URBAN RESILIENCY TOWARDS CLIMATE CHANGE

ABSTRACT

India will experience massive urbanization in the coming decades, with the country's urban population expected to double by 2050. Climate change is a major threat to urban systems all over the world. Its consequences are expected to worsen over the next few decades. The consequences of climate changes are more in urban areas than rural due to rapid urbanization, health issue, decreasing water level and industrialization etc. Climate change consequences such as increased rainfall intensity, storm surges, temperature fluctuation and flooding are expected to have a global impact on urban health, sustainability, coastal areas, urban infrastructure, migrants, ecosystems and urban water use. On the other hand, humanity able to take collective action to mitigate the severity of these impacts. Mitigation and adaptation strategies, such as climate resilient agriculture, rooftop farming, extreme weather mitigation, resilient water use and so on, will almost certainly be required to deal with these effects. It is encouraging to note that urban planning has the potential to play a key role in developing and implementing adaptive responses in urban systems. The benefit of urban planning is sustainable and required some urban planning regimes around the world which include, plan-making, stakeholder engagement, development management and design standards to make a better and greener urban ecosystem.

Keywords: Climate Change, Mitigation, Sustainability, Urbanization, Urban Policies

1. INTRODUCTION

The Ministry for Housing and Urban Affairs (MoHUA) said that India is the second-largest urban system in the world with 310 million people living in 5161 cities in 2020 [10]. The UN estimates that around 416 million people will be added to the urban population between 2018 and 2050 [12]. Although presently the 5100 urban centres hold less than 30% of the total Indian population, this figure is expected to rise to 40% by 2030 in an estimated 70,000 urban settlements, as urban population is likely to grow by 575 million over the next 50 years. By 2025, 70 Indian cities are expected to have more than 1 million inhabitants [35, 2].

Climate change poses a significant threat to urban sustainability, putting many cities at risk. Due to this the global rate of natural disasters has nearly doubled in the last 30 years,

resulting in increased human and economic losses [33]. Climate change would definitely increase the susceptibility of urban communities if suitable adaptation is not adopted, notwithstanding widespread scepticism about the extent and frequency of dangers as well as their precise effects [14]. Cities will play a vital role in achievement of not just India's economic targets, but also its sustainability goals, Indian cities contribute almost 70% to the national GDP while accounting for 44% of greenhouse gas emissions [17]. On the other hand, Green-house gases (GHG's) emission from the combustion of fossil fuels, degraded air quality and with a high degree of uncertainty can modify the climatic system, resulting in historic changes in urban ecosystem. Increase in temperature and humidity due to climate change can affect the frequency and severity of extreme events, the spread of vector-borne diseases, the intensity of heat waves and contribute to sea-level rise; all of which have direct and indirect effects on human health and well-being in cities [22]. Moreover, as a result of these variables, lower socioeconomic groups in metropolitan areas are disproportionately sensitive to air pollution, noise, water scarcity and extreme events [27]. Many problems are being caused by global climate change in today's urban and rural environments which has an immense impact on city stakeholders' behaviour. These changes are reflected in the urban structure in a variety of ways, including morphological, organisational, functional, economic, social and environmental changes [4].

The United Nations Human Settlement Program (UN-Habitat) defines urban resilience as a city's ability to respond to and absorb shocks while reforming and adapting over time thus by proper planning and execution can make a city greener and sustainable [3]. Actions aimed primarily at reducing greenhouse gas emissions in cities can bring immediate local health benefits and lower health-care costs through a variety of pathways, including reduced air pollution, improved access to green space, sustainable water use and opportunities for active transportation on foot or bicycle [46]. Thus, the purpose of this paper is to comprehend the interconnections between climate change and urban ecosystem as well as the exposure to multiple stressors in public spaces, not only in terms of urban form, infrastructure and health systems, but also in terms of socioeconomic systems and community cohesion.

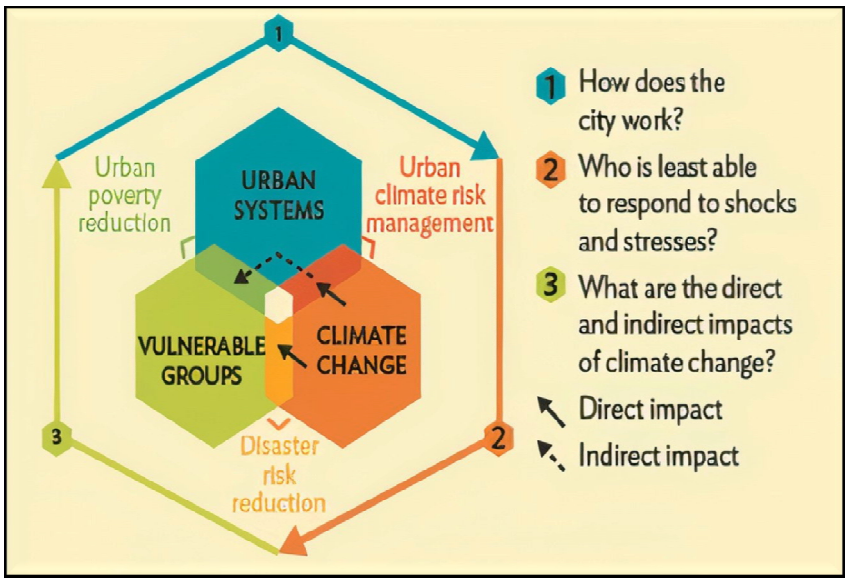


Fig 1: conceptualizing urban resilience to climate change [43]

2. WHAT IS CLIMATE CHANGE

Climate change is a long-term change in the statistical distribution of weather patterns that poses a significant threat to ecology and persists at harmful levels for a long period of time. Greenhouse gas (GHG) emissions are well-known contributors to climate change [9]. Climate change can be natural (caused by continental drift, volcanoes, earth's tilt and ocean currents) or anthropogenic (caused by urbanisation, industrialization, fossil fuel burning, deforestation and unscientific agricultural practises); natural climate change can be synchronising with nature, but anthropogenic climate change dominates nature's synchronisation power; however, nature can also synchronise with some mitigation and adaptive green technologies [41].

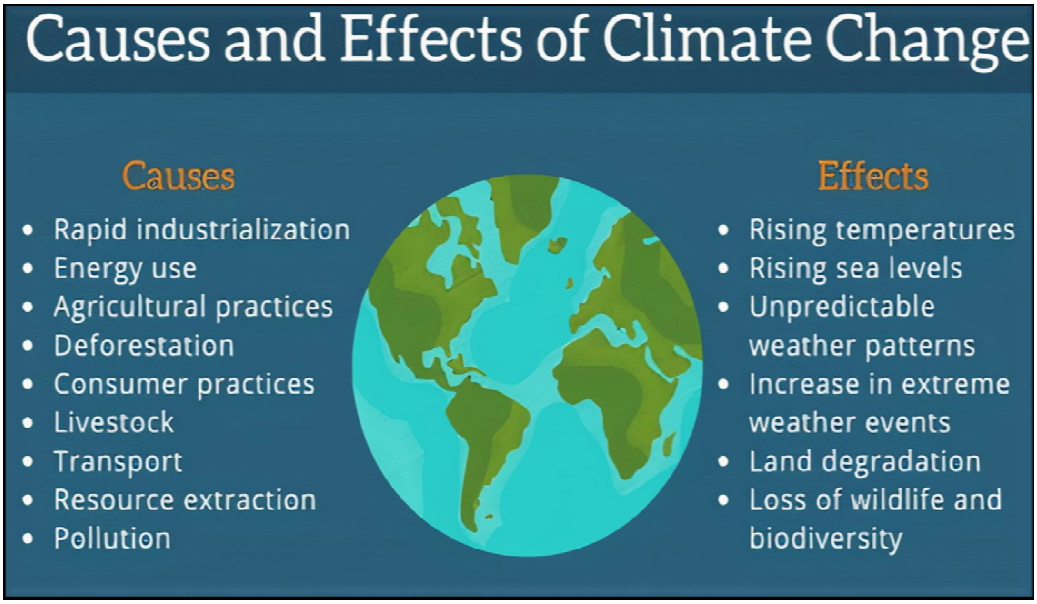


Fig 2: Causes and effect of climate change [42]

3. IMPACT OF CLIMATE CHANGE IN URBAN AREAS

As a result of climate change and extreme events, the risks of illness and injury in the cities are increasing rapidly. Storms, floods, extreme heat and landslides are among the most dangerous weather-related health hazards in cities. Climate change will increase the risks of morbidity and mortality in urban areas due to the increased frequency of weather extremes.

3.1. Impact of climate change on urban health

Climate change will exacerbate some chronic health issues (such as respiratory and heat-related illnesses) as well as infectious diseases in urban areas. Extreme weather condition disrupts the air quality, ecosystem balance, waste management, water supply and drainage systems, energy and fuel supplies, all of which have a significant impact on public health in cities [29]. Climate change is expected to increase the prevalence of environmental diseases. As a result of global warming and extreme events the labour output will drop by up to 20% in hot months by 2050 [19]. Excessive rainfall or droughts, a warmer and/or wetter breeding season as a result of global warming will provide ideal conditions for the spread of mosquito-borne diseases [19]. Better health outcomes will be the result of more resilient urban infrastructure, both during and after natural disasters. Poor people may suffer more because

they have fewer options for adaptation [7]. As stated by UNFPA, “poor areas that lack health and other services, combined with crowded living conditions, poor water supply and inadequate sanitation, are ideal for spreading respiratory and intestinal conditions and for breeding mosquitoes and other vectors of tropical diseases such as malaria, dengue, typhoid and yellow fevers [34]. Changes in temperature and precipitation can spread disease in previously unaffected areas and escalate it in areas already affected.

Table 1: Impact of extreme weather on urban health [16]

Extreme weather event	Health impacts
Heat wave	✓ An increase in the number of people dying from heat stroke. ✓ Increases in cardiovascular and respiratory mortality in the short term
Flood	✓ Floods, landslides and windstorms have both direct and indirect impacts (deaths and injuries) (infectious disease, loss of food supplies, long-term psychological morbidity) ✓ Water and sanitation systems are disrupted. ✓ Providing mosquito vectors with nesting grounds, leading in disease outbreaks ✓ Post-traumatic stress disorder (PTSD) is a condition that occurs after a severe flood
Drought	✓ Reduction in availability of water for hygiene, which can lead to diarrheal and respiratory diseases ✓ Increase in drought conditions may affect water availability and water quality (chemical and microbiological load) due to extreme low flow
Higher temperatures	✓ Diseases transmitted by mosquitoes and ticks (e.g., malaria, dengue) ✓ Temperature affects the survival of major bacterial infections.

3.2. Impact of pollution on urban sustainability

Air pollution is a combination of hazardous elements originating from both natural and man-made sources [62]. Vehicle emissions, fuel oils and natural gas used to heat homes, by-products of manufacturing and electricity generation companies; particularly coal-fuelled power plants and odours from chemical production are the primary sources of man-made air pollution. Traffic-Related Air Pollution (TRAP), which is caused by motor vehicle emissions, is the most visible form of air pollution [37]. It contains the majority of the components of anthropogenic air pollution, such as ground-level ozone and various carbon forms. Smog is a term used to describe the presence of ozone, an atmospheric gas, at ground level. Noxious gases such as carbon dioxide, carbon monoxide and nitrogen are components of motor

vehicle emissions and by-products of industrial activities. PM 2.5, a type of particulate matter, is 30 times thinner than a human hair [30]. If inhaled, it can penetrate deep into the lungs tissue and cause serious health problems. PM 2.5 is responsible for majority of the health effects associated with air pollution. PM is found in vehicle and industrial emissions from the combustion of fossil fuels, cigarette smoke and the combustion of organic matter, such as wildfires. Those susceptible to serious health problems as a result of air pollution include [44]:

- ✓ Added stress to heart and lungs, which must work harder to supply the body with oxygen
- ✓ Aggravated cardiovascular and respiratory illness
- ✓ Development of diseases such as asthma, bronchitis, emphysema and possibly cancer
- ✓ Lung damage, even after symptoms such as coughing or a sore throat disappear
- ✓ Wheezing, chest pain, dry throat, headache or nausea
- ✓ Development of chronic bronchitis or chronic obstructive lung disease
- ✓ Irregular heartbeat and non-fatal heart attacks
- ✓ Premature death in people with heart or lung disease, including death from lung cancer

3.3. Impact of climate change on Agriculture and Food Security

Agriculture and climate change are inextricably linked and both occur on a global scale. Climate change is having a particularly negative impact on agriculture [72]. Climate change presents a number of challenges including changes in temperature, CO2 and rainfall-all of which have an impact on plant development, both directly and indirectly via land availability, irrigation, weed growth, insect and disease outbreaks and so on [9]. Climate change will have a negative impact on food security and agricultural systems by lowering the productivity of existing food systems, affecting the livelihoods of people who are already food insecure and complicating the supply of clean water. Changes in rainfall patterns and rising temperatures will reduce crop yields, putting additional strain on food production resources. Changes in the environment will have an impact on fisheries, aquaculture, livestock production, forestry and all agro-ecosystems as well as the physical structures that support them [26]. These will have immediate consequences for crop growth and water requirements as well as soil fertility, irrigation water supply and pest and disease prevalence. Climate change will have an impact on the amount and quality of feed and water available to animals. Drought reduces the quality of fodder available for grazing by livestock. Rising sea and river temperatures are expected to

have an impact on fish spawning and migration. Increased acidity in the world's oceans may have an impact on shellfish by weakening their calcium rich shells [36].

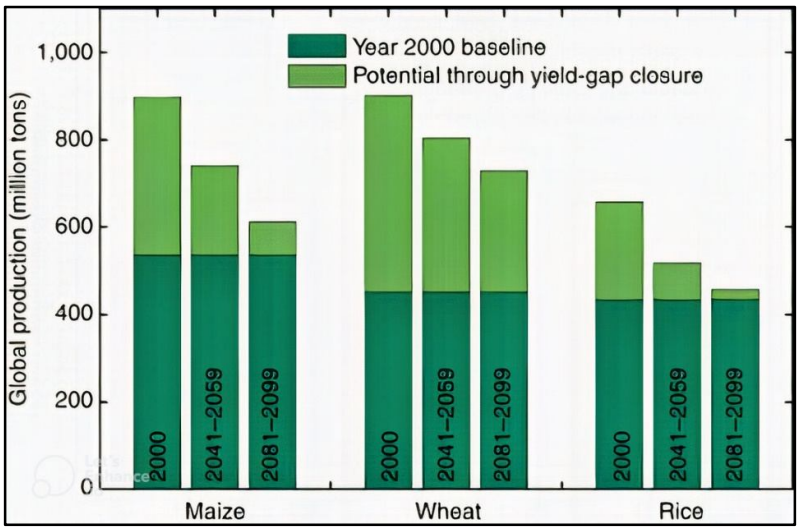


Fig 3: Studies show that a decrease in crop yield under global climate change [24]

3.4. Impact of climate change on extreme weather

The global mean temperature has risen by 0.8°C in the last century and is expected to rise by another 1.5–4.8°C in the next century [63]. Climate change is expected to alter climatic patterns such as floods, draughts, El Nino and La Nina events, thereby affecting human life support systems and global food production, resulting in food insecurity in terms of food availability, accessibility, utilisation and food system stability [6]. Due to change in land surface change, water resources and waste heat generated by high-energy use; cities are more front to "urban heat island effect" which makes cities 2 to 6 degrees warmer than surrounding. Heat waves that can kill hundreds of people may become more frequent and intense [39].

Table 2: Impact of climate change on urban extreme weather [47]

Change in climate	Possible impact on urban areas
Temperature	✓ Increased energy demand for heating / cooling ✓ Worsening of air quality ✓ High temperature impacts exaggerated by urban heat islands in cities

Sea-level rise	✓ Coastal flooding ✓ Reduced income from agriculture and tourism ✓ salinization of water sources
Extreme rainfall / Tropical cyclones	✓ More intense flooding ✓ Higher risk of landslides ✓ Disruption to livelihoods and city economies ✓ Damage to homes, infrastructure and businesses
Drought	✓ Water shortages ✓ Higher food prices ✓ Disruption of hydro-electricity ✓ Distress migration from rural areas
Heat- or cold-waves	✓ Short-term increase in energy demand for heating / cooling ✓ Health impacts for vulnerable populations

3.5. Impact of climate change on coastal urban areas

One of the most concerning possibilities is the impact of climate change on sea level rise. The wrath of the seas does not spare Mainland India which has 5,700 km of coastline [45]. According to Aggarwal and Lal, sea level rise along the Indian coast is expected to range between 30 and 80 cm over the next century [64]. If no precautions are taken, residents of coastal areas may be affected. Three major cities in the LECZ, Mumbai, Kolkata and Chennai, are located on the coast and have an average elevation of 2-10 metres [23]. Flooding of lands, especially during high tides, salinization of water sources and destruction of ecosystems and natural resources that sustain them are all likely to have an impact [18]. Cities in deltaic regions, such as Kolkata, are more vulnerable to coastal floods because they are at a lower elevation, experience more or less natural subsidence and in some cases receive

more water from rivers feeding melting glaciers.

Fig 4: An aerial view of floods in Kerala [48]

3.6. Impact of climate change on urban infrastructure

India will undergo immense urbanization in the coming decades, doubling its urban population by 2050. India's urban transformation will, therefore, have deep implications for not only local welfare and environmental conditions but also for climate mitigation and climate adaptation [60].The demand for essential services will rise in combination with urban population growth, raising issues of inclusion and bringing additional strain on already overburdened infrastructure and resources alongside climate change increases the probability, frequency and intensity of extreme weather events such as severe heat waves, torrential rain, flooding from heavy precipitation and coastal storm surges [59]. Storms, floods, cyclones and coastal flooding are all expected to become more common in the future, posing a threat to infrastructure. Transportation and communication networks (roads, trains, bridges, ports and airports), water supply, sewage, gas pipelines, drainage, flood and coastal defence systems, electricity and telecommunication infrastructures, industrial units and plants are all covered. In terms of structure, informal and traditional houses are the most vulnerable to storms and floods. Tropical cyclones will devastate infrastructure and structures, particularly high-rise buildings. The Housing and Urban Development department said that Cyclone Fani that hit the Odisha coast on May 3 damaged ₹525 crore worth of assets. Infrastructures like drains, roads, culverts playgrounds, community centers, town halls and others have been badly affected [61].

3.7. Impact of climate change on urban migrants

Droughts and floods caused by climate change are expected to increase rural-to-urban migration, city overcrowding and the number of poor and vulnerable people living in cities. According to estimates, water scarcity in India will affect 500 million people as a result of global warming (major risk of desertification in North-Western and Central India, alternation of droughts and floods in the Indo-Gangetic and Brahmaputra plains and coastal flooding due to sea-level rise) [65]. Migrants are one of the most vulnerable groups in any city. These people live in illegal slums with no access to basic amenities, no connection to the city's livelihood network and no skill sets to help them survive [24]. These populations are

extremely vulnerable to a variety of problems as a result of living on hazardous sites, including poor sanitation, water supply, little or no drainage and solid waste services, air and water pollution and the constant fear of eviction. Climate change will force many people to relocate over the next 40 years. Many people will be displaced within emerging countries. The impact of climate change on migration will become clearly tangible when global temperature rises 2 °C [1]. Migration may also increase violent conflicts, while adaptation policy will minimize the risks.

3.8. Impact on urban economics

Because cities are at the heart of many economies, the impact of climate change on urban people has a negative impact on the country as a whole. According to the World Bank, a one-meter rise in sea levels will result in a 2% loss in national GDP due to a lack of fresh water, damage to agriculture and fisheries, disruption of tourism, decreased energy security and other effects [40]. The health effects of climate change, particularly heat waves, heat cramps, heat exhaustion and heat stroke could have a significant economic impact and would affect a large proportion of the population, especially the poor because heat stress weakens the immune system and increases vulnerability to illnesses [13]. As a result, individuals' health-care cost would rise, adding to their stress. People spend a large portion of their income on necessities such as housing, electricity and food, which are expected to bear the brunt of the consequences. People's health will suffer as a result of poor housing quality, resulting in higher morbidity and mortality rates [32]. Individuals with low income who live in informal settlements, particularly in developing countries, are the most vulnerable to the effects of climate change. They frequently live in areas that are particularly vulnerable to the effects of global climate change, with little or no infrastructure in place to protect them from disasters or provide mobility. In informal settlements, there are no building codes and home financing is scarce. Low-quality housing will be vulnerable to floods, global warming and extreme events [25]. In 2005, 1.6 billion people out of 6.5 billion lived in substandard housing, accounting for nearly a quarter of the global population, with 100 million homeless. This accounts for nearly a quarter of the global urban population and the number of slum dwellers is expected to increase to around 2 billion by 2030 [1].

3.9. Impact on Ecosystem

Climate change, droughts and other calamitous events drive animals to migrate in search of better living conditions. Roads, settlements, canals and power lines impede ecosystem migration, causing human harm, property damage and habitat loss [1]. Migration, in particular, has an impact on biodiversity on a regional and global scale and migratory species have an impact on ecosystem processes. Animals rely on predictable environmental cues to time and navigate migration. Changes in these cues will have an impact on the phenology and scope of migration. Higher temperatures cause hatchling bird bug prey to emerge earlier, putting pressure on birds to breed earlier so that hatchling development coincides with peak prey abundance [15]. The arrival time of the adults at the breeding site as well as the time between arrival and the start of breeding, are both critical factors in advanced breeding. These characteristics can change synchronously or asynchronously and population declines can occur as a result of a mismatch between prey quantity and hatching. According to a recent study, the phenology of aphid migration in India has shifted as a result of climate change, similar to that of birds. Over the last 50 years, data has revealed that over 55 species of aphids have begun to fly earlier in the year, with the majority of species extending their flying season [28].

3.10. Impact on urban water

Average global temperatures are rising, causing extreme weather cycles such as droughts and flooding; seawater levels are rising; and many areas are becoming significantly drier,

affecting water sources such as lakes and rivers. Groundwater supplies are being depleted as precipitation rates decrease and extraction rates increase [8]. Water scarcity is caused by climate change impacts such as droughts, floods and higher temperatures as well as low accessibility, deterioration of quality and demand for water in cities [49]. Floods degrade the quality of the water and raise the temperature, both of which raise the demand for water. Water scarcity is worse in slums and informal settlements. The effects of climate change on urban water availability have resulted in the loss of lives and millions of dollars ($2.5 billion) per day and 768 million people lack access to proper sanitation and water [1]. Cities in low-elevation coastal zones, for example, are under threat from rising sea levels as well as storm surges. In the face of concurrent urbanisation and climate change, cities must strengthen their resilience to a variety of stressors. A critical component of urban resilience to climate change is ensuring that there is enough drinking water to service the city, especially given the

projections of more frequent and intense droughts in some areas. Climate change reduces water access in cities while increasing water quality issues and demand.

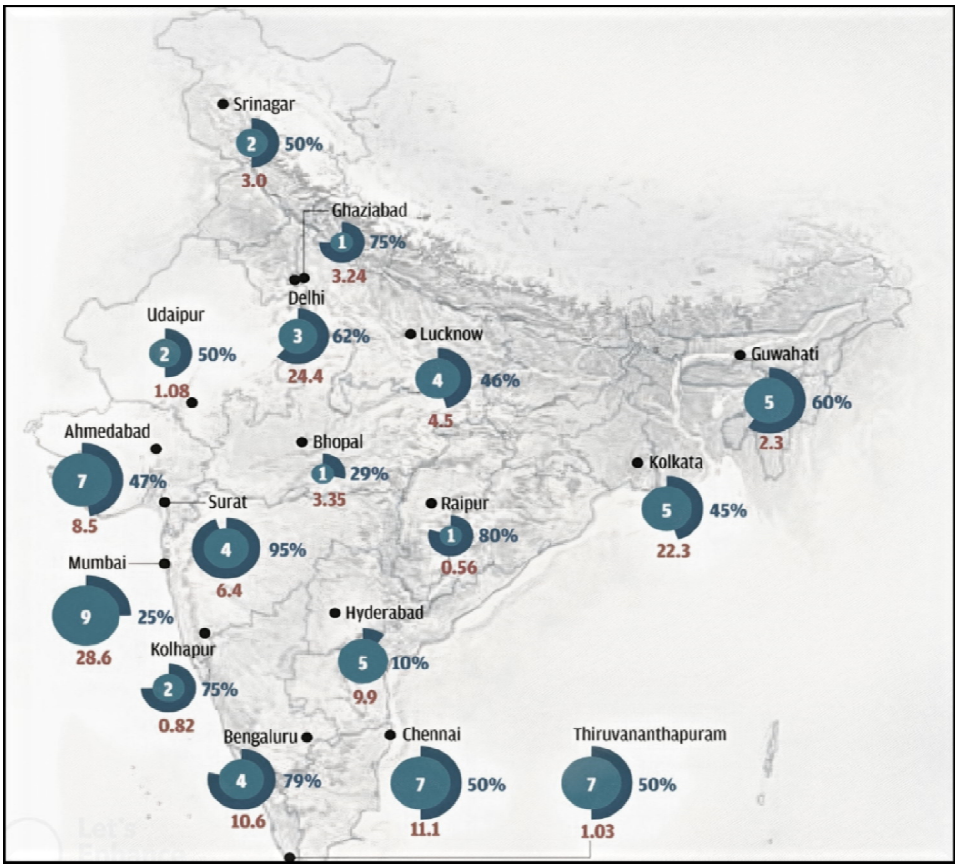


Fig 5: status of availability of water in waterbodies (India) [50]

3.11. Impact on tourism

Climate change will have an impact on tourist flows and destinations. Mountain regions and coastal destinations are the most vulnerable to climate change risks [19]. Beaches, nature and winter sport tourism are the most affected tourism segments. Tourism-dependent regions face the threat of sea level rise (SLR), which will submerge small islands and coastal regions. Desertification and water scarcity make regions less appealing to tourists. Deforestation also has a negative impact on biodiversity and melting snow has an impact on sky-resorts and biodiversity in the mountains. The construction and maintenance of recreational buildings will be reduced as a result of the economic loss caused by tourism [1].

4. URBAN RESILIENCY TOWARDS CLIMATE CHANGE

According to UN-Habitat, urban resilience is the ability of any urban system, with its inhabitants, to anticipate, prepare for, respond to and absorb shocks, positively adapt and transform in the face of stresses and challenges, while facilitating inclusive and sustainable development [66]. On the other hand, the ability of a city to function so that its residents and workers, particularly the poor and vulnerable, can survive and thrive regardless of the stressors or shocks they face is referred to as urban resilience. The ability of a city to function in such a way that residents and workers, particularly the poor and vulnerable, can survive and thrive in the face of shocks and stressors caused by climate change is referred to as resilience.

Table 3: Examples of mitigation and adaptation in practice [51]

Type of response to climate change	Autonomous (by households, communities and firms)	Policy-driven
Mitigation in urban areas	✓ Solutions for urban flooding in low-lying areas; ✓ Water re-use and improved resource efficiency in water supply (municipal and industrial); and ✓ Coastline protection from the increasing frequency of cyclonic events.	✓ Increasing awareness of climate risks and vulnerabilities ✓ Improving emergency response ✓ Nature-based solutions (NBS) that would allow for ecosystem-based adaptation (EBA)
Adaptation in urban areas	✓ Energy-saving lighting and appliances ✓ Local renewable energy sources ✓ Inclusion of low-carbon and non-motorized transportation infrastructure as well as electric mobility, community organisation or firm	✓ Investing in the construction or modification of major infrastructure, such as larger reservoir storage, increased drainage capacity and higher sea-walls. ✓ Avoiding negative consequences, such as land-use planning to limit development in floodplains and at-risk coastal sites.

4.1. Resiliency towards urban health

The health of a population is a critical dimension of the resilience of a society. Population health is both a consequence and a cause of social changes, an important component of social systems that shapes their capacity to adversity and to maintain their essential structure and function under the pressure of hostile events and circumstances [73]. While rapid urbanization and climate change constitute growing threats to population health in cities. Some strategies include:

- ✓ Having green areas near home, cycle lines, good and connected transportation, safety, lightened streets have the capacity to increase physical activity, which in turn reduce obesity, depression, stress and improve the overall health of people [74].
- ✓ Pay attention to severe weather and pollution advisories. Examine the amount of particle matter present outside, in particular. According to the World Health Organization's air quality guidelines, the annual mean concentration of PM 2.5 should not exceed 10 $\mu m/m^3$ and the annual mean concentration of PM 10 should not exceed 20 $\mu m/m^3$ [67].
- ✓ Putting in place urban forestry, tree and landscape programmes and staying hydrated is vital in the summer
- ✓ Keeping an eye out for any water quality advisories issued in the aftermath of flooding or in reaction to blue-green algae blooms on the EPA's Air Watch website [71].

4.2. Climate resilient agriculture

Climate resilient agriculture (CRA) is a sustainable approach for converting and reorienting agricultural systems to support food security under the new realities of climate change through different adaptation and mitigation mechanisms [9].

Climate-resilient agriculture (CRA) include 3 phases, i.e.,

Recognition Phase: "The system detects adversarial threats quickly." Climate change-related hazards include erratic rainfall, cyclones, droughts, floods, heat or cold waves, long dry spells, frost, insect and pest outbreaks and other risks. It is also referred to as the CRA's first phase. The system (in this case, the agricultural system) recognises its threats during the recognition phase; however, as the rate of climate change has increased, human intervention is now required for threat recognition. There are two types of threats: long-term threats and short-term threats.

Curing Phase: "The system heals itself through various adaptive and mitigating mechanisms" [9]. Conservation agriculture, cover crops, integrated farming systems, carbon sequestration, direct seeded rice, precision farming and site-specific nutrient management are examples of such mechanisms. It is the CRA's intermediate stage. It includes;

- ✓ Weather stations at KVK and mini-weather observatories in villages have been established to record real-time weather parameters such as rainfall, temperature, relative humidity and wind speed.

- ✓ Choosing a climate-smart crop variety is the best adaptation option; crops with more sowing windows can be sown in a wider range of sowing dates. An efficient cropping system is one that can meet market demand, improve soil health, provide consumer choice, control weeds and reduce pest outbreaks in a specific location.
- ✓ Contingency crop planning for reverent rainfall refers to planning for alternate crop and cultivator to suit the resource endowments of rainfall and soil in a given location.
- ✓ Site specific nutrient management and integrated farming system (IFS)

Sustaining Phase: "System should sustain their adaptive mechanisms over a long time". CRA with these mechanisms is building itself in such a way that it can break through any hurdle that would come its way. It is the final phase of CRA [9].

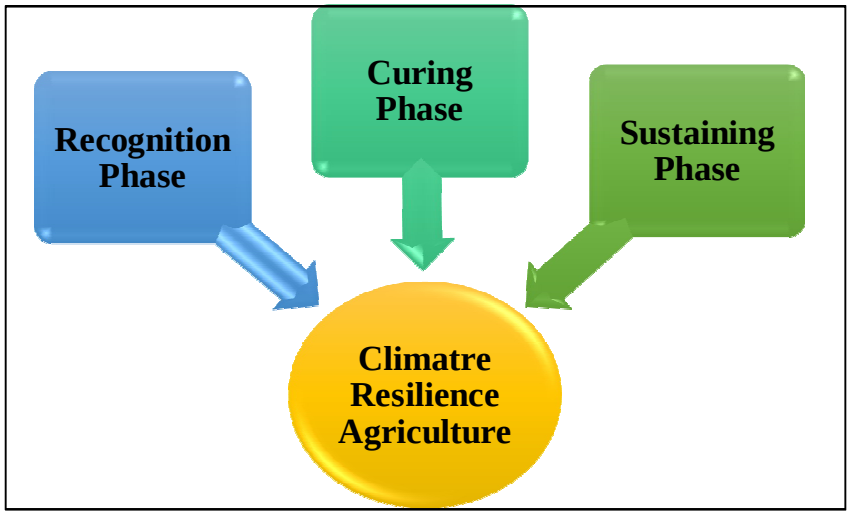


Fig 6: Recognition Phase, Curing Phase and Sustaining Phase act together to bring the climate resilient agriculture [9]

4.3. Resiliency through rooftop farming

Land has become an expensive unit in India as a result of its diversion as a result of urbanisation, industrialization and other factors. Furthermore, migration and settlement from rural to urban areas has been increasing at an alarming rate [20]. By 2030, urban areas are expected to house 40.76 percent of India's population [45]. As a result, increased food demand in cities will put additional strain on natural resources and production volume in rural areas. There is already a scarcity of cultivated land in urban areas. As a result, rooftop space on urban homes, government and non-government offices can now be used to grow a variety of crops [11]. Green roofs are specially designed roofing systems that allow plants and

vegetation to grow on their surface. They could be used in a variety of structures, including residential, commercial and industrial ones. Traditional roofing materials such as slate, tile and lead allow rainwater to run off the roof and into sewer systems. This puts additional strain on water management systems, especially during heavy rains or storms. When using green roofing, rainwater flow is slowed and some of it is absorbed by the roof. Because vegetated surfaces retain, attenuate and treat rainwater, storm water runoff and pollution into drainage systems are reduced [5]. They also provide urban cooling and help to reduce urban heat islands by lowering solar absorption and release, while water trapped in foliage increases local humidity and allows for cooling via evapotranspiration. They can also help to preserve local biodiversity by providing habitat and food for insects and birds [5].

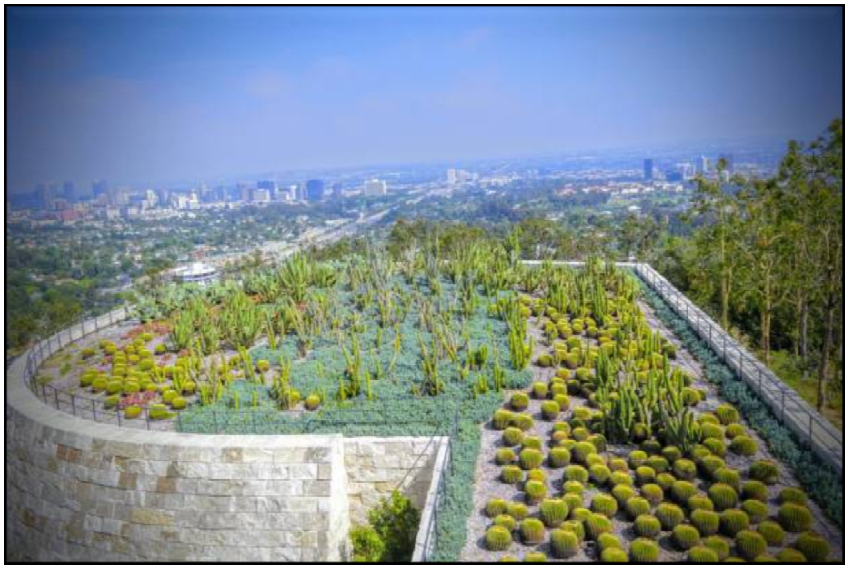


Fig 7: Urban Living and Rooftop Farming Trending in India [52]

4.4. Resilient towards extreme Weather

There are increasing indications that climate change is influencing the frequency and severity of natural disasters. If scientific global climate models are correct, the current problems will worsen in the near future. According to scientists, wind storms, floods, droughts and other climate-related hazards, which appear to be increasing at a faster rate than geophysical disasters, account for more than three-quarters of recent economic losses caused by natural disasters (i.e., earthquakes or tsunamis etc.) [31]. Some methods for boosting resilience in the face of extreme weather.

Table 4: Examples of asset-based actions at different levels to build resilience to extreme weather [53]

Areas of intervention	Household and neighbourhood	Municipal/city	Regional or national
Protection	✓ Actions at the household and community levels to improve housing and infrastructure ✓ Disaster-resilient assets can be built through community-based efforts.	✓ Collaborate with low-income communities to help slum dwellers. ✓ Support increased supply and lower costs for safe housing sites.	✓ Frameworks for government action to support household, neighbourhood and municipal action
Pre-disaster damage limitation	✓ Community-based disaster preparedness and response plans including ensuring early warning and ability to move quickly	✓ Early warning systems that reach and serve groups mostly at risk, preparation of safe sites with services	✓ National weather systems capable of providing early warning; support for community and municipal actions
Immediate post-disaster response	✓ Support the recovery of assets, develop and implement responses	✓ Encourage and support active engagement of survivors in decisions and responses; draw on resources	✓ Funding and institutional support for community and municipal responses
Rebuilding	✓ Support for recovering the household and local economy.	✓ Ensure reconstruction process supports household and community actions	✓ Funding and institutional support for household, community and municipal action

4.4.1. **Adaptation strategies in case of flood events**

- ✓ Improving public information and awareness; and creating and updating flood (risk) maps

- ✓ Planning for land use to avoid locating structures in high-risk areas (e.g., declaration of flood areas, change zoning to prevent development in flood-hazard areas)
- ✓ Conservation of ecological buffers (e.g., wetlands)
- ✓ Requiring more flood-resistant structures in floodplains by updating building codes.
- ✓ Technical flood defence measures (e.g., construction or improvement of dikes, flood protection walls, retention ponds, river dams, barrages for low- lying developments)
- ✓ Expanding the capacity of storm water collection systems

4.4.2. **Adaptation strategies in case of drought**

- ✓ Forecasting irrigation demand is necessary in order to anticipate and plan for future water supply needs, particularly in drought-prone areas.
- ✓ To reduce agricultural water demand, utilities can work with farmers to adopt advanced micro-irrigation technology (e.g., drip, sprinkler irrigation).
- ✓ Modelling the groundwater conditions will help with groundwater resources management and projected changes in water quantity and quality.
- ✓ Conjunctive use usually involves the coordinated, optimal use of both surface water and groundwater on an intra- and inter-annual basis (Examples of diversified source water portfolios include using a varying mix of surface water and groundwater).
- ✓ Watershed management entails the prudent use of land and water resources for maximum and sustained productivity with the least amount of risk to the environment.
- ✓ These watershed helps to mimic natural watershed hydrology by increasing groundwater recharge, reducing runoff and improving runoff quality.

4.5. Resilient strategies in coastal areas

The purpose of the selected coastal resilience measure or measures must be compatible with the local conditions and the overall resilience strategy proposed for that area. For example, if erosion is a major concern, a resilience strategy that prevents or mitigates erosion is required. It is important to note that a variety of alternative resilience measures may be appropriate for a given area [54].

Nature's physical, biological, geological and chemical processes causes resilience to form and evolve over time. Natural resilience measures are influenced by the same processes as natural

features, but they are designed, engineered and constructed to perform specific functions [55].

Table 5: Summary Table of Benefits (Functions) and Performance Factors of resilient strategies [56]

Resilient strategies	Benefits/Processes
Beaches and Dunes	✓ Breaking of offshore waves ✓ Slow inland water transfer
Land Restoration or Creation	✓ Wave attenuation and/or dissipation ✓ Shoreline erosion stabilization
Levees	✓ Surge and wave attenuation and/or dissipation ✓ Reduced flooding ✓ Reduced risk for vulnerable areas
Storm Surge Barriers	✓ Surge and wave attenuation ✓ Reduced salinity intrusion
Breakwaters	✓ Shoreline stabilization behind structure ✓ Wave attenuation
Floodplain Policy and Management	✓ Improved and controlled floodplain development ✓ Reduced opportunity for damages ✓ Improved natural coast environment
Flood Warning and Preparedness	✓ Reduced opportunity for damages ✓ Increased community resiliency ✓ Improved public awareness and responsibility

4.6. Resilient economic strategies

Making new infrastructure resilient, strengthening early warning systems, making water resource management resilient and improving dryland agriculture crop production are among the adaptation priorities derived from India's unique risks cape, followed by protecting mangroves on the East and West coasts [38].

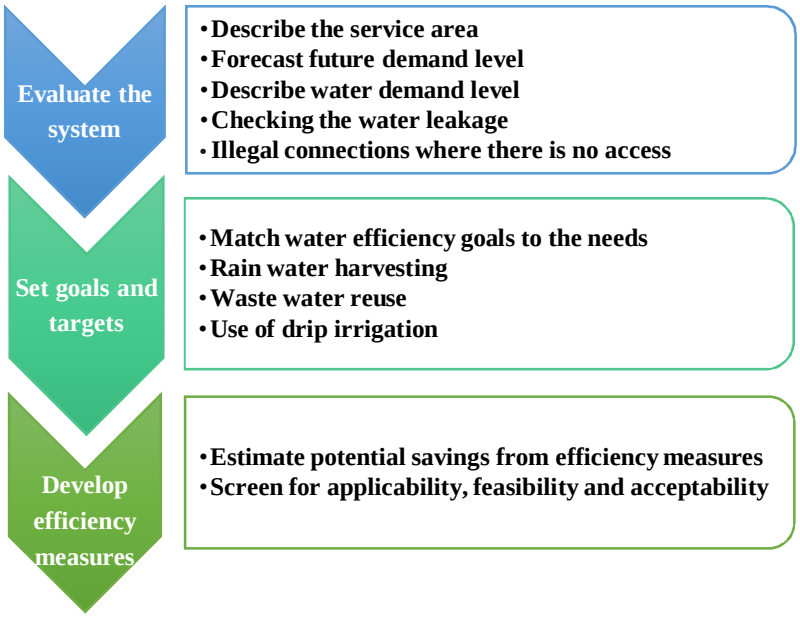
- ✓ The Mahatma Gandhi National Employment Guarantee Act (MNREGA), which has a budget of $13 billion for 2020, largely addresses all of the adaptation priorities. Which creates a large number of jobs [68].
- ✓ For the next 25 years, India has launched a $1.3 trillion plan to develop integrated infrastructure. This is essentially to promote next-generation infrastructure and is known as Prime Minister *Gati Shakti* (the power of speed). Assuming that the cost of resilience is between 5% and 10% of the cost of infrastructure construction. Foreign direct investment should be permitted and encouraged only in those sectors which would significantly contribute to income generation, employment creation and net export earnings [38].

- ✓ Promoting rooftop farming, which increases the value of land vertically
- ✓ India is best suited to remain in the mixed economy framework, in which the public, private and cooperate sectors coexist.

4.7. Resiliency in urban water use

Climate change, population growth, land development and increasing water-use regulations all have an impact on our water supply, which means we must be more diligent in conserving the water we have now in order to ensure a future supply [69]. Everyone pays a price for wasting water. Water prices rise as a result of waste and developing new water supply solutions such as more reservoirs, water recycling and desalination are all costly. The following are some of the most important measures that can be implemented in a holistic manner to improve water use efficiency.

Fig 8: Resiliency in urban water use [57]



4.7.1. *Jal Shakti Abhiyan:* During the Mann Ki Baat programme (June 2019), the Honourable Prime Minister of India called on the Indian people to band together and launch a Jan Andolan for water conservation, similar to the Swachh Bharat Mission. Jal Shakti Abhiyan, a water conservation and security campaign launched in July 2019 by the newly formed Jal Shakti Ministry under the guidance of the Prime Minister of India [21].

4.7.2. *Rain water harvesting:* Rain water harvesting is the collection and storage of rain water that falls from roofs, parks, roads and open spaces, among other places. This

runoff water can be stored or recharged into the ground water. A rainwater harvesting system is made up of the Catchment (Used to collect and store the captured Rainwater), Conveyance system (It is used to transport the harvested water from the catchment to the recharge zone), Flush (It is used to flush out the first spell of rain), Filter (Used for filtering the collected Rainwater and remove pollutants), Tanks and the recharge structures (Used to store the filtered water which is ready to use) [70].The rainwater harvesting system is one of the most popular and widely used water conservation methods. In recent years, a major source of concern has been the scarcity of high-quality water. If the rainwater is pure and of good quality, it can be used for irrigation, washing, cleaning, bathing, cooking and other livestock needs. Some of the benefits of a rainwater harvesting system are as follows:

- ✓ Helps in reducing the water bill by reduction in need for imported water
- ✓ Decreases the demand for water
- ✓ Promotes both water and energy conservation
- ✓ Improves the quality and quantity of groundwater
- ✓ Does not require a filtration system for landscape irrigation
- ✓ This technology is relatively simple, easy to install and operate
- ✓ It reduces soil erosion, stormwater runoff, flooding and pollution of surface water with fertilizers, pesticides, metals and other sediments
- ✓ It is an excellent source of water for landscape irrigation with no chemicals and dissolved salts and free from all minerals

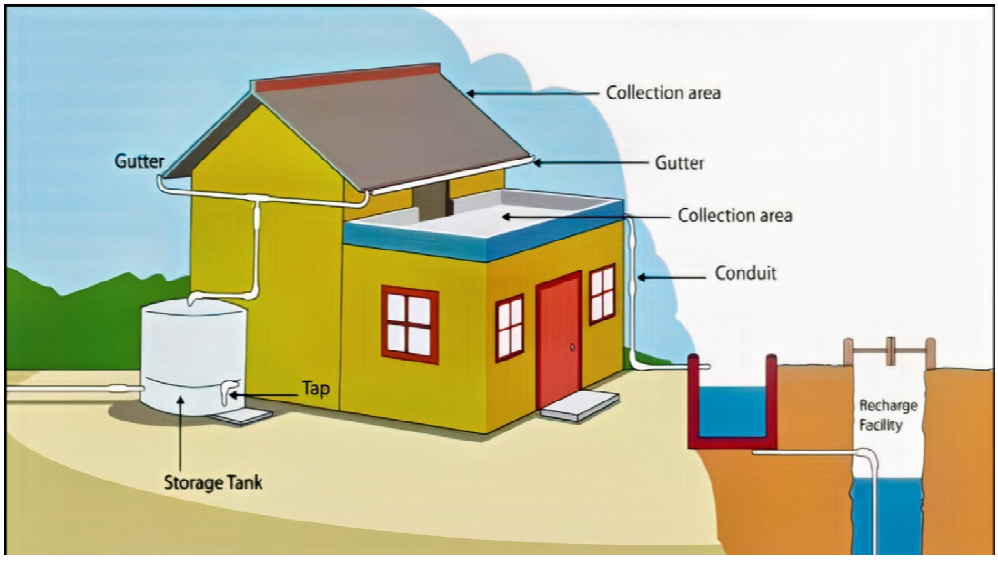


Fig 9: working principle of rainwater Harvesting system [58]

CONCLUSION

There is no single action that will make a city resilient against the climate change. The effects of climate change and urbanisation are so complex, there is a strong need for collaboration among different levels of government (international, national, regional and local) as well as various types of organisations (governmental, public, municipal and private) and disciplines (land management, water management, housing, energy supply, industry, transport) to anticipate the effect of climate change. To close major research gaps, the capacity of the public sector must be increased, knowledge sharing between the planning and health sectors encouraged and tools for collecting and analysing health data made available. At that end, a process for integrating various competencies and involving various stakeholders in a participatory process was proposed with the goal of developing a tool for a comprehensive assessment of the interlinkages between climate and health, social, environmental and economic vulnerabilities and urban space quality.

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