CARIAA
Collaborative Adaptation Research Initiative in Africa and Asia

ASSAR
Adaptation at Scale in Semi-Arid Regions

Assessing climate change risks and contextual vulnerability in urban areas of semi-arid India

The case of Bangalore

CARIAA-ASSAR Working Paper #3

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About CARIAA Working Papers

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Titles in this series are intended to share initial findings and lessons from research and background studies commissioned by the program. Papers are intended to foster exchange and dialogue within science and policy circles concerned with climate change adaptation in vulnerability hotspots. As an interim output of the CARIAA program, they have not undergone an external review process. Opinions stated are those of the author(s) and do not necessarily reflect the policies or opinions of IDRC, DFID, or partners. Feedback is welcomed as a means to strengthen these works: some may later be revised for peer-reviewed publication.

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Abstract

The discourse on urban vulnerability over the last decade and a half has undergone substantial shifts prompted by differences in disciplinary orientations. This enables multiple framings and causal linkages, influencing the nature and scale of responses. This paper builds an understanding at the interface of cities and climate change, building on its multiple notions and the underlying risk character, each of which incrementally and over time influences the other. This paper reinstates the multiple climate change- urban linkages, disaggregating it into its various key components through a generic 'urban risk framework'. It further contextualises this framework in the context of a fast-growing city, Bangalore[1], in a semi-arid ecosystem to demonstrate the range of risks and vulnerabilities that are both unique and generic to many other Indian cities. The paper argues that the bundle of risks and multi-dimensional vulnerabilities are shaped by geographies of location and growth trajectories. This paper underscores the existence of diverse and complex dimensions of vulnerability – physical, social and institutional and establishes linkages with poor developmental outcomes. It establishes the various components of a given an urban region that are exposed to varying intensities of cross interactions between climatic as well as non-climatic risks, but also vividly elucidates the 'sensitivity' as well as the capacity of internal components and processes to cope, that determine the level and intensity of impacts and persistence of differentiated vulnerability. The paper proposes a nuanced approach towards addressing composite risks at urban scale, particularly in the context of semi-arid ecosystems, and argues in favor of responses that have the potential of addressing multiple challenges, and yielding benefits spanning across adaptation, mitigation and development objectives.

Key words

Climate change, Urban, Vulnerability, Adaptation

[1] Bangalore was the earlier name of the city, which has now been officially renamed as 'Bengaluru'. For simplicity and historical connect, the earlier name has been retained for this paper.

About ASSAR

All authors of this working paper are team member in the ASSAR (Adaptation at Scale in Semi-Arid Regions) project, one of four hotspot research projects in CARIAA. The international and interdisciplinary ASSAR team comprises a mix of research and practitioner organisations, and includes groups with global reach as well as those deeply embedded in their communities. The ASSAR consortium is a partnership between five lead managing institutions - the University of Cape Town (South Africa), the University of East Anglia (United Kingdom), START (United States of America), Oxfam GB (United Kingdom) and the Indian Institute for Human Settlements (India) – and 12 partners – the University of Botswana, University of Namibia, Reos Partners, INTASAVE, the Red Cross/Crescent Climate Centre, University of Ghana, ICRISAT, African Wildlife Foundation, University of Addis Ababa, Watershed Organisation Trust, Indian Institute for Tropical Meteorology, and the Ashoka Trust for Ecology and the Environment.

Working in seven countries in semi-arid regions, ASSAR seeks to understand the factors that have prevented climate change adaptation from being more widespread and successful. At the same time, ASSAR is investigating the processes – particularly in governance – that can facilitate a shift from ad-hoc adaptation to large-scale adaptation. ASSAR is especially interested in understanding people's vulnerability, both in relation to climatic impacts that are becoming more severe, and to general development challenges. Through participatory work from 2014-2018, ASSAR aims to meet the needs of government and practitioner stakeholders, to help shape more effective policy frameworks, and to develop more lasting adaptation responses.

This working paper draws from ASSAR's first phase (Regional Diagnostic Study) which took stock of the current state of knowledge on the climatic and non-climatic risks in our research sites. In this paper, we focus on India to interrogate the overlaps and divergences between adaptation and development, and the actors and institutions operating in this space. www.assaradapt.org

Why focus on semi-arid regions?

Semi-arid regions (SARs) are highly dynamic systems that experience extreme climates, adverse environmental change, and a relative paucity of natural resources. People here are further marginalised by high levels of poverty, inequality and rapidly changing socio-economic, governance and development contexts. Climate change intersects with these existing structural vulnerabilities and can potentially accentuate or shift the balance between winners and losers. Although many people in these regions already display remarkable resilience, these multiple and often interlocking pressures are expected to amplify in the coming decades. Therefore, it is essential to understand what facilitates the

empowerment of people, local organisations and governments to adapt to climate change in a way that minimises vulnerability and promotes long-term resilience.

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Contents

1. Setting the Context

The world is presently experiencing rapid urban transitions[2] as well as rapidly changing global climate (IPCC, 2014). Urbanisation and majority of urban population growth at present and projected in the future, is markedly different from the past. It is taking place at an increasing pace in small-to-medium-sized cities of the Global South (primarily in Africa and Asia), characterised by lower levels of economic development, and follows a trend different to that observed in the developed cities of the North (UCCR, 2015). Urban regions the world over drive economic outputs of nations and increasingly, recognition of climate change and its impacts at city scale is gathering steam[3] owing to the severe economic fallouts that climate-induced events could trigger. This is reflected in the growing importance towards understanding future climate projections at regional and sub-regional scales (as opposed to coarser scale climate projections in the past) to be able to ascertain impacts at the scale of urban agglomerations and individual urban centers. Recognizing differential exposure to risks and impacts of climate change on cities (for instance coastal cities and urban centers in island countries are at highest risk compared to others) and vice versa is also gaining momentum, reflected in the growing number of city-level leaders and networks coming together to look into the urban-climate change nexus though varying degrees of science-policy interface[4]. Despite the growing recognition of cities being seriously vulnerable and active contributors to climate change, evidence indicates to a range of complex challenges encountered while translating global and national climate agenda into local leadership and action[5].

Getting started now will thus help in avoiding potentially damaging or counterproductive, long-term lock-in pathways of development, especially in the context of climate change, wherein urban centers appear both in the causal chain and the impact chain of climate change (ibid). Ensuring well thought out and effective urban growth and development models are therefore of utmost importance in charting out pathways of transformation to make cities resilient to climate change. In this context, it becomes imperative to understand the nature and form of climate change-urbanisation linkages. The next section introduces the conceptual and operational bounds of this paper and introduces the fundamental arguments put forward in succeeding sections.

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[2] the expansion of urban areas is on average twice as high as urban population growth and the expected increase in the urban land cover (in the first 3 decades of the 21st century) is expected to surpass that witnessed in the entire history of mankind (Revi et al., 2014).

[3] Global recognition of urban areas as important climate hotspots and potential sites for responses through a mix mitigation and adaptation strategies; IPCC WG2 Chapter 8, 11, and sector specific chapters; Inclusion of Urban sustainability and climate resilience in the revised SDGs (2015, Goal 11) and other emerging networks focusing on climate change and urbanisation such as ACCCRN, UCCRN, C40 , CCCI, ICLEI, Future-Cities, K4C and so on.

[4] Refer to the footnote above (2)

[5] Captured by Agrawala and Remi (2009), and published and converted into policy toolkit for practitioners and government officials engaging on mainstreaming adaptation into urban governance design and delivery.

2. Introduction

Interactions between urbanisation processes and climate change have multiple direct and indirect impacts, of variable intensities, on the extent of vulnerability and well-being of a significant share of the global population, dwelling in urban centers. These impacts (environmental, social, economic, biophysical) go beyond the physical boundaries of the city, across spatial and temporal scales, increasing risk exposure, constraining people's capacity to cope and give rise to new sets of localized critical vulnerabilities (Hallegatte and Morlott, 2011). Together, climate change and urbanisation, alter the profile of risks and vulnerabilities. Understanding and acting at the interface of climate change and urbanisation is the most pressing and desirable challenge of the 21st Century (IPCC, 2014).

The aim of this paper is to critically look at the structure and dimensions of 'this' urban vulnerability, an outcome of an interaction between climate change and the urban process. It situates the discussion in the broader framework of conceptualizing risk in the context of climate change, as proposed by IPCC Assessment Report 5 (IPCC, 2014), adapting it to the 'city' scale. The paper uses this framework to illustrate the structure and dimensions of urban vulnerability in the context of Bangalore, Karnataka - a fast growing urban centre in India. It is imperative to understand that Bangalore is one of the critical economic centers in South India. It majorly supports the regional economy and is equally grappling with rapid socio-economic transitions and biophysical changes, equally driven by climatic changes and the urban process.

2.1 Structure of the paper

The paper first, broadly describes the two processes (urbanisation and climate change in the urban context) separately. It further argues that these processes don't occur in isolation but feed into each other and operates through complex feedback loops and cycles. The first section of the paper draws from the existing literature on climate change impacts on urban centers to understand the causal loop and filters out the climate component of this complex interaction. The paper further describes the urban process, breaking it down to key elements and makes the connections with accumulated risks across space, within communities and sectors and attempts to describe the characteristics of how certain people and systems are more vulnerable to environmental and other risks than others. It further argues that understanding urbanisation processes and associated risks and vulnerability outcomes is critical in planning response mechanisms to climate change and related environmental changes. Before the paper proceeds onto the discussion on contextualisation of vulnerability with respect to the city of Bangalore, the idea of vulnerability and its importance has been explored in section 3. This sets the background for steering forward the discussion on vulnerability pertaining to Bangalore and its relevance for furthering critical thinking along the lines of formulating a risk management framework at the scale of cities. It argues that the risk management framework could be prospectively used as a lever

to bring elements of adaptation and mitigation responses together and thereby provide a comprehensive mechanism through which a whole range of existing and emerging climatic and non-climatic risks could potentially be addressed.

Bangalore has been used as a case to demonstrate the interplay of the processes of climate change, urbanisation & development in one of the fastest growing metropolises of India. The case of Bangalore sits within the broader context of stress due to climate change in semi-arid regions that are already experiencing challenges with respect to water availability. The case illustrates a mechanism through which we can understand risks and vulnerability in the context of cities and how a response mechanism can be framed (see Fig.1 risk conceptualisation framework adopted from IPCC, 2014). By doing so, we argue through the broad city development narrative and the evolution of risks, it further elaborates on the various dimensions of vulnerability, linked to climatic and non-climatic dimensions. *Stating this, the paper is broadly structured around the following key questions:*

1) In general, how do urbanisation processes and climate change interact and what is the nature of these interactions?
2) How does this interaction manifest itself through differential risks and vulnerability? This is explained using a framework conceptualizing risks at the urban scale (adapted from IPCC WG2, AR5, 2014)
3) Focusing on urban vulnerability, how do we understand vulnerability in the context of cities and how is it shaped by the two interplaying processes - climate change and urbanisation?
4) Using the case of Bangalore, how do development processes, rapid urbanisation and climatic risks shape vulnerability? Keeping the city frame in mind, what is the emerging normative policy and research agenda that would, possibly, address urban risks in the context of the complex interaction of climate change and urbanisation?

2.2 Setting the context within the larger Adaptation at Scale in Semi-Arid Regions (ASSAR) of Africa and Asia project

This working paper is one of the many preliminary outputs from the diagnostic phase of the ASSAR project. The project is built on the premise that climate change and variability and also other socioeconomic or biophysical risks impact different people in different ways. Likewise, the ability to respond and adapt to these risks and impacts are also differential in nature, governed by social differences (e.g. by age, caste, language, gender and ethnicity) and determined by a complex set of structural and non-structural factors. The ASSAR project through its course aims to answer important and relevant questions on how vulnerability and responses to current and future risks varies among social groups across spatial and temporal scales. It is in this context that this paper elaborates on the nature of differential vulnerability and situates it within the urban setting. It is widely recognized that urban vulnerability is largely a neglected domain and understanding it in the context of climatic and non-climatic changes sets up a basic response framework that would potentially enable decision makers to frame policy and program-based interventions.

3. Climate change and urbanisation: interaction and impacts

3.1 Climate change impacts on urban areas

Climate change induces a range of impacts on different components of diverse urban systems; physical, ecological, social and economic and influences interaction between various coupled systems such as inducing variations in microclimate (for e.g. urban heat island impact) (IPCC, 2014). Climate change further impacts species compositions and functions, interferes with biophysical cycles, impacts resource availability such as water and food and impacts the frequency and intensity of hazard occurrence (such as floods, droughts) (ibid). The severity and complexity of many of these impacts are heightened through the interactions with the processes of urbanisation. These are illustrated through the examples of local heat island impact and local flooding events that can be attributed to poor planning and development, further aggravated by climate change. Another example emphasizing the interplay of these two factors together are related to the association of long-term trends in surface air temperature in urban centers and urbanisation [6](IPCC, 2014). Empirical and theoretical studies have underscored the two-way interactions and the resulting impacts on the quality of urban environment and the microclimate (Trusilova et al., 2008; Oleson, 2012) along spatial gradients.

Important climate induced impacts felt across cities, big or small, range from urban flooding, sea level rise (for coastal cities), flood risks due to storm surges, urban heat island effect and drought-induced changes in water availability (Walsh et al. 2013).

3.2 Urbanisation and its interactions with changing climate

Urbanisation is largely underpinned by complex economic, demographic, and socio-political transitions. All wealthy nations of the Global North are predominantly urbanized while the fast urbanizing centers in low- and middle-income countries are coupled with noticeable growth and shifts in their economies, employment patterns (Satterthwaite et al., 2010)[7] and localized environmental changes.

Cities are highly reliant on energy-intensive processes (such as transportation, industrial processes, water supplies, heating or cooling.) to keep the economic engines running and therefore contribution of cities, through increased greenhouse gas emissions, to climate

[6] Urbanisation (micro to meso scale) involves high use of building materials which alter the urban temperature regimes in certain pockets, strengthening UHI effect at a local scale, further altering small scale processes; land-sea breeze effect, local precipitation and temperature trends and so on.

[7] For instance, Satterthwaite (2007) points out that rapid urbanisation in low-to middle income countries is driven by rapid livelihood shifts from agriculture to industry and services and within services to information production and exchange.

change has become critical in recent times. The changing form of urban economic system and altered resource endowment and flows are equally responsible for their contribution to climate change (ibid).

3.3 Why urban centers are important?

Urban areas around the world are sufficiently dense, house more than half of the world's population, contain high concentrations of built assets and economic activities, most of which, are at risk from climate induced changes (IPCC, 2014). Cities are thus crucial seats of economic activities, rapid demographic, structural and aspirational transitions, fuelled by high energy use practices which feedback into the climate systems in the form of GHG emissions and streams of wastes, contributing to climate change (IPCC, 2014). Consequently, urbanisation processes lead to variations in the local micro-climatic which upon complex interactions with climate change at regional, national and global spatial scales, exacerbate the cumulative magnitude and intensity of climate risks. However this very aspect of heavy concentration of economic activities, people, technologies, large interdependent sectors (e.g residential, transport, energy) and the synergies therein and possibilities of leveraging private capital offer vast opportunities for adaptation and mitigation integration into urban development and processes of planning (IPCC, 2014; UCCRN, 2011) and due to the enormous scale, leverage the possibilities of achieving impactful benefits and contribute to mitigating incremental GHG emissions.

It is important to reiterate that cities and climate change have complex interlinkages. While the manifestation of climate change into localized impacts is emphasized above, it is equally important to recognize that cities play a crucial role in being the main contributor to global climate change. Studies[8] have attempted to measure the net contribution of all urban processes put together to global carbon emissions. Assessments at the urban scale have even attributed as much as 80% of the global GHG emissions released from urban centers (Walsh et al., 2013).

It is thus logical to assume that if urbanisation and economic growth go hand in hand, there will be higher incentives and resources to ensure sustenance and efficiency of cities through good design, planning, effective governance, and climate resilient development (through mainstreamed adaptation and mitigation interventions). In reality, however, emerging and fast growing cities of many low and middle- income countries have been unable to manage their economic and physical expansion, and have incurred vast deficits in infrastructure and service provisions, which have become increasingly complex in the context of climate change and evolving developmental priorities.

[8] Refer to Sattherwaite (2008) and assessments conducted by the International Energy Agency which comes out with country wide reports tracking both energy demand and utilisation and GHG emissions, refer to IEA (International Energy Agency)

Role of governance

Urban governments are supposed to play a crucial role in addressing climate change related challenges because of heavy concentration of people, assets and economic activity. They also have to play an important role while operationalizing the adaptation and mitigation agenda, partly because of the potential nature of impacts. We have observed numerous examples of successful local climate-centric local solutions, following the principle of subsidiarity and most of these successful interventions have been contingent on having appropriate governance and institutional processes, jurisdictions and structures which partly reflect through sound investments, policies and regulatory frameworks (IPCC, 2014). In addition, strengthening institutional and human capacity at the local scale also provides opportunities for gradual transformation into less-resource intensive, or more resilient development pathways by leveraging on a strategic 'policy space[9]' for deliberate engagement with primary stakeholders (those affected, those who can benefit, those governing and others supporting the process), experts and practitioners (Corfee-Morlot, 2011). Cities are also an appropriate scale for mobilizing institutional support, through co-ordinated support from private actors, civil society, and practitioners for incremental adaptation and linked co-benefit processes, taking into cognizance multiple political interests and other local agenda that often has the ability of top-down constrained policy imperatives, provided processes of subsidiarity are constitutionally provided (ibid).

However, some of the glaring challenges, within the governance mandate, that needs deliberate attention going beyond the 'urban' scale and spanning across scales are a) lack or poor local mandate to address climate-centric issues b) national and/or provincial policies that may lead to maladaptation or increase vulnerability over time c) pressures of addressing short term administrative agenda , d) mismatch between electoral and administrative time cycles, while thinking of reaping political and administrative benefits and at the same time respond to climate-centric challenges e) insufficient funding and resources f) lack of willingness to deviate from business-as-usual practices g) inadequate understanding of climate risks and potential processes to overcome those h) lack of scale-relevant information and appropriate technical skills (Adger et al., 2009; Bulkeley, 2010; Mosser et al., 2009), which is practically the 'operational' agenda that needs to be explored through the ASSAR research questions.

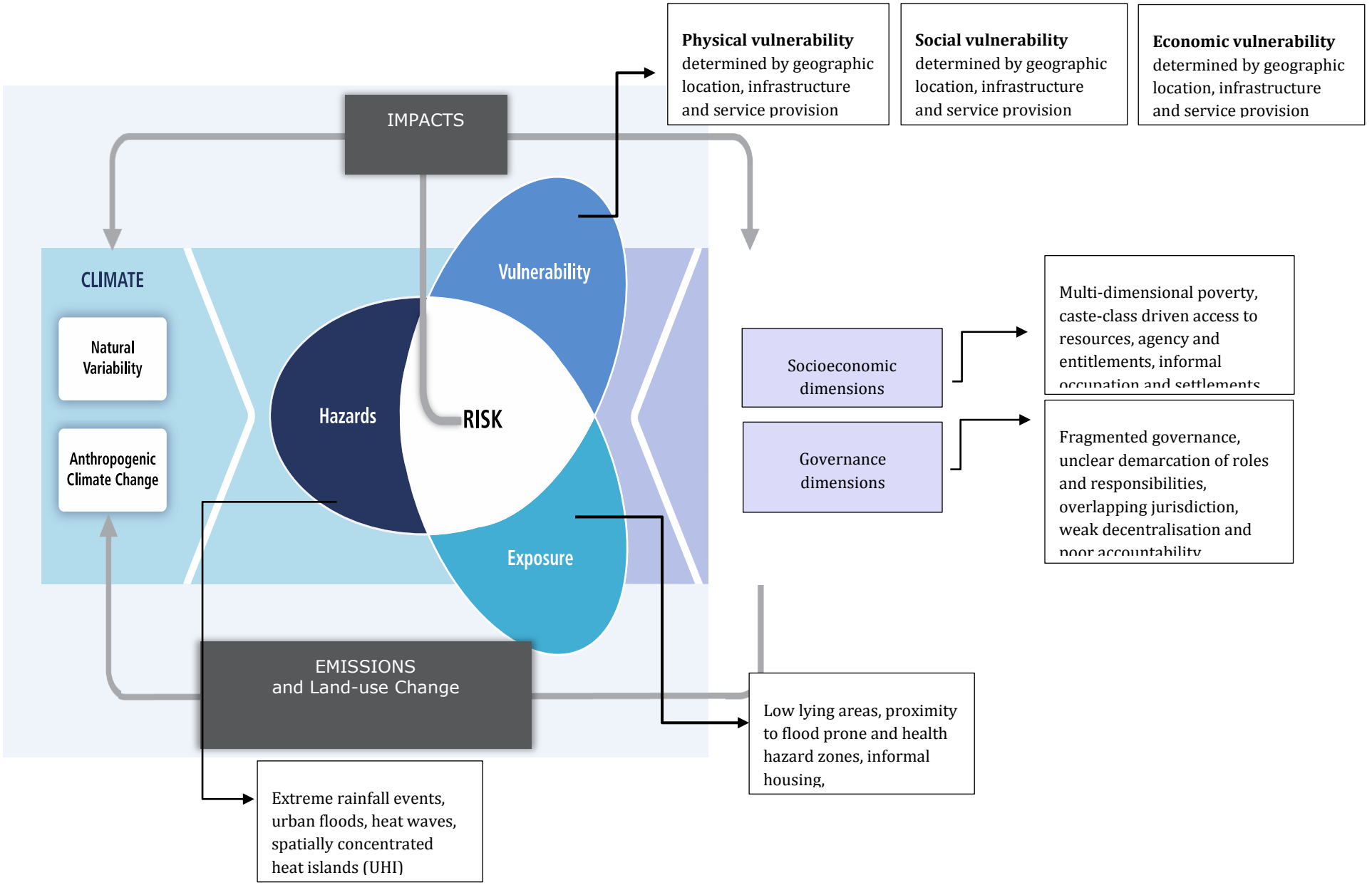
3.4 Multiple interactions

Given the way in which urbanisation and climate change processes unfold, we attempt to explicitly identify the principal linkages between the two, and the multiple interlinkages within systems and processes comprising the two (see fig. 1). Doing so, we rationalize the need for understanding urban vulnerability to climate change as a critical factor to plan for

[9] Here, the strategic policy space is the political moment that characterises urgent action to mitigate and adapt to climate change

effective, widespread and sustained responses. Urban centers are increasingly assuming the label of' climate hotspots' due to the dual and interacting processes at play; rapid urbanisation and climate change. It is therefore not surprising that 'cities' make for a compelling case for 'first responders' to climate change through local level responses (IPCC, 2014). Much of the key emerging risks are concentrated in the fast growing cities of low- and middle-income countries, aggravated by large concentrations of vulnerable urban populations and poor to limited institutional capacity to effectively address complex climate change concerns (Rosenzweig 2010). The urban poor constituting a dominant share of the urban vulnerable population are also extremely prone to stress arising from macroeconomic shocks that impede their earning capacity and thereby negatively impact access to food, housing and health services (Mehrotra et al., 2009). These, in addition to other social, economic and environmental stressors, compound risks to individual as well as collective well-being of marginal communities. Climate change, in turn, is expected to further aggravate social and economic inequities (ibid). Additionally, the vulnerable non-urban groups that span across the rural-urban transect and which are characterised by natural resource-based livelihoods could be severely impacted by climatic changes. Amidst the presence of climate-sensitive livelihood options, it becomes equally important to understand livelihood trajectories and transitions across the rural-urban continuum, in addition to the structural changes in the economy. There are large differences between and within urban centers in the extent to which their economies are dependent on climate-sensitive resources (including commercial agriculture, water, and tourism), people and systems exposed to climatic risks and in their capacities to cope. Understanding these differences is fundamental in shaping the extent and magnitude of response desirable to alleviate vulnerability of people and systems. The next section explores the conceptualisation of vulnerability at the scale of 'cities' using the framework adapted from IPCC (2014) risk framework (see Figure 1).

Figure 1: Conceptual Framework to understand "risk" at urban scale *(adapted from IPCC WG II, AR5)*



4. How do we understand 'vulnerability' and why is it important?

The concept of vulnerability originated in research that examined risks and hazards, climate impacts and resilience. There have been shifts in its framing and theoretical underpinnings, owing primarily to its adoption and application by a wide range of disciplines (Fussel and Klein, 2006; Eakin and Luers, 2006; Joakim et al., 2015)[10]. The vulnerability or security of individuals and of societies is determined not only by the likely impacts on resources in terms of its properties and availability on which individuals depend, but also entitlement of individuals and groups to call on these resources. This is well documented across a wide range of political and economic circumstances and developmental processes (Ribot, 2009). Vulnerability can therefore be regarded as a socially constructed phenomenon that is influenced by climatic, institutional and economic dynamics.

The vulnerability of a system to climate change is defined as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2007). It is typically determined in terms of its exposure to stresses and shocks; capacity to cope and ability to recover (IPCC, 2007). This perspective suggests that vulnerability affects a system and its people differentially. Further, people and places that are most affected are the ones who are most exposed to stresses and shocks and/or the ones that have the weakest capacity to cope (i.e. likely to suffer more).These groups or individuals are likely to face most challenges in responding to and recovering from shocks.

This vulnerability framework formally recognizes the role of macro-level human-environmental interactions influencing dynamics at the local scale, which together shape the impact of stresses and shocks. For example, the cumulative effect of economic slowdown may potentially reduce a society's capacity to cope with environmental stresses (Scheffran and Battaglini, 2011). While it may be argued that during economic slowdown some damaging economic activity, like industrial economy driven by poor quality fuel, may lead to health-related gains among poor neighbourhoods but the lack of linked economic opportunities tend to over-ride the influence. It is quite apparent that more empirical evidence might be required in this space, particularly in the temporal context. Co-occurrence of drought and economic compression can then synergistically enhance the vulnerability of people and systems, manifesting itself in variable intensities across scales (De Sherbinin et al., 2007; Patwardhan et al., 2007).

[10] Disciplines ranging from economics and entitlement, poverty studies, anthropology, gender and caste, ecology and resilience and so on.

At the city scale, perturbations caused by alterations in climate due to macro and micro level variations expose people and economic activities to multiple risks exacerbated by societal shifts. Urban climate change-related risks such as rising sea levels and storm surges, heat stress, extreme precipitation, inland and coastal flooding, landslides, drought, increased aridity, water scarcity and air pollution are increasing with widespread negative impacts on people (and their health, livelihoods and assets) and on local and national economies and ecosystems. These risks are amplified for those who live in informal settlements and in hazardous areas and either lack essential infrastructure and services or where there is inadequate provision of it (Revi et al., 2014), typically observed in the developing countries of the global South.

Moreover, climatic variability is also expected to affect the timing and intensities of regular rains and adversely multiply urban impacts through water, food, health, migration connections (Sohan et al., 2008; Revi, 2008). Most urban centers in low and middle income countries have been unable to keep up with both sufficient and equitable economic expansion and provisions for infrastructure and services (Mitlin and Satterthwaite, 2013). This has resulted in large developmental deficits; around one in seven people in the world live in poor quality, overcrowded accommodation in urban areas with inadequate provision (or none) for basic infrastructure and services, mostly in informal settlements and exposed to a wide range of health risks (Mitlin and Satterthwaite, 2013; UN-Habitat, 2003). These challenges have amplified manifold due to challenges posed by global climate change.

Box 1. Summarizing the importance of recognizing vulnerability in urban centers

- Urban areas are key contributors to economic, social and cultural development. They are important nodal centers as they concentrate more than half of the global population, political and decision making structures.
- In many urban areas, particularly in developing countries and emerging economies, we observe rapid economic growth and expansion. This economic growth and expansion is characterised by poor governance, inequitable access to public services and high levels in social inequality. This has resulted in many pockets within urban centers inherently vulnerable, in particular large urban agglomerations (UN-Habitat, 2011), with high potential of risk exposure to climatic variability.
- Conversely, high concentrations also imply increased opportunities for adaptation and strategic responses. Cities are thus both the drivers as well as epicenters of multiple dimensions of vulnerability - economic, political, sociocultural and environmental (Revi, 2008; Kraas 2007; Johnston et al. 2002).
- Cities, by the virtue of being characterised by interlinkages of various processes and flows (economic, administrative, political), play a massive role in the functioning of large-scale economies and social systems (Olorunfemi 2009). Climate induced collapse of these functions and processes would therefore result in crisis at larger scales, far beyond city boundaries (Kraas 2003).
- It is equally important to note that urban centers depend on resources and functions provided by rural and peri-urban areas and any changes in the rural and peri-urban regions will have profound impacts on the adjoining urban centers.
- Rapid growth and expansion in cities has repercussions for effective governability. Increase in informal activity may constraint the existing formal governance machinery to steer development and adaptation interventions and adoption of preventive measures (Birkmann et al., 2010)
- Lastly, the urban landscape is characterised by built forms. Bringing changes in the built environment and infrastructure takes longer time periods and has high cost implications. Therefore, existing vulnerabilities tend to persist.

5. Contextualising urban vulnerability: Introducing the case of Bangalore

Bangalore is located in the southeast of Karnataka state on the Deccan plateau approximately 900m above sea level. It is drought-prone and has a dry, tropical savanna climate with generally moderate temperatures. It receives rain during both the summer (June-September) and winter (October-November) monsoon phases, together yielding approximately 860 mm of rainfall. As per the agro-climatic zonation delineated by the Indian Meteorological Department (IMD, Government of India), Bangalore falls within the North-Eastern Dry Zone, characterised as semi-arid climate. Understanding vulnerability in a city like Bangalore therefore calls for taking into account both the existing vulnerabilities due to its semi-arid climatic conditions, inherent non-climatic vulnerabilities and the impacts of climate change in further aggravating and adding new risks.

We build on the same conceptual risk assessment framework introduced above and situate it in the context of Bangalore. The framework is generic enough to be adapted for any urban region and specific enough to capture the risk and vulnerability concerns of spaces demarcated and operationally functioning as 'urban centers'.

5.1 What is so peculiar about semi-arid areas in the context of Climate Change & urban areas?

Arid and semi-arid regions even under status quo (considering a scenario where climate change is not a risk) face the fallouts of recurrent and frequent droughts (Schwabe and Conner, 2012). However, with impacts of climate change becoming more and more pronounced, future projections suggest that both the intensity and geographical coverage of drought will pose the most serious climate induced risks to these regions (Revi, 2008)[11]. The primary effects of drought are borne by rural areas and economy. Primary livelihoods such as agriculture, animal husbandry, forestry and fishery draw heavily from climate sensitive resources. Typically, urban centers experience secondary impacts of drought, manifested in the form of issues such as drinking water shortages[12] (Bartlett, 2008) and availability of food and other resources (Revi, 2008; Gasper et al., 2011). Increasing intensity and number of hot days can have serious physiological health implications triggered both by drought conditions and long-term climatic changes.

[11] Drought typically makes up one half to two-thirds of the natural hazard risk exposure (Revi, 2008). Climate change is expected to increase the severity of drought, especially in western India where five river basins are expected to face acute to severe water shortages, impacting a large number of cities in Western India (especially Gujarat, Maharashtra and southern India).

[12] Extreme event such as floods and droughts expose urban food markets to price shocks, it also causes large amounts of household level supplies to get spoilt and damaged.

Climate induced droughts impede the sustenance of agriculture, especially subsistence farming and consequently lead to a cycle of debt and distress migration[13] (Revi, 2008; Gober, 2010). This to a great extent explains the constant outflow of distress farmers from large semi-arid tracts of central, western and southern India to nearby urban centers (Revi, 2008). There is however growing evidence that migration opens up income diversification opportunities (Skeldon, 2003). It is thus pursued as a strategy to reduce vulnerability arising from certain environmental and non-environmental risks[14] (Tacoli, 2009).

The poor migrant community from semi-arid rural areas, mainly comprise of marginal farmers, temporarily or permanently moving out of uneconomical and unreliable agriculture and allied activities. However, even in the cities, they form a sizeable section of the vulnerable population due to inherent limited skills, poor education, and lack of access to capital and social networks. The distress migrant communities are concentrated in the informal, illegal and unserved pockets of the city. The location and socio-political context of these settlements expose them to a range of environmental and health risks. Other pressing risks associated with informal settlements are continual cycles of demolition, eviction and displacement associated with lack of security of tenure. The poor migrant urban community is therefore doubly exposed to both climate-induced risks and new exposure and risks characterizing urban regions (Revi, 2008).

5.2 Bangalore: Evolution of the City and Vulnerabilities

Physical vulnerabilities

Most of the physical vulnerability in the city is experienced by informal settlements. These settlements are either continually vulnerable to multiple dimensions of poor physical infrastructure like housing or are potentially exposed to risks beyond their homes, such as lack of appropriate service infrastructure. Risks are potentially amplified manifold for residents and workers of informal and hazardous settlements and sectors. What varies is the extent of exposure to climate risks and deprivation with regards to access to basic infrastructure, services and safety measures, considered adequate for adaptation[15]. Informal settlements are mostly located in hazardous or risk prone zones, facing the consequences of systematic exclusion from formal planning and development processes (Revi, 2008).

[13] See the risk conceptualisation framework

[14] Non-environmental risks affecting agricultural and allied livelihoods include market failures, unfavourable changes in governance regimes, social marginalisation

[15] For instance, lack of safety nets and social support systems such as health insurance, access to low interest credit facilities, property rights and tenure.

Socio-economic vulnerabilities

In order to understand the existing socio-economic vulnerabilities of Bangalore, it is important to understand the developmental context in which the city has evolved. It has its origins as a modern city in the 1500s. Until the 1990s, Bangalore was a comfortable middle-class town majorly run by large public sector research and manufacturing firms (Goldman, 2011). At present however, it is one of India's fastest growing metropolis, with a distinctive 'informal' economy catering to the poor and middle income groups. The strategic location of the city on the border of two states (Andhra Pradesh and Tamil Nadu) and in close proximity to a third state (Kerala) has strongly influenced the nature of these development trends and consequently, the influx of people with varied ethnic backgrounds and skill sets.

While the 1950s to the 1980s were characterised by public sector investment, the 1990s saw rapid growth in private sector investment in industries and services sector. To entice businesses, the sub-national government offered land and tax incentives and built infrastructure such as elevated roads, a new metro, and a new airport. The onset of the 1990s exposed the Indian economy to liberalisation, which played an important role in forming and shaping Bangalore's tertiary sector. The rapid growth of new economic sectors (IT/ITES, Biotechnology) boosted the real estate market, both locally and regionally (Nair, 2005; Benjamin, 2006). The high end real estate market (that subsequently developed), was specifically aimed at serving high-income groups; both immigrants from other metropolitans (investing for future resale), as well as the local elite.

Alongside this economic boom, the informal economy (falling outside the ambit of Master plans) also kept expanding. Despite being termed 'unplanned' and considered 'insignificant', these were critical in generating livelihood options and provide support services to the fast growing urban region. The local economies noticeably grew in size between late 70s to late 80s, spurred by heavy inflow of public investments in the formally planned manufacturing sector. A large part of the 'informal' economy was supporting light manufacturing activities and ancillary support units that fed into the local textile sector (Benjamin, 2000).

Even today, most of Bangalore's informal economy functions outside the purview of formal planning mechanisms, and recognition of slums and informal settlements as legitimate parts of the city is still problematic. Especially in peri-urban areas, unclear jurisdictions create neglect and pockets of settlements at high risk. There are, for instance, major disparities regarding access to potable water. The city core is generally well connected, but in some peripheral areas fewer than 10 per cent of households are connected to the civic water supply system. Irregular water supply (and the need to store for bad times) has created problems of hygiene, with the highest risks in the poorest residential areas and in informal settlements. Although water supply is a critical concern (Ranganathan et al., 2009), weaknesses in provision extend to other services as well.

Simultaneously, the 1990s also witnessed the emergence of Bangalore's 'mega-city problems' which exacerbated and got carried over into the next decade (2000s). Of these,

the prominent issues that got magnified include slum proliferation, severe water supply and sewage problems, extreme road congestion, pollution and associated health issues, as well as rapidly escalating social inequality. Initially, new slum settlements came up near industrial hubs and factories along the city peripheries, but overtime have mushroomed within the city (Goldman, 2011).

Critical issues in the city concentrate around the rapid growth of inequality and poverty, the result in part of the skewed focus of public policy towards the globalized hi-tech growth sector (CDP, 2009; Benjamin, 2006). While the promise of the city's livelihood opportunities and quality of life attracted a massive inflow of migrants from all over the country, the benefits of its substantial economic growth have not been equally distributed. By the late 1990s, the process of industrial stagnation (primarily the formal manufacturing sector) began in Bangalore. Industrial slowdown severely affected the employment structure, with massive shrinkage in the public sector as well as a consequential impact on indirect employment supporting local manufacturing. Alongside, the IT sector was on a rising trajectory (peaking in 1999-2000). While this made noteworthy contribution to the city's employment situation, it had serious distributional implications. Disparities between the rich and the poor became sharper, visibly observed in growing inequality in access to services, especially water and sanitation (Benjamin, 2000). Growth of the IT sector and provision of rental spaces for well-paid internal and international in-migrants transformed the city periphery. This growth was matched by a growth in informal settlements (characterised by inappropriate housing and poor access to services like water) that supported ancillary service provision to the IT and the housing sector.

The informal settlements are largely inhabited by migrant workers who arrive in the city in search of livelihood opportunities and are already vulnerable due to their social and ethnic backgrounds, negligible rural land holding and poor prior occupation. Newer migrants live in poor quality houses located in small informal settlements, built often with temporary plastic roofing material. Many first generation migrants work as casual labourers in the construction industry, considered to be the 'lowest paid and least secure sector in the occupational spectrum' (Krishna, et al., 2014: 581). Rising prices of essential commodities such as water, fuel, electricity, and food also affect the poor tremendously. As of 2014, about 43% of the population lives in multi-dimensional poverty and the disparities are growing, specially pertaining to living conditions (CDKN, 2014).

Understanding the historical context of 'differential vulnerability'

The characterisation of differential vulnerability in the context of varied social groups is closely tied to its economic history and the attendant outcome in terms of imparting the city a spatial character that speaks of caste- livelihood-economic-differentiated well-being nexus. As discussed elsewhere in this paper, we observe certain distinct phases in the

trajectory of economic development of the city, goes back to the period of the King's rule [16]that overlapped with Bangalore's colonial past.

During the early colonial phase, the city was spatially divided into two main segments- military city (the cantonment area) and the non-military area organized around two main roads (pet`e) - north to south (known as doddapet`e, meaning big road) and east to west (chickpet`e meaning small road).These pockets were organized around caste and housed mostly textile and other minor economies, characterised by caste based occupations. The cantonment population was largely European and others comprised of the 'Hindu' agglomerates that were mostly inhabited by Tamil migrants, flocking into the city in large numbers in search of employment and trade, spurred by substantial European presence. Towards the end of 1800s, the population in the cantonment area was 25 percent more than that of the pete area, conspicuously distinct and the two sub-regions were marked by the presence of two most prominent social groups, arranged around differences in racial and socio-cultural lineage, education (cantonment population was largely English educated, facilitated by missionary presence), and employment profiles (many of the residents trained in engineering and technical fields)[17].The administrative, judicial and policing functions still largely rested with the locals dwelling outside the cantonment, within the caste framework. Narendra Pani, an eminent city based economist writes- 'There were deep divisions between the City and the Cantonment before Independence, and it took several decades post-independence for the mutual distrust to be openly addressed'. Most of the conflict and challenges of integration of the two communities arose from issues of language and politics of bureaucracy (Pani, 2009). What we observe here, through an analysis of the past of the city, is that the city residents were already demonstrating differential starting points - while some were reasonably enjoying the benefits of improved economic opportunities, the others were struggling within their occupational and caste domains.

Post-independence phase

The first Prime minister of the country imagined Bangalore as a futuristic city and India's intellectual capital. The first two decades since the 1950s, dominated by public sector interventions[18], had a remarkable influence on expansion and development of infrastructure; especially residential complexes and transportation networks, and spurred the establishment of several formal small-to-medium sized enterprises. The following decades, at the onset of the 1990s, were strongly marked by the partial substitution of the

[16] Bangalore was part of the Mysore Kingdom and was a crucial cantonment area supporting Britain's wars in terms of raising resources and army for the war, read more here.

[17] This trend continued and by mid 1980s, Bangalore boasted a substantial manpower, both English educated and having technical skills. This later in the beginning of 90s made Bangalore one of the ideal Indian cities equipped to bag the title of India's Silicon Valley.

[18] Specially in the areas of defence (DRDO, Hindustan Aeronautical Limited, Bharat Electricals Limited etc.), knowledge based sectors and, research and production facilities and industries

local economy by the capital and skill-intensive IT sector (refer to the section 4.2.2). Encouraged by this development, a bustling local informal economy that was interlinked with the mainstream public undertakings (a lot of it was dominated by the then soaring textile/garment industry) got partially re-oriented towards the private IT sector. This was also the initiation of the dominance of Bangalore by the IT-based industrial development. The residual textile industry and the new IT sector opened up a wide range of avenues for locals and others outside of Bangalore, across multiple economic and social groups. Consequently, Bangalore's image became that of a promising city, breathing of growing global presence and increasingly negotiating its local identity to accommodate newer global, national and regional practices and cultures. It started drawing diverse people (socially and economically divergent) in significant numbers from in and around Bangalore (from neighboring states of Tamil Nadu, Andhra Pradesh and Kerela) as well as from far- off places of the country (Benjamin, 2000; Dittrich, 2004; Bhuvaneshwari). This led to a de-homogenisation of Bangalore's community structure and thereby created pockets that were strongly linked with economic centers and pockets that were primarily driven or supported by informal economic processes, the trend is still visible. Bangalore's very own globalisation process (discussed in detail in the socioeconomic section) has although provided opportunities to many, the process is deeply embedded within the historical evolution of the city's economic character and occupational structures, and is presently skewing towards certain skill sets, educational levels and inherent political and social capital, derived from caste identity, origin, political agency, social networks and accumulated wealth and assets. This has resulted in certain groups been more successful in navigating themselves out of poverty.

In the last decade there has been a conscious effort towards understanding the nature of heterogeneous vulnerability within the urban region, particularly in the context of ascertaining the nature of poverty concentration; access to water, sanitation and infrastructure and housing conditions[19]. One such study by Balakrishnan and Anand (2015) used statistical cluster analysis method on census data to empirically create sub-typologies (that is intra-ward) in Bangalore to spatially tease out areas (ward level) that have higher concentration of poverty. The study concludes by pointing towards in and around zones (mostly in peripheral areas, around industrial clusters) that are neglected in terms of planning and access to public service. Incidentally, these are the pockets that house a large worker/ migrant population who have poor economic backgrounds[20] and agency. In

[19] City based CSOs like Janaagraha (2013) and think tanks such as the Centre for Sustainable Development (2012) have done ward level studies across 198 wards to evaluate access to urban infrastructure and environmental quality; important aspects of urban poverty and quality of life. Another empirically rigorous study analysing the status and spread of areas, primarily deficient in housing condition; one of the important poverty criteria can be understood in the study by Jana and Bhan (2015), called ' Reading Spatial Inequality in Urban India'.

[20] Observation in agreement with the city master plan, called The Bengaluru Master Plan–2015 (Bengaluru Development Authority 2007) that denotes areas that are deficient in services, access to health and education infrastructure as 'shadow areas'.

essence, we are talking about historical embeddedness of vulnerability but at the same time, as discussed above, the planning and management processes that are governing the present period is unable to contain the spread of vulnerability - partly characterised by historical social groups and their agency, new migrants and informal nature of economic activities/economy.

This narrative further strengthens the observation around Bangalore's spatial nature of differential poverty and hence vulnerability being structural in nature, owing to caste-based historical occupational and livelihoods structure, that emerged during the King's s rule and progressively, due to the entry of new types of economic activity, resulting in the inability of the economic development processes in ensuring that the new entrants to the city are not vulnerable.

6. Risk spectrum: Climatic and non-Climatic risks

6.1 Important climate risks characterizing Bangalore

As explained above, climatic risks do not play out in isolation but exacerbate vulnerability in interaction with other existing vulnerabilities. Critical risks that can be termed as climate hazards impacting Bangalore at present and that can potentially challenge future prospects of growth and prosperity are a) urban flooding- directly impacts infrastructure that deliver crucial services and thus has the potential of disrupting various critical systems and impact people directly, b) impacts of urban heat island effect (UHI) - pose serious threats to people' health and well-being and also affects energy demand.

Incidences of urban flooding has gone up in recent years causing damage to the low lying areas of the city and severely affecting transportation systems (road and rail networks, aviation). Important service delivery infrastructure responsible for supply of water and sanitation (drainage and sewage, solid waste disposal systems) are at risk from urban floods. This is expected to further aggravate due to the impacts of changes in the microclimate and absence of sound flood proof infrastructure (Guhathakurta, 2011). The impact of increasing urban heat island effect has serious health implications for the local population as implied by climate projections that show an increase in the number of extreme hot days. In general, projected climate risks in Bangalore are likely to impact a range of sectors such as food and water, health, buildings, transport and natural ecosystems.

The figure (2) below, provides a comprehensive assessment of the interaction between the direct and indirect impacts of climate change in Bangalore. The column on the left depicts the direct impacts (for e.g. increase in temperature, extreme rainfall events, heat wave intensity) while the column on the right suggests likely incidence of these direct impacts. Important to note here is the nature of first and second degree interactions and the potential of cumulative impact which alters the city's risk and vulnerability profile and affects people's lives differentially.

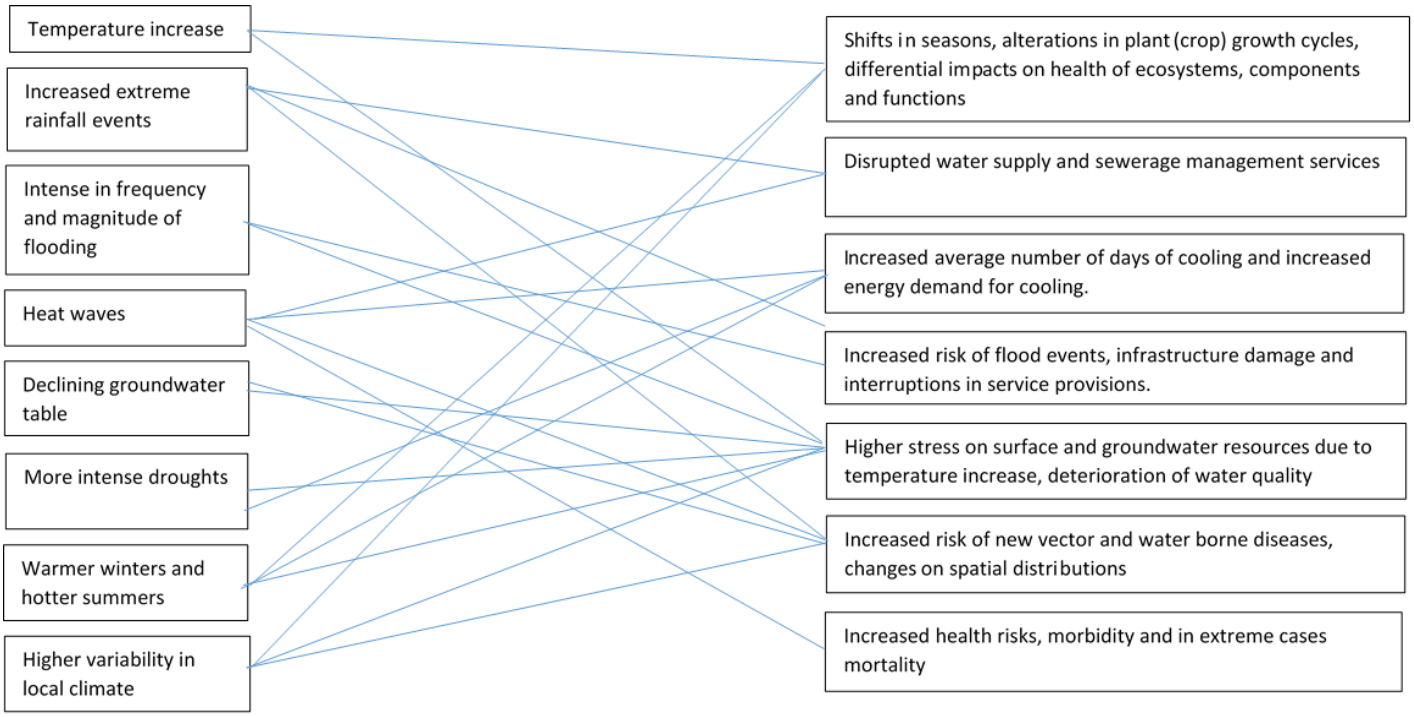


Figure 2. Depicts the direct and indirect impacts of climate change, adopted from IPCC, 2014

6.2 Development induced risks: Changing economies, urban sprawl and land use alterations

Bangalore's extensive spatial growth has been accompanied by rapid population increase. A quiet city of under a million in the 1950s, it witnessed massive population increase over decades (Census, 2011). The estimated population for 2015 is almost 11 million, making it the third most populous city in India (CDKN, 2014). First decade of the 21st century also saw a change in administrative boundaries of the city, because of which the overall population density seems to have declined but it created spatially distant pockets (from the central core) with little or no governance and lack of public services.

Over the decades (since the 70s), the built-up area has also increased steadily (more than six folds), driven by large scale construction activity that has transformed the neighbouring rural economy, landscape and culture of Karnataka as a whole (Goldman, 2011). By 2011, the Bangalore metropolitan area covered 741 square kilometres and it continues to grow. The city sprawled towards the periphery, away from the relatively low density core. Reasons include preferential investments in the periphery (in housing and commercial activities), limited ability to change designated land-uses in the core, and greater personal mobility as middle class disposable incomes rise. Locked, expensive and unavailable land in the central areas of the city is another major factor driving proliferation of legal as well as illegal settlements in the periphery (ibid). The rising prices of land and rentals have made

housing a major issue, and although the percentage of population living in slums is lower than in other larger cities in India, the number of informal settlements has grown significantly, housing more than half a million people (KSCB, 2011; Sudhira et al., 2007).

Between 1992 and 2009, Bangalore's physical footprint increased by over 100 percent (CDKN, 2014). The primary reason for this rapid growth is the expanding service sector economy. Growth on the city's expanding peripheries continues to put considerable pressure on natural surroundings, resulting in a sharp decline in water bodies and natural vegetation. Bangalore has long depended on a system of wetlands and constructed lakes, ponds and water tanks, many built in the 16th century by damming springs and streams for drinking water and irrigation. These constitute a vital ecosystem, serve multiple livelihood and domestic purposes, and also capture rainfall, helping replenish groundwater and modulating the city's microclimate. However, almost 300 such water bodies (counted in the 1960s) have mostly dried up or vanished as the city sprawled and densified in certain locations. More than 70 percent of the wetlands have disappeared since 1970s, the result of cascading development pressures and rapid urbanisation – encroachment and construction, pollution, illegal mining and quarrying (SoER, 2008).

6.3 Governance dimensions

A critical aspect of Bangalore's governance is its land-use management. The rapid transformation of the rural landscape has, as noted, put tremendous pressure on peri-urban ecosystems. Ecological commons such as lakes, wetlands and community gardens, providing livelihoods and social and cultural services, used to be managed through community systems of oversight (Sundaresan 2011). Much of the city's transformation has also resulted not from planned interventions, but from the activity and strategies of the private sector, civil society and poor inhabitants themselves (Goldman 2011). Informal settlements expanded without oversight, and even the transfer of agricultural land to real estate agencies and developers, which started in the mid-1990s, often took place without necessary legal approvals or attention to basic standards with regards to such features as access roads and sewer lines.

All of this is now within the purview of the local Development Authority and there are attempts to address it through Comprehensive Development Plans (CDP) drafted every ten years, including coordinating decisions and actions of various other agencies and departments. While, in the context of rapid growth and change, a transition from informal to planned management was essential, it has not been highly successful. Implementation has often been ineffective and the process is inaccessible to most of the population. While formal mechanisms exist for more strategic long term planning, actual plans focus more on opportunities for land development rather than on the kind of zoning and management that is responsive to the full range of the city's development needs. For instance, while the administration has clearly identified the importance of sustaining the existing emerging industrial sector and has underscored the importance of the planned unlocking of land in

the city core and the periphery (CDP 2009), there are weaknesses in the policy-implementation space with regards to, for example, safeguarding areas at risk from flooding or protecting water bodies from encroachment. The lack of an effective mechanism for acquiring and distributing serviced land to both citizens and industry also reduces the city's effectiveness in meeting its development needs and impedes sensible growth (CDKN 2014). The city's vision for its development seems in effect to be driven by processes which for the most part conform to pressures of economic growth rather than to the objective of long term sustainability. Table 1 below summarizes some of key sectors at risk in Bangalore and the potential climate change induced impacts.

Table 1: Key risk sectors and potential impacts due to climate change

Key risk Sectors	Climatic drivers	Potential impacts of climate change
Overall urban systems	Climate hazards such as extreme events induced by variability in temperature and rainfall.	Profound impacts on infrastructure, services, ecosystems and therefore impact economies and populations. These interact with existing social, economic and environmental risks to compound vulnerabilities.
Terrestrial ecosystems and ecological infrastructure	Untimely, irregular and intense spells of precipitation and temperature variation	Alteration in ecosystem services and functions due to changes in temperature and rainfall regimes, variations in evaporation rates, impact on soil moisture, changes in humidity affecting healthy functioning of people.
Water supply systems	Drying trend, extreme and unpredictable precipitation	Reduced water availability due to damaged water supply infrastructure and inadequate supply, contaminated water supplies, and reduced capacity to effectively meet competing water demands by different sectors.
Waste water system	Extreme precipitation	Vulnerability of sewage treatment infrastructure to damage by extreme precipitation event and inability to clean up the water system due to inappropriate design (if design does not take into account extreme precipitation condition).
Energy systems	Drying and warming trends, extreme precipitation	Power supply interruptions due to damaged energy production and transmission infrastructure and the associated high dependence on conventional energy supply systems, absence of decentralized options.
Food systems and security	Temperature increase, alterations in precipitation and humidity	Disrupted food production, supply and direct implications on food prices and hence food security of the poor, assuming that the public food distribution systems are poorly managed.

Key risk Sectors	Climatic drivers	Potential impacts of climate change
Transportation and communications systems	Extreme precipitation	Disrupted networks directly affecting livelihoods, that are partly linked to spatial alterations in the city character and therefore, heavy reliance of the poor on public transport and other communication systems
Housing	Warming trend, extreme precipitation	Low quality housing in flood prone zones or other vulnerable locations are prone to destruction. Directly impacts health and permanence of shelter. Quality of housing bears direct implications for energy requirements
Human health	Warming and drying trends, extreme temperature and precipitation events	Direct health impacts due to breaching temperature thresholds of social groups or due to over exposure (like in open construction or mining activities), poor quality and inadequate water availability leading to water-related health problems, flood situation triggered by extreme precipitation events creating health hazard in poorly located habitations.
Poverty and access to basic services	Variable precipitation and temperature	Water shortages leading to water related diseases, temperature alterations impacting functionality of population – together impacting livelihoods. Informal settlements are mostly cut out from basic services, these are also places that are characterised by chronic poverty and hence lack the financial capacity to access private services.
Poor and marginal social groups	Warming and drying trends, extreme temperature and precipitation events	Direct impact on livelihoods, health capacity due to disruptions in other key sectors (terrestrial ecosystems and services, water, other economic sectors) and services and breach of thresholds of individual groups – partly because of poor adaptive capacities and chronic poverty. Also, impacts on food security of the poor that gets disturbed due to climate change disruption food production and supply chains (some of the poorer neighbourhoods lack effective public food distribution systems)

7. Conclusion and way forward

Urban systems are comparable to ecological entities, wherein comprising sectors are interlinked through critical resource and service flows. Together, they deliver functions that make cities important economic and growth agglomerates. Given how complex and intertwined the nexus is between the various components (sectors, sub-systems and people) of the urban system, all comprising units are rendered risk prone to climate change to a certain degree. The magnitude of impacts caused is however variable depending on the levels of exposure and robustness of the system to cope or absorb negative impacts, while delivering essential roles and functions. Set on this pretext the risk and impacts table (1) highlights key urban sectors/aspects (such as urban ecosystems, housing, transport, energy, health) that are exposed to climate change. Notable climatic drivers in this respect are variations in precipitation and temperature regimes, frequency of extreme weather events, and duration and intensity of dry spells. As the table suggests, the impact on a particular sector, such as water shortage, has severe developmental consequences (like health implications). Likewise, alterations in temperature and precipitation regime influence a range of issues, spanning across key sectors such as urban ecosystems (green patches, lakes, tanks), energy systems (power supply and demand aspects), food systems and security (by negatively impacting food storage and disrupting the food supply chain). It is crucial to recognize that although on one hand the impacts of these climatic changes play out visibly and follow a more or less intuitive trajectory (for instance rising temperature leading to severe heat stress; impacts on health etc), on the other hand, the interactions with non-climatic stressors (such as poverty, environmental degradation, failed management) increase the risks many fold and render attribution to one or more individual factors almost impossible.

Within these complex interactive processes of urbanisation facing climatic and non-climatic risks; vulnerabilities often go unnoticed and are aggravated. Responding to the existing and prospective climatic and non-climatic risk continuum becomes an important question. There are many approaches that have been articulated or promoted but building on the already described risk assessment framework, this paper argues for a more comprehensive response framework towards addressing climate change related challenges. Addressing adaptation and mitigation issues, within sectoral/issue perspective, appears to be the most feasible risk management framework; particularly in the context of resource constraints within urban financial architecture and advantages of utilizing synergies (co-benefits). Table below identifies a potential response framework that links climatic drivers, potential impacts due to climate change and possible adaptation prospects, used more as an illustration but to be explored more during the RRP.

Table 2: Linking adaptation and prospects, key risk sectors and potential climate impacts

Key risk sectors	Climatic drivers	Potential impacts of climate change	Adaptation issues and prospects
Overall urban systems	Climate hazards such as extreme events induced by variability in temperature and rainfall.	Profound impacts on infrastructure, services, ecosystems and therefore impact economies and populations. These interact with existing social, economic and environmental risks to compound vulnerabilities.	An appropriate urban governance frame with focused adaptation measures concerning built environment, infrastructure and services and overall risk reduction has high potential for reducing key climate risks.
Terrestrial ecosystems and ecological infrastructure	Untimely, irregular and intense spells of precipitation and temperature variation	Alteration in ecosystem services and functions due to changes in temperature and rainfall regimes, variations in evaporation rates, impact on soil moisture, changes in humidity affecting healthy functioning of people.	Attempts to bridge knowledge gaps with respect to ecosystem thresholds and thus carefully designed adaptation strategies and prevention of maladaptation. Demarcation and protection of green areas, provision of more drainage systems and protection of urban wetlands and ground water resources. Strategize development controls using a mix of effective policy instruments, informed by evidence and guided by experts.
Water supply systems	Drying trend, extreme and unpredictable precipitation	Reduced water availability due to damaged water supply infrastructure and inadequate supply, contaminated water supplies, and reduced capacity to effectively meet competing water demands by different sectors.	Strengthening water networks and demand management. Improvement in water resources management and increased efficiency in water supply systems. Interventions to reduce risks to floods and endeavour towards improving water quality.
Waste water system	Extreme precipitation	Vulnerability of sewage treatment infrastructure to damage by extreme precipitation event and inability to clean up the water system due to inappropriate design (if design does not take into account extreme precipitation condition).	Increase in spatial coverage of sewerage systems. Managing wastewater flows, reduce clogging and infrastructure breakdown possibilities by using quality material and proper regulations and scheduled interventions for waste management.

Key risk sectors	Climatic drivers	Potential impacts of climate change	Adaptation issues and prospects
Energy systems	Drying and warming trends, extreme precipitation	Power supply interruptions due to damaged energy production and transmission infrastructure and the associated high dependence on conventional energy supply systems, absence of decentralized options.	Reduce dependence on hydropower as the main source of energy by replacing it with alternative energy sources. Implement interventions for demand side management in addition to energy source diversification, including decentralized options.
Food systems and security	Temperature increase, alterations in precipitation and humidity	Disrupted food production, supply and direct implications on food prices and hence food security of the poor, assuming that the public food distribution systems are poorly managed.	Promote urban agriculture practices, promote ecosystem based adaptation to regulate ecosystem services essential for food production systems, devise new adaptation policies to take into account impacts of climate change on urban food supply chain and accordingly design market interventions, strengthening of public food distribution system and governance.
Transportation and communications systems	Extreme precipitation	Disrupted networks directly affecting livelihoods, that are partly linked to spatial alterations in the city character and therefore, heavy reliance of the poor on public transport and other communication systems	New design standards in the context of climate change and enforcement of development controls.
Housing	Warming trend, extreme precipitation	Low quality housing in flood prone zones or other vulnerable locations are prone to destruction. Directly impacts health and permanence of shelter. Quality of housing bears direct implications for energy requirements.	Integrate effective building code practices into climate change action plans at the city scale, effective development control and upgrading of informal settlements and retrofitting of old buildings.
Human health	Warming and drying trends, extreme temperature and precipitation events	Direct health impacts due to breaching temperature thresholds of social groups or due to over exposure (like in open construction or mining activities), poor quality and	Improvement of water supply, solid waste management, housing conditions, land use planning and food security and provision of market-based social security instruments like health

Key risk sectors	Climatic drivers	Potential impacts of climate change	Adaptation issues and prospects
		inadequate water availability leading to water-related health problems, flood situation triggered by extreme precipitation events creating health hazard in poorly located habitations.	insurance.
Poverty and access to basic services	Variable precipitation and temperature	Water shortages leading to water related diseases, temperature alterations impacting functionality of population – together impacting livelihoods. Informal settlements are mostly cut out from basic services, these are also places that are characterised by chronic poverty and hence lack the financial capacity to access private services.	Formalizing informal economic sector, upgrading of informal settlements, improving of housing conditions and empowering local communities in tackling problems related to climate change.
Poor and marginal social groups	Warming and drying trends, extreme temperature and precipitation events	Direct impact on livelihoods, health capacity due to disruptions in other key sectors (terrestrial ecosystems and services, water, other economic sectors) and services and breach of thresholds of individual groups – partly because of poor adaptive capacities and chronic poverty. Also, impacts on food security of the poor that gets disturbed due to climate change disruption food production and supply chains (some of the poorer neighbourhoods lack effective public food distribution systems)	Ensuring that the poor and marginal social groups have adequate public service provision, means to cope with sudden climatic event, availability of appropriate livelihood diversification opportunities, access to sufficient food and health care. Improvising on governance innovation to legitimize bottom-up processes of resource management and use, promotion of community and neighbourhood led adaptation processes. These processes have to be constitutionally mandated or implemented through innovative governance instruments.

7.1 Way forward

The ASSAR project, within the social differentiation research stream, aims to understand the nature of differential vulnerability in the context of our case sites. It further aims to

understand the landscape of response within a wider network of state and non-state actors and work towards identifying an appropriate response mechanism that has the potential for effective, sustained and widespread adaptation. The context of Bangalore offers a unique opportunity to distil the nature of differential vulnerability further, particularly in the context of the most poor and vulnerable. By doing so, we intend to identify transformational pathways for adaptation and situate it within the context of broader vulnerabilities and development dynamics of the region. We will also understand the risk management framework from the perspective of the poorest through widening of and a nuanced understanding of the assessment and operational framework described above, which includes mitigation.

7.2 Recommendations

The ASSAR project is an opportune political, research and practice moment that could potentially provide a meaningful entry point to the local climate change discourse in India. Within this opportunity, through the research phase of this project, we need to contribute towards answering four critical aspects within the domain of climate change adaptation and linked co-benefits agenda:

How do we create an impact and research-into-use pathway in the local context and use the research findings as an entry point towards resolving the inappropriate local implementation and governance processes and mandate? Through this working paper we have come to realize that there are conflicting positions that underpin management processes in Indian semi-arid city context and it is these dilemmas that need to be resolved through our research, principally in the realm of reconciling response and impact pathways in the formal and informal domains.

How do we, in a very micro-setting, understand the interactive pressures of climatic and non-climatic risks on human well-being? This project, we hope, would be addressing some of the most critical questions that intersect across macro-, micro- and sub-micro life experiences and processes, and their drivers and create empirical knowledge around a deep understanding of differential vulnerabilities at such scales and ensure that they do not go unnoticed.

While researching for this working paper, we found hardly any recognition of gender at the city-scale; particularly in the context of climate risks and Bangalore. It will therefore be our endeavour to enquire into the intersection of gender and climate change and attempt to look at gendered experience of climate and non-climate risks. We believe that a lot of understanding around power, voice, agency and adaptive capacity - critical for an effective climate change response, will emerge through this exploration.

Finally, through this research phase, we intend to create implementable climate action plans in the context of a semi-arid region and India. The research phase should be able to provide us with enough evidence that could be used to build an architecture of a response

framework, backed by empirical evidence, co-explored through the identified set of questions and the issues highlighted above. We realize that we are sitting within an opportune moment where global Sustainable Development Goals (SDGs) need to be operationalized and our attempt would be to ensure that we develop implementable action plans that provide an opportunity to be coherent with the global, national and regional development agenda (SDGs) as well as provide an opportunity that transforms the development form and processes.

The above highlighted issues have to be read together with the key questions that we intend to explore through the research narrative that has been finalized around social differentiation, gender, governance, ecosystem services and knowledge systems. What we intend to do is to connect with the historical evolution of vulnerabilities in the city and its embeddedness, identify key typologies that capture poor and marginal social groups – co-explored through intensive secondary data analysis and scoping visits, understand dimensions of differential vulnerability in the wider relational context with the city and the larger region, explore the cross-linkages and synergies between the identified different lenses like governance, build an understanding around current coping and adaptive response and work towards building an impact pathway that addresses the well-being of the poor and marginal social groups effectively, in sustained manner and is widespread. We will be consciously exploring opportunities that have potential in terms of its scalability within the wider regional and national narrative and thereby increase the prospects of its effectiveness. We are consciously adopting a mixed-methods approach while we address these critical questions – a detailed quantitative assessment that helps in building typologies and implement a distributional analysis (who is the most vulnerable and why) and following it up with intensive qualitative field work comprising of focus group discussions, interviews so as to capture the nuances of risks and vulnerability. We have consciously adopted a linked framework that co-explores the dimensions of risks and vulnerability through the multiple identified lenses, which would lead towards answering the critical issues highlighted above.

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