system significantly improved, including its operation and maintenance. This and measures such as widening of roads for providing storm water drains have minimized the impact of pluvial flood risk and has mobilized the administration to extend the existing storm water drainage system, ensuring quick recovery from major floods;
- ***Public Health*** - A real time disease surveillance, quick diagnosis and vector control operationalized with active participation of over 350 doctors across the city. This will significantly contribute to reducing the disease spread.
- ***Enhancing city preparedness*** - River embankments strengthened to enable it to withstand moderate discharge from Ukai dam. SMC has put in place a Disaster Preparedness and Municipal Response Plan; Disaster management plan available at the ward level; rain water harvesting in new large buildings are being implemented; Skill enhancement of SMC staff done through capacity augmentation initiatives.

Outcomes

- SMC started to initiate projects keeping climate change proofing as a central issue. The strategy for climate change will henceforth be built on the initiatives of SMC to leverage further actions.
- "Multi-scalar approach" enabled the SMC to address physical and socio economic issues.
- Relationship with state and national level institutions emphasized to incorporate lessons learned from Surat into national urban development policies.
- Based on the generation of municipal information in various sectors and interaction with multiple stakeholders, the resilience strategy devised short, medium and long term interventions.

Tools for Assessing Vulnerability, Risks and Building Scenarios

In order adapt to climate change, the vulnerability and risks posed by climate change need to be assessed and scenarios of climate change affecting the city/ region need to be built. A number of tools are available for identifying and prioritizing risks posed by climate change. Some of these tools are given below:

Climate Adaptation Tool (CAT)[71]

Introduction

The Climate Adaptation Tool (CAT) was launched in September 2010 as UK's first comprehensive tool to guide organizations through the full process of adapting to risks posed by climate change. It is a three step practical tool:

i. Identifying risks – This step is meant for identifying and prioritizing risks posed by climate change.
ii. Identifying and appraising options – This step helps in deciding the most appropriate adaptive responses to the posed risks.
iii. Auditing the performance of the implemented options – This step helps in reviewing the options, and auditing the opted adaptive measures after the implementation is done.

Appropriate use

CAT is a complete tool and useful for all organizations. Its aim is to provide a complete framework for organizations in identifying and prioritizing climate change risks, identifying and appraising adaptation options, and auditing those that are implemented. This tool can be used by all types of organizations and institutions, at different levels and for all kinds of climate risks.

How to use this tool

CAT recognizes that some organizations may already have risk assessment procedures equivalent to Stage 1, which is identifying the risks, and so Stage 1 has been designed not as a prerequisite for Stages 2 and 3 but rather as a means for conducting a climate change risk assessment for those organizations just starting to think about how climate change might impact upon them. Stages 2 and 3 are independent of Stage 1, which help decision making and the implementation of the opted adaptation measure. A guiding document is available which details out the stages and the inputs required.

Adaptation Support Tool[72]

Adaptation Support Tool assists users in developing climate change adaptation strategies and plans. This tool works through a 6-step process:

[71] https://unfccc.int/adaptation/knowledge_resources/databases/items/7723.php
[72] http://climate-adapt.eea.europa.eu/adaptation-support-tool

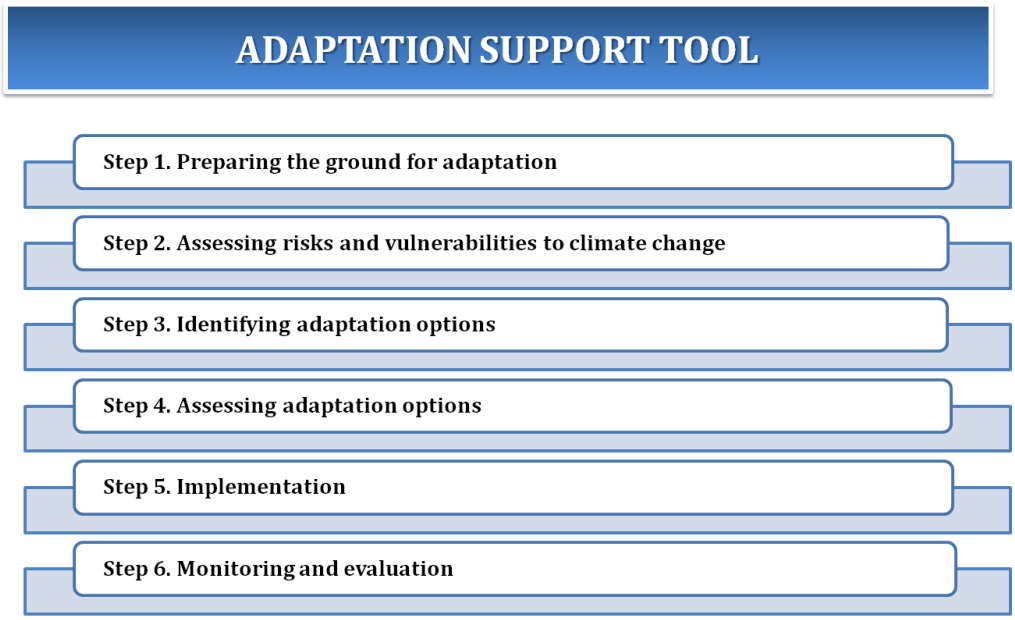


Figure 19: Steps of Adaptation Support Tool

i. Preparing the ground for adaptation

This requires high level support set up, coordination mechanisms and defined roles and responsibilities, exploration of funding opportunities, identification of available information and increased awareness or understanding of climate change issues. This could be achieved through an Integrated Management System (IMS) for the Local Climate Change Response. IMS is a 5 step cyclic process:

Baseline Review – Where are we right now?

The review aims at creating the basis for setting priorities and targets in the city's climate change response. It scrutinizes the present climate conditions and expected changes, to identify strengths and weaknesses, risks and opportunities in terms of climate mitigation and adaptation efforts.

Target Setting – Where do we go from here?

Climate targets could be prioritized using SWOT analysis. Setting targets would inspire and motivate the team to move forward with climate change actions. This step involves stakeholder participation, political note of state of affairs (emissions, energy supply and consumption, climate vulnerabilities), and related reference data to develop city's climate vision. Based on this, select the indicators to identify targets. Set the identified targets followed by a climate action plan that is smart, achievable and realistic covering elements

of: *What* – describe actions; *Why* – reasoning in regard of targets and expectation of impact; *Who* – responsibilities and partnerships; and *How* – tools, resourcing and financing.

Political Climate Commitment – Who is to decide?

Climate change response depends upon good governance and management, which requires strong political leadership and commitment. Extreme weather events explore the adaptive capacity of urban systems and management. Impacts of such events may be interpreted as results of previous long-term political objectives. An understanding of significant benefits offered by effective and efficient climate change response would help in obtaining political commitments. An outline of co-benefits and direct and indirect links of climate change response with local governments' themes could help in this regard.

Implementation and Monitoring- generic action plan to fine-tuned project plans

Implementation demands organization and coordination and refining the climate action plan. Refinement is a two-tier exercise: overall coordination of the generic action plan and implementation of individual projects. Planning implementation of projects is crucial. However, mere planning itself does not ensure progress and agreement with the strategy. Thus there is a need for an effective and continuous monitoring to track the status of projects. This could be done with help of indicators that are long-term (e.g. improved air quality, GHG emissions) or short-term (e.g. energy consumption).

Evaluation and Reporting- what has been achieved

After implementation, and monitoring, next step is to evaluate what has been achieved. Evaluation instigates the last step of the cycle, simultaneously providing the basis for starting a new cycle. It analyzes what has happened and the causes of success or failure. One of the ways to evaluate is through auditing. The information thus obtained from evaluation could be used by implementers to improve results and hence enhance the project performance.[73]

ii. Assessing risks and vulnerabilities to climate change

This step will help in assessing risks and vulnerabilities due to climate change, which will further aid in identification of opportunities and barriers arising from climate change. Adaptation is planned on the basis of climate projections; information on risk and vulnerabilities and the knowledge of climate interactions with socio-economic issues. All these, when combined together, provide an indication of future climate change impacts, risks and vulnerabilities.

Note*: An important tool in this respect could be* www.atrisk.in

Identifying adaptation options

The concerns identified in previous step are next addressed through various adaptation options. These options can range from actions that build adaptive capacity (e.g. sharing information, creating supportive institutional framework) to concrete adaptation measures (e.g. technical solutions, insurance mechanism). Collect appropriate adaptation options

[73] http://www.localmanagement.eu/index.php/cdp:local_authorities_tools

relevant to your city's main concerns from literature review and databases, from scientific experts and/or colleagues from other authorities and through stakeholder involvement. Exploring good practices and existing measures could be helpful as this could provide insights into the adjustments/improvements required to accommodate future climate changes and to identify the existing gaps and barriers.

Assessing adaptation options

The identified options are next assessed and prioritized based on time, cost, benefits and efforts needed. The adaptation options should be in sync with wider policy areas/sectors to avoid conflicts and promote synergies. Often a multi-criteria analysis (including an assessment of effectiveness and efficiency) is useful for ranking and selecting preferred options. Effective options reduce a particular vulnerability or number of vulnerabilities to a desired level. Efficient options are those whose benefits exceed costs and are more cost-effective than the alternatives.

Implementation

Next step is to implement the strategy which starts with preparing an action plan stating what needs to be done for converting adaptation options into action. An important aspect of successful implementation is collaboration and agreements with all affected stakeholders.

Monitoring and evaluation

Being an iterative process, adaptation calls for close monitoring to ensure its effectiveness. Monitoring ensures that, adaptation works and determines if any change is required to respond to changing conditions.

Baltic Climate Toolkit[74]

The Baltic Climate toolkit focuses on knowledge transfer to those groups which play an important role in decision making and implementation of climate change measures, but are not experts in the field of climate change. The toolkit targets three different groups: policy makers, spatial planners and business community. It takes a step beyond the political measures which to date have been focused on the international and national levels or targeted towards larger industries. This toolkit is specific to areas and actors of cities and rural areas in all Baltic Sea Region countries.

For policy makers the information in the toolkit focuses on recognising the problem and dealing with climate change (preparing ground, assessing vulnerability, setting strategic direction, plan and implement). For spatial planners the toolkit addresses more detailed and scientific information. The business community is plugged in through their main concerns: to know about the impacts on a business in a given region and to know what kinds of opportunities exist under new situations and circumstances[75].

[74] http://toolkit.balticclimate.org/en/spatial-planners/introduction
[75] https://www.youtube.com/watch?v=gOp0MQaH0cE#t=44

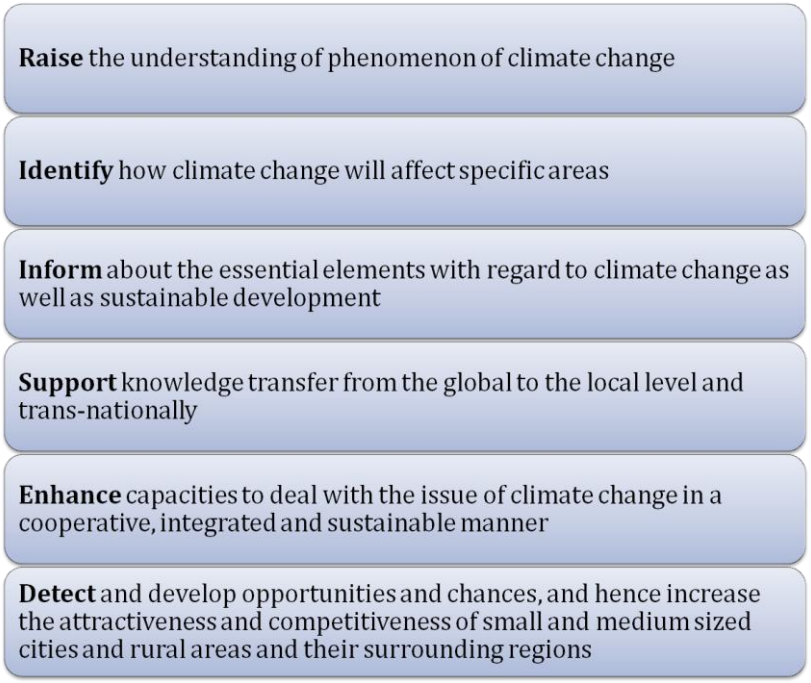


Figure 20: Aims of Baltik Climate Toolkit

MEDIATION Adaptation Platform (MAP)[76]

MAP is a platform helps to specify the tasks that have to be performed to address climate hazards effectively. It provides access to a Toolbox with methods and tools that are suitable to inform decision-making, depending on the situation[77]. It provides interactive access to methodological guidance on (i) assessing climate change vulnerability, impacts and adaptation, and (ii) implementing, monitoring and evaluating adaptation.

AT RISK – a Tool for Scenario Building

Developed by TARU **at risk** allows scenario building for different locations

Engaging partners for building resilience and learning

Building resilience to climate change requires coordination and cooperation from all stakeholders. The urban local government is the main stakeholder in the process of building resilience. There has to be intra-department cooperation within the municipal body and also cooperation with state level agencies such as the Departments of Irrigation, Housing, Health, Transport, and so on. The private sector, non-government and community based organizations, technical and academic institutions etc. also play a critical role in building resilience at city level.

[76] http://www.mediation-project.eu/platform/
[77] ibid

Box 6: CROSS-SECTOR COLLABORATION

At the city level, many different municipal departments have been active stakeholders in ACCCRN activities, from Departments of Public Works to Departments of Housing and Construction to Departments of Irrigation. However, the challenge of building urban climate change resilience is not for governments alone. There are several key drivers for private sector involvement in this area. Effective responses to climate change impacts require action from multiple sectors and stakeholders:

Financial services and insurance companies need to develop and distribute products that insure against new combinations and permutations of risk

Agriculture, water, tourism, and energy businesses, to name a few, will need to understand the risks and impacts of climate change on business sustainability, and be prepared to react accordingly – including capitalizing on new business opportunities

Infrastructure will need to accommodate new standards and incorporate a new flexibility that can respond to climate change uncertainty

Health systems will need to build local response capacity for widespread events such as heat waves, while simultaneously extending the reach of efforts to mitigate climate-related diseases such as malaria and dengue fever

Disaster relief organizations will need to plan for new types of disasters on a larger scale.

Source: http://www.acccrn.org/about-acccrn/acccrn-partners

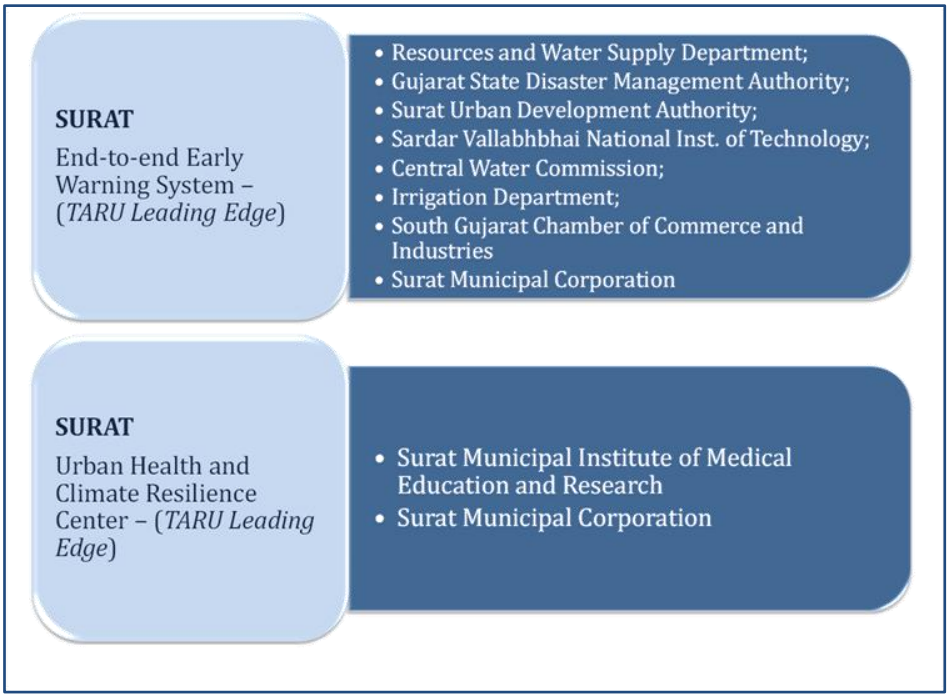


Figure 21: Examples of involving partners for resilience building in three ACCCRN cities

These examples indicate that successful implementation of resilience measures need collaboration with a wide array of stakeholders with varying interests and specializations.

Knowledge Networking and Learning Partnerships

Climate change is an issue that concerns all citizens and knowledge networks needs to be created and strengthened. 'Knowledge management is about the capture and sharing of

knowledge to enable people to work more effectively, improve decision making and enhance innovation'[78].

Peer Exchange and Reflective Learning (PEARL)[79]: The National Institute of Urban Affairs (NIUA) hosts a web portal (www.indiaurbanportal.org)for knowledge networking called PEARL. This platform was created under JNNURM[80] for sharing knowledge and experience amongst the 65 Mission cities. PEARL shares knowledge through documentation of best practices, data resources, holding seminars/workshops, exchange visits etc.

Asian Cities Climate Change Network (ACCCRN)[81]: "This is a network which spans India, Vietnam, Thailand, Bangladesh, Philippines and Indonesia. ACCCRN is working in over 20 cities to generate practical examples of how cities in fast urbanising, low and middle income countries, can build urban resilience to the various impacts of climate change. This initiative will help catalyse action within cities to build climate change resilience"[82].

The Climate and Development Knowledge Network (CDKN)[83] : CDKN aims to help decision-makers in developing countries design and deliver climate compatible development. It provides information on projects, and resources and on priority themes such as climate negotiations, disaster risk management, climate finance, and policy and practice.

TERI Project websites[84]**:** This website has been developed for dissemination, networking and information-sharing on projects that TERI is working on.

EMBARQ India[85] **Multimedia:** EMBARQ India's project activities and initiatives are documented through the use of innovative multimedia such as slide shows, videos, images and blog entries.

Cities Alliance[86]: The Cities Alliance website offers a variety of knowledge resources. The website provides links to reports and studies, including those on climate change.

ICLEI – Local Governments for Sustainability[87]: **"**ICLEI is an effective sustainability and environmental *Agency* strengthening the capacity of local governments and their networks to identify and implement radical solutions and act rapidly; providing advanced knowledge and delivering training to local leaders, planners and decision makers; demonstrating creativity and excellence in developing innovative methods and tools; serving as the cities gateway to solutions for the future"[88].

The above are a few examples of how knowledge on climate change and development can be shared by institutions by putting information in public domain through their websites. These are open access information that can be accessed by all.

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[78] http://www.acccrn.org/acccrn-knowledge-forum
[79] http://indiaurbanportal.in/AboutUs
[80] Jawaharlal Nehru National Urban Renewal Mission (JNNURM), implemented by the Ministry of Urban Development, Govt. of India, for providing infrastructure in 65 Indian cities.
[81] http://www.arup.com/Projects/Asian_Cities_Climate_Change_Resilience_Network
[82] Ibid
[83] http://cdkn.org/
[84] http://www.teriin.org/our-work/project-websites
[85] http://embarqindia.org/multimedia
[86] http://www.citiesalliance.org/
[87] http://www.iclei.org/iclei-global/who-is-iclei.html
[88] Ibid