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Role of Green Infrastructure in Enhancing Climate Change Resilience of Cities: Issue of Flood

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ABSTRACT: Cities are growing at fast pace along with broad band of adversities and challenges in this modern century. It forms a web from the impacts of climate change to the growing migration which in turn possess inadequate infrastructure. Emmy Werner was the early scientists to coin the term Resilience. Resilient cities are those which are able to absorb, adapt, transform and prepare themselves for past and future stresses in order to achieve sustainable development. Resilient People or community is those which have ability to get recover from stress, opportunistic and adaptation to a healthy social connectivity.

Green Infrastructure is the most widely acceptable and efficient way to combat and overcome the adverse consequences of climate change and enhance positive augments to adapt life. To improve city resilience in respond to urbanization, an adhesive green action management plan must be taken care. This paper presents the conceptual strategy being developed in the past with the help of case studies in order to increase and promote ecosystems resilience, using them to reduce uncertainty and natural risks. Strengthening the cohesive bond between the government and achieving capacity building through Public –private partnership in Disaster risk reduction provides a way for constructing resilient infrastructures.

KEYWORDS: Resilience of cities, Green infrastructure and climate change

I. INTRODUCTION

Cities and urban areas, mainly because of the urban sprawl, represent dense and complex systems of interconnected services. They face a growing number of challenges that drive disaster risk so there should be a proper mechanism to combat with uncertainty. A **disaster resilient city** is one where [4] disasters are reduced to some extent because the population lives in homes and neighborhoods with organized services and infrastructure that adhere to sensible building codes; without informal settlements built on flood plains or steep slopes because no other land is available.

There are many caution risk drivers prevailing in the disaster risk sphere:

- Growing urban populations and increased density, which put pressure on land and services.
- Weak local public participation.
- Inadequate water resource management, drainage systems and solid waste management, causing floods and landslides.
- Dilapidated structures.
- Uncoordinated emergency services, which decreases the capacity building which decreases or step backs from preparedness.

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- Adverse effects of climate change

It is the one where the local authorities and the population understand their risks and develop a shared, local information base on disaster losses, hazards and risks, including who is exposed and who is vulnerable. A *Global Agenda and Campaign to Build [4] Resilient Nations and Communities*:

The Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters (HFA), was endorsed by the member states of the United Nations in 2005.

- Build institutional capacity
- Know your risks: Enhance early warning.
- Build understanding and awareness: Education to build a culture of safety and resilience at all levels.
- Reduce risk: Reduce the underlying risk factors through land-use planning, environmental, social and economic measures.
- Be alert and ready to act

Green Infrastructure

Green Infrastructure “is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces and other physical features in terrestrial (including coastal) and marine areas. It helps us in providing [9] multiple benefits in the form of supporting and giving out way to promote a green economy, increasing the quality of life, protecting biodiversity hotspots and enhancing the capacity of ecosystems to deliver services such as water purification, and air quality, space for recreation and climate change mitigation and adaption.

II. LITERATURE REVIEW (CASE STUDIES)

Flood management and resilience concepts: The concept of resilience in an ecological context was defined by Holling (1973) as the amount of disturbance an ecosystem could withstand without changing its self-organising processes and structures. More recently, there has been a trend to adopt the concept and apply it to the functioning of human societies and to link it to sustainability (Perrings, 2001). In the fields of disaster and flood risk management, the idea of applying resilience as a way of understanding how individuals and communities cope and recover has been gaining ground (Mileti, 1999; Petak, 2002; de Bruijn, 2004; Rose, 2004).

The 2017 Mumbai flood refers [8] to the flooding that occurred on August 29, 2017 following heavy rain on 29 August 2017 in Mumbai. *Reasons for Floods in Mumbai*:

- Heavy Rains and Rising Sea Level
- Extensive Reclamation and Faulty Zoning Regulations
- Faltering Drainage Systems
- Mumbai’s Natural Drain: Mithi River
- Incapable Storm Water Drains
- Bandra - Worli sea link

Methods adopted to reduce urban flooding risk:

- Increasing The Capacity Of The 'Storm Water Drains'
- PERCOLATION TANKS
- PLANTING AND PRESERVING OF MANGROVE

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1. Green Infrastructure and Climate Resiliency in Grand Rapids, Michigan

On October 6, 2015, the EPA Green Infrastructure Program and Urban Waters Partnership Program organized a Green Infrastructure and Climate Change Resiliency Charrette in Grand Rapids, Michigan. In 2013, Grand Rapids experienced a significant flooding event, which highlighted the vulnerability of the city to heavy precipitation events. Climate models predict the following:

- Air temperature will rise.
- Average precipitation could increase.
- Extreme flood events will increase.



Flooding of the Grand River in Downtown Grand Rapids, April 2013

There are several positive actions that the City can draw upon:

- Citizen awareness of tree canopy benefits.
- Requests for bike lanes.
- Local food interest.
- New economic development strategy

Stormwater Design Standards: The City of Grand Rapids[6] recently completed a study to understand how to better design for future precipitation events (Tetra Tech 2015). Hydrologic events are summarized through Intensity-Duration-Frequency curves, which are used to develop design standards. The study found that there is a high probability of increased risk for the city due to more intense storms and greater design volumes under future climate projections. Green infrastructure was identified as an adaptation strategy that can be used to meet projected climate change impacts.

Focus on Trees: The City of Grand Rapids has developed aggressive tree canopy goals. Participants agreed that focusing on trees would provide significant benefits for the city: reducing stormwater runoff, atmospheric CO₂, energy use, and urban heat islands; increasing groundwater recharge; and improving air quality, habitat, and community livability.

Stakeholder Engagement: Participants agreed that there are several examples in Grand Rapids[7] that successfully show the efficacy and multiple benefits of green infrastructure. Stakeholder awareness and engagement are critical to implement and scale up green infrastructure.

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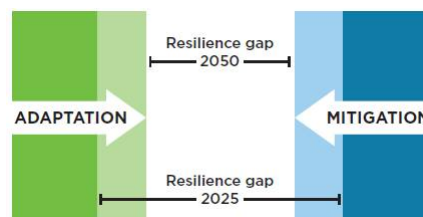
A green roof over an exhibit at the John Ball Zoo in Grand Rapids

Several lessons learned emerged from these and other regional efforts:

1. Stakeholder engagement and awareness are essential.
2. Networks across city departments are critical to foster planning.
3. Creativity and flexibility are important when addressing complexity.

III. APPLICATIONS

The “resilience gap” represents the degree to which a community or nation is unprepared for damaging climate effects—and therefore the degree to which people will suffer [1] from climate-related events.



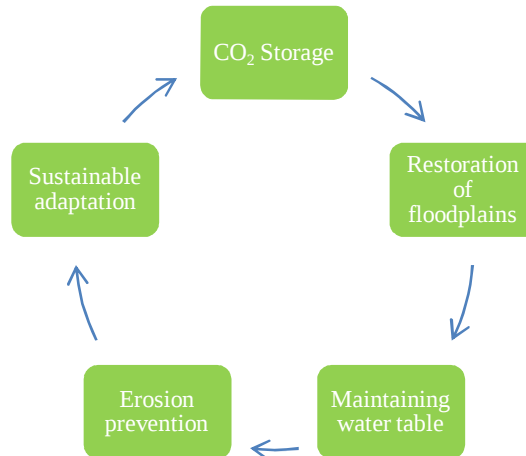
Climate adaptation related Green Infrastructure measures are an important instrument for achieving sustainable adaptation, while creating multiple benefits. Restoring floodplain forests is often cheaper in terms of maintenance costs than purely technical solutions such as building dams and floodplain reservoirs which sometimes included in the environmental cost. Green Infrastructure thus can serve the same level of flood prevention, often at lower cost, while being more resilient (easy for adaptation).

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The Ten Essentials for Making Cities Resilient Checklist[4]:



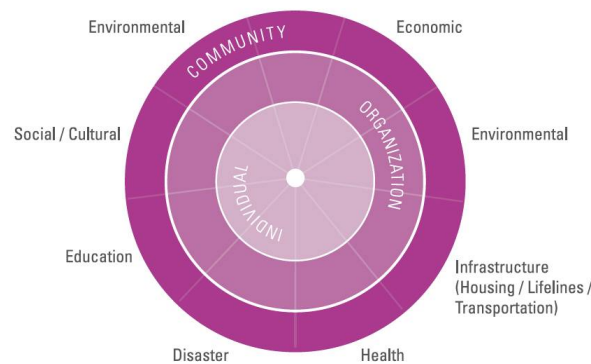
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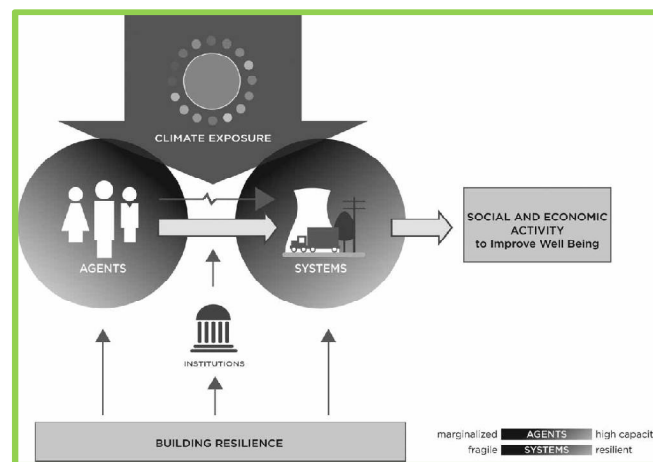
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Resilience Wheel [4]:



Urban systems enable agents to improve their well-being by adopting new strategies as conditions change [7]:



Adaptation versus Resilience:

- Adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. [Adaptation] refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change (UNFCCC 2014).
- The IPCC in its 2014 Fifth Assessment Report uses a definition of resilience developed by the Arctic Council: The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (Arctic Council 2013).

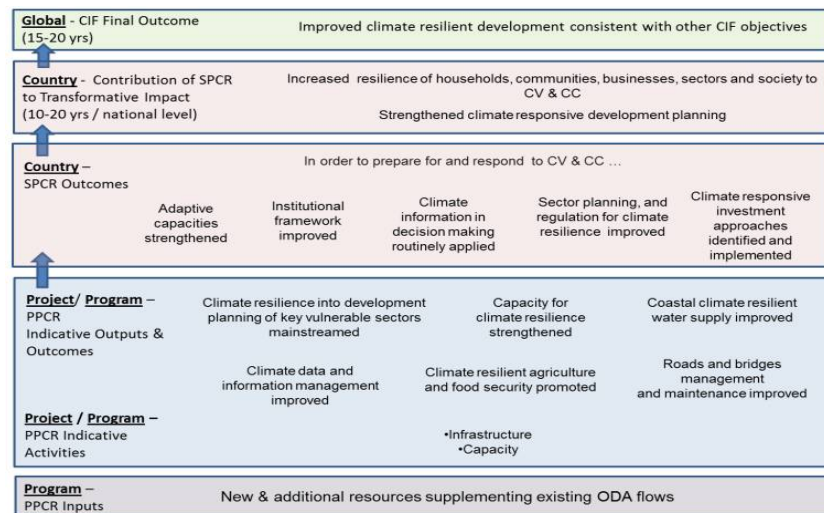
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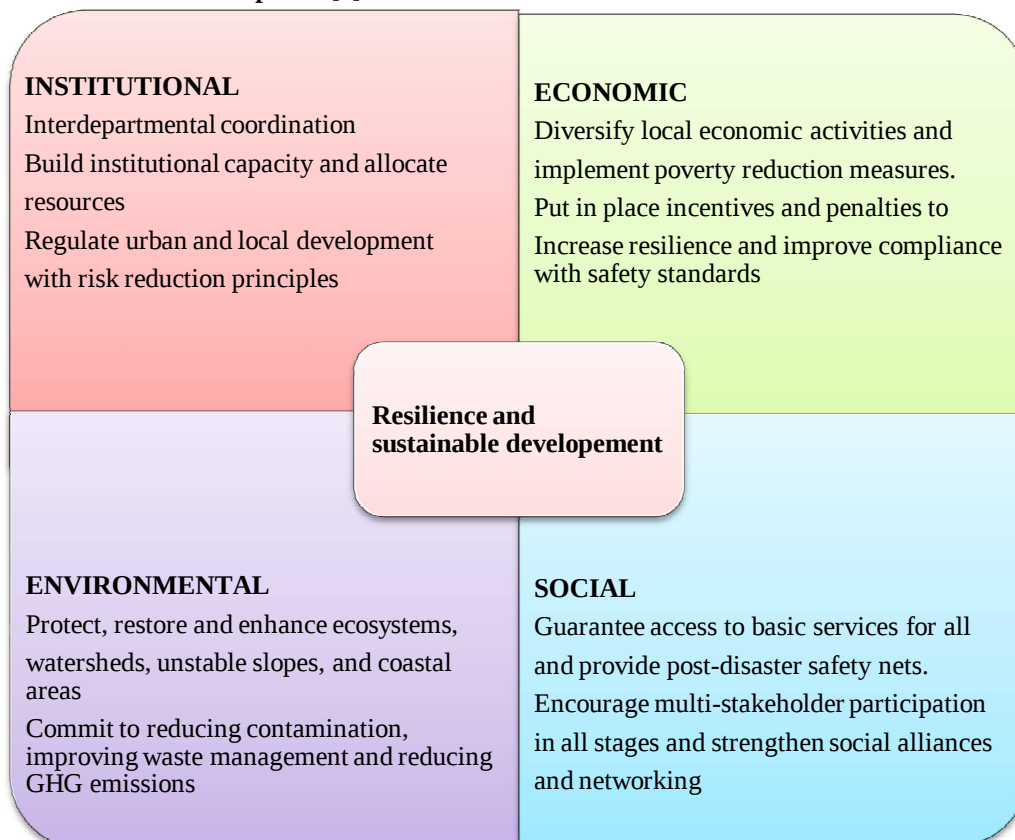
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Pilot Program for climate Change[11]:



Resilience and Sustainable Development [1]



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Green Infrastructure Options to Reduce Flooding [3]:

S.No	Green Infrastructure practices	Benefits	Limitations
1.	STORMWATER WETLANDS: Stormwater wetlands is coordinated of adequately designed basin that contains water, a substrate (e.g., soil, sand), and wetland plants.	Provides aesthetic appeal; increases property value; and improves air quality.	Space constraint and is not well-suited for urban areas.
2.	TREE PLANTINGS AND CONSERVATION: Planting native trees capture and store runoff in the canopy and release water into the atmosphere through evapotranspiration.	Tree plantings reduce stormwater, absorb carbon dioxide; provide recreation. Larger, older trees can intercept more stormwater	Trees need adequate space and soil to ensure Their health.
3.	STORMWATER TREE TRENCHES: A stormwater tree trench is a row of trees that are connected by an underground trench compacted with layers of gravel and soil filter stormwater runoff.	Maintains water balance and provide groundwater recharge; reduce runoff.	A careful selection criteria of tree species and an absence of conflicts with utility structures (such as electric wires and signs).
4.	BIOSWALES AND RAIN GARDENS:[10] Bioswales convey stormwater at a controlled rate, and the flood-tolerant vegetation allowing infiltration. Rain gardens are composed of drought-tolerant shrubs, flowers, and grasses and they lack a complex soil matrix and underdrain.	Reduce stormwater runoff volumes and increase groundwater recharge.	These features are best for smaller sites or neighborhoods and can be expensive for large areas. Colder climates experience frozen soils, which limit infiltration rates.
5.	PERMEABLE PAVEMENT: Permeable pavement includes both pavements and pavers with void space that allows runoff to flow through.	Reduces runoff quantity during storm events; reduces surface ice formation in cold climates; and improves water quality from filtration through pavement or pavers and underground media	Snow plowing can catch the edge of pavers and damage pavement surface. Applying sand and salt can clog pavement pores. Soil substrate below the pavers must have adequate filtration rates to allow water to dissipate.

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Urban Green Infrastructures[12]:



IV. CONCLUSIONS

Challenges and opportunities:

Although Green Infrastructure is already relatively well established in climate adaptation strategies, further actions and uptake would be encouraged through:

1. Stronger focus on integrated spatial planning and methods to stimulate cross sectorial/regional cooperation.
2. Stronger focus on long-term investments and budgeting, planning and focusing on sustainability in decision making process.
3. Stronger evidence base forming an account on the multiple scenarios of benefits of Green Infrastructure, quantifying both the economic and social benefits and avoidance of costs and environmental overburden.

When community based development exists for historical climate conditions that no longer exist, they can make themselves more vulnerable and accessible to current and future climate risks. As communities, states, and the federal government invest in climate adaptation, it is important that the costs are fairly distributed which maintains transparency and the benefits are widely felt. Adaptation to climate change is not cheap, but the costs of investing in preparedness versus recovering from a disaster are hiking even today. Not everything can be protected. But adaptation planning can help to some extent in ensuring that creatures, places, and human history endure the accelerating impacts of climate change. Even as cities, states, and nations work to adapt to climate change, the best way to limit the pace and magnitude of climate change is still through deep reductions in heat-trapping emissions.

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