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Original Paper

Assessing Barriers and Opportunities for Ecosystem Based Approach to Adaptation in High Altitude City of Thimphu

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Abstract

Scientific studies to understand challenges and opportunities for adaptation are crucial for adapting to climate impacts and averting disasters in cities. In this study, we attempt to assess baseline social and environmental conditions, identify challenges and barriers, and recommend ecosystem based opportunities for adaptation. The city's infrastructure is poorly planned triggering congestion (which leads to increased carbon emission, road rage, etc.), flooding of sewage systems exposing humans to infections. Majority of the poor who live in informal settlements lack adequate access to basic facilities turn to natural resources thereby depleting the environment around the city. This leads to the loss of ecosystem services and protection against natural hazards such as flash floods, landslides, and forest fires which affects the vulnerable groups disproportionately. To improve socio-ecological resilience to cope with changing climate, the study also identified ecosystem based adaptation interventions such as urban agriculture, agroforestry, greening projects, resettlement of informal settlements, education on coping strategies, and building institutional, technical, and individual capacities to be integrated into climate adaptation strategies into development plans. The study also recommended that the city authority secure adequate funds and build capacity to plan ecosystem based adaptation and implement interventions.

Keywords

ecosystem based adaptation, climate change, Bhutan, urban resilience, urban adaptation, climate impacts

1. Introduction

Climate change is emerging as a single most powerful threat to global environmental and social integrity (Carter et al., 2015). Climate change has significantly damaged environmental and social resilience and is expected to increase the frequency and intensity of natural disasters and create new hazards such as sea level rise, melting of glaciers, etc. (IPCC, 2007). Global cities, which are the engines of economic development (Sherbinin et al., 2007) and crucible of civilization with large populations, are most vulnerable to the impacts from climate change (Geneletti & Zardo, 2015). Most cities are strategically located along the coastal areas or on low-lying areas near the mouths of rivers, which are best located for cost effective trade and transportation. These locations are believed unfortunately to have high exposure and are at greater risk from climate change hazards such as increasing incidences of heat waves, flooding, water scarcity resulting from rainstorms and wind storms, which could devastate settlements, vital infrastructure and ecosystem services (Carter et al., 2015; Hebbert & Jankovic, 2013). An assessment by the United Nations, (UN-2015) reported that about 82% of the cities hosting about 1.9 billion people were located in areas that faced high risk of mortality associated with natural disasters. Cities are characterized by high concentration of population and population growth with increasing number of urban poor who lack adequate resources to adapt to the impacts of climate change. In addition, over 82% of the cities with 2.1 billion people were located in areas that were highly vulnerable to economic losses associated with at least one of the six types of natural disaster. Floods were the most common type of natural disaster affecting cities, followed by droughts and cyclones. These three types of disaster are also the most devastating for city dwellers globally in terms of the mortality and economic losses they caused.

On average, cities in the less developed regions are at higher risk of exposure to natural disasters and are more vulnerable to disaster-related economic losses and mortality than those in the more developed regions. According to the figures from the United Nations over 54.4% of the world population in 2016 lived in cities and it is projected to increase to 60% by 2030 (UN, 2016). This increase is increasing at a higher rate in the developing countries where the cities are growing. This growth in the face of lack of adequate basic facilities exacerbates the risk of mortalities and risk from natural disasters. Despite these challenges, cities in the developing countries are growing into centers of human growth, cultural exchange, tourism, employment generation, and their sustainable growth and hence growth is inevitable.

Parallel to the growth of cities, threats of sea level rise, flooding, glacier melting due to climate change over the coming years will aggravate hazards thereby jeopardizing the sustainability of cities. This demands addressing unique challenges and opportunities for urban adaptation and mitigation responses

and for mainstreaming them into development plans. Despite this urgency, a paucity of scientific studies that grounds urban emission trajectory and alternative adaptive options and capacities (Hardoy & Lankao, 2011) not to mention of studies that looks at integration of mitigation and adaption into urban development. Of the existing studies majority of them concentrates on mega urban cities in developed countries where they have good infrastructure and lots of emission or coastal cities prone to tropical cyclones and sea level rises (Leichenko, 2011; Hardoy & Lankao, 2011; Kithiia, 2011; Lankao & Qin, 2011; Carter, 2011; Tanner et al., 2009; Sherbinin et al., 2007). Few climate change studies have focused on high altitude, land locked cities, and no study exists in these cities that attempts to apply ecosystem-based approach to adaption. Based in land locked high altitude city of Thimphu, this paper attempts to fill in this gap by: i) assessing baseline socio-economic and environmental conditions; ii) Ascertaining current and future climate hazards and need for response strategies; iii) identify ecosystem based adaptation options, and; iv) identify barriers and opportunities integrating Ecosystem based Adaptation (EbA) into local city development plans.

1.1 Linking Ecosystem Based Adaptation (EbA), Urban Resilience, Sustainable Development

Resilience, adaptation, and sustainable development are emerging as dominant concepts in assessment of social ecological systems especially when it concerns climate change induced disasters and coping strategies (Vogel et al., 2007). Although they emerged out of different disciplines, their uses are gaining integration especially with the development of sustainable development goals by the UN. Below we attempt to frame each of these concepts and their linkages.

Resilience: The concept of resilience was originally introduced in the climate and disaster literature in the 1970 (Torry, 1979). Similarly, resilience was also used in child psychology (Werner et al., 1971) and ecology (Holling, 1973). Since then resilience has been used widely by both the ecological and as well as social scientists (Gaillard, 2010). Resilience is viewed as a biological capacity of ecosystems to absorb shocks and recover functions (Holling, 1973; Leichenko, 2011). Resilience alliance (www.resaliance.org) has defined resilience as, “the ability of a system to absorb shocks, avoid crossing thresholds into an alternate and possible irreversibly new state and regenerate after disturbance”. This becomes feasible through the maintenance of the systems identify, structure, functions, and especially the capacity to reorganize itself while the change takes place (Walker et al., 2002). In the face of one or more disturbing face resilience focuses on the system performance and determine desirable pathways towards a sustainable state (Adger et al., 2005; Walker et al., 2002). If the origin of resilience is heterogeneous, its interpretation is equally diverse with urban resilience quickly emerging to take a central stage, indicating a shift from vulnerability to response-capacity building in recent climate change literature that explores properties of people (social resilience) and the environment (ecological resilience). Drawing upon the traditional definition of resilience, urban resilience is defined as the ability of a city or urban system to absorb disturbance while retaining identity, structure, and key processes (Resilience Alliance, 2007). Urban resilience studies have ranged from an early focus on urban-based ecosystems (Alberti et al., 2003) to the analysis of coupled human

environment systems (Liu et al., 2007) to examination of cities and urban networks as complex adaptive systems (Resilience Alliance, 2007). Within these literature extreme climate events and slow changing climate are regarded as shocks and stressors that destabilize urban systems and render them more vulnerable to hazards (Ernstson et al., 2010; Maru, 2010). A stable and resilient urban system is a pre-requisite for sustainable development of urban systems. This demands adaptation and mitigation interventions focused on enhancing the capacities of cities, infrastructure systems, society, and ecosystems to quickly and effectively recover from hazards and adapt to emerging conditions. Urban resilience is critical for sustainability and ecosystem-based adaptation will improve the resilience of both ecosystem and society.

Ecosystem based Adaptation (EbA): Adaptation is an adjustment in natural and human systems, which occurs in response to actual (autonomous adaptation) or expected climate changes or their effects (anticipated adaptation) or planned activities supported by policy decisions (planned adaptation), in order to reduce harm or exploit benefits (IPCC, 2007). Adaptation to climate changes is expected to reduce the degree of sensitivity, exposure, and danger through adaptive measures (Wang et al., 2017). For instance, in agriculture it is addressed through policies and programs aimed at improving productivity using interventions such as optimizing water usage, improved varieties of crops, livestock, etc. (Venkateswarlu & Shanker, 2009). Successes of adaptation programs depends on variety of factors including socio-economic, locational aspects, infrastructures, institutional, and political. Adaptation program are mostly based on the four conceptual building blocks of climate change resilience development with respect to: reducing sensitivity, reducing exposure, enhancing community based capacity for adaptation, and institutional capacity. These would lead to development of climate change and disaster resilience through: technology development, preparedness and awareness strengthening, and livelihoods protection and development. In general, adaptation strategies include: social networks for support in times of climate stresses; common resource management; diversified income sources; and traditional innovations such as ploughing early morning before dew or fog has evaporated (Kelkar & Bhadwal, 2007; Ullah & Rahman, 2015). In the context of urban cities, adaptation responses must be sensitive to both the needs of the society and the health of its ecosystems due to high intensity of resource uses.

Ecosystem based Adaptation is gaining increasing popularity (Geneletti & Zardo, 2015). EbA is defined as the use of biodiversity and ecosystem services to help people adapt to the adverse effects of climate change (CBD, 2008). The concept of EbA emerged in response to a need for a more holistic approach that integrates approaches to conserve and improve ecosystems as well as provide goods and services for human well-being with better mitigation co-benefits. Since its introduction into the international policy arena by UNFCCC in 2009, EbA has been receiving popular adoption by many environmental and sustainable development organizations (Colls & Ash, 2009; TNC, 2009). EbA generally includes the restoration of important ecosystems that underpin livelihoods/well-being of communities. Unlike traditional adaptation approaches, EbA offer the advantage of promoting “no

regrets" interventions such as urban reforestation (Lafortezza et al., 2013), wetland restoration within urban areas, urban agriculture, etc. (Müller et al., 2013; Gill et al., 2007), that provides multiple socio-economic and environmental co-benefits (Jones et al., 2012). Some of these benefits include, among others, biodiversity conservation through enhanced habitat conditions; climate, pollution, and heat mitigation through carbon sequestration; conservation of traditional knowledge, livelihoods, food security, poverty of local communities; improved recreation, tourism opportunities and water security (Demuzere et al., 2014; Naumann et al., 2011; Vignola et al., 2009).

2. Methodology

2.1 Data Collection

The study used a mixed method, with a combination of consultations with key officials from the city office, key informant interviews, field observation, and document review, to assess baseline information, current threats from climate related hazards such as flooding, storms, landslides, and explored drivers and impacts. The study also explored options for ecosystem based adaptation and identified barriers. Purposive sampling was used to select respondents who are either directly or indirectly in charge of storm water management (engineer, site inspector, planners, etc.). The snowball method was used to select residents who were affected by hazards such as flooding for consultation and interviews. Questions relating to the frequency and magnitude of climate related hazards such as flooding, challenges in managing such events, adaptation measures, the Thromde (City authority) interventions in adaptation and mitigation. Discussions by the way of stakeholder workshops was held to discuss root problems, agree on common barriers and challenges, and identify ecosystem based adaptation options to improve socio-ecological resilience of the city.

2.2 Study Area

The study is based in Bhutan's capital city of Thimphu (26km^2) because it is landlocked, located at high altitude (7000m) and one of the 15 most vulnerable cities to climate change (IIED, 2009). In addition, government of Bhutan has adopted environmental conservation as one of the four pillars of developmental philosophy the Gross National Happiness (GNH).

Bhutan is a small land locked Country of about 38,394 sq.km (NEC, 2011), with a population of about 740,000 people of which over 69% is primarily subsistence agriculturists. The socio-economic development of the country is guided by the concept of Gross National Happiness with four pillars, of which one is the environmental conservation. The Government is determined to pursue its developmental plans to reduce poverty and maintain its reputation as an environmental leader through green development. However, the impacts of climate change present itself as a formidable challenge to attaining these goals. Bhutan's fragile geographical setting, lack of technological knowledge, and information on climate impacts, and human capacity, further exacerbates the problem. Climate impacts are felt in the forms of extreme weather events, rainstorms, droughts, and floods (GLOFS), landslides, rainstorms, forest fires, changing rainfall patterns (early arrival and late departure), etc.

Realizing Bhutan's vulnerability to the slightest changes in climate and its lack of capacity to respond to climate related disasters, the government has formulated environmental policies that require all developmental plans to be environmentally sensitive. National Environmental Commission (NEC) was set up and entrusted with the mandate for looking after Bhutan's environment including climate change adaptation and mitigation. The Constitution of the Royal Kingdom of Bhutan requires 60% of the country to be maintained under forest cover for all times to come (Kingdom of Bhutan, 2008). Internationally, Bhutan also is a party to UNFCCC and the Kyoto Protocol. In addition, Bhutan committed to remain carbon neutral at the COP15 held in Copenhagen, Denmark in 1999.

Despite these efforts, Bhutan continues to suffer the consequences of climate change. One particular section of the society that is directly bearing the brunt of the impacts from climate change and economic development is the fast expanding urban poor. Bhutan has a high rate of urban population growth (3.7%) thereby exacerbating negative impacts on the ecosystems associated with the urban cities. Such a high rural urban migration in a traditionally agricultural country is fueled partly by increased difficulties faced by the agricultural sector some of which are induced by climate change impacts (drying water sources, erratic rainfall, pest and disease, storms, landslides, etc.). This makes life very difficult for the urban poor who are particularly reliant on ecosystem services. This is because these communities often lack access to basic services, such as clean water, sanitation, and electricity. Inadequate infrastructure, limited resources and poverty further compound this problem. In addition, vulnerable urban communities often live in slums, many of which are situated in marginal areas that are vulnerable to natural hazards. Goods and services provided by functioning ecosystem can provide poor urban communities with important livelihood options to cope with economic stresses and buffer them against natural hazards. Consequently, environmental degradation associated with urbanization is increasing the vulnerability of these poor urban communities. Furthermore, current climate variability and change is further exacerbating the above-mentioned environmental stresses and associated vulnerabilities. In addition, increases in intense rainfall events throughout the region have resulted in severe floods, landslides, and mudflows.

Like many major cities around the world, Thimphu, Bhutan's capital city is grappling with classic challenges of increasing population, lack of adequate infrastructure, unemployment, sprawling urban slums. These factors alone or combined has put excessive pressures on natural resources in and around the city thereby exposing the vulnerable groups to the impacts of climate change. Forest fires, landslides, flash floods, flooding of storm drains, and drying of water sources are becoming a familiar event in the city. International Environment Development (IIED) has classified Thimphu city as one of the 15 most vulnerable cities in the world (IIED, 2009).

The country is administratively divided into 20 districts (known as *Dzongkhags* in Bhutan), and 205 sub districts (known as *Gewogs*). Heads of the *Dzonghags* (called the *Dzongdags*) are appointed from the Civil Service while the head of the *Gewogs* (called *Gups*) are elected by the respective citizens of the *Gewogs*. Thimphu city (known as Thimphu *Thromde*) falls in the Thimphu District and is managed

by the Thimphu *Thromde* headed by a democratically elected Mayor (known as *Thrompon*). The *Thrompon* is elected through a secret ballot and administratively supported by an executive secretary appointed from the Civil Service. For planning and management purposes, the city is divided into three parts namely the north, central, and south. Central part of the city is the most developed and populated, while the northern and southern areas are in the process of being developed.

3. Findings and Discussions

3.1 State of Socio-Economic Conditions

Demographic profile: Available information from Thimphu city administration showed that there are about one hundred and four thousand (104,000) people living within the city limits that covers a total area of about 26 km^2, implying a population density of 4000 people per km^2 of land. However, in reality the population is concentrated in the central zone of the city where much of development and socio-economic attractions are. This population density is further exacerbated by expat workers especially in the construction and tourism sectors exerting extra pressures on the city's infrastructure, natural resources, and ecosystem services (Tourism Council of Bhutan, 2016). Records from Ministry of Work and Housing (2008) indicated that around 40% of the population are employed by government while the rest are engaged in the private sector especially in tourism and travel business.

Health Care: Health care is the responsibility of the Government in Bhutan and all citizens and visitors receive free health care. Thimphu city is the home of the national referral hospital, army hospital and an indigenous hospital. Aside from the residents of the city, patients from across the country are referred to the referral hospital in the city. Respiratory diseases' such as common cold, tonsillitis, laryngitis, asthma, pharyngitis, sinusitis, bronchitis, etc., are not common as compared to pregnancy or alcohol related complications and as such air pollution or environmental problems may not be a very significant causative factor for the high percentage of patients in Thimphu. However, light haze layer of air is constantly seen floating low above the city especially during winter months indicating the presence of air pollution. Given the current level of immigration and visitation coupled with increasing number of cars, and the closed nature of the valley, the city needs to prepare for adapting and mitigating air pollution.

Education: The literacy rate of Bhutan stands at 66% with almost 100% primary enrollment across the country (Ministry of Education, 2016). Records with Ministry of Education (MoE, 2016) indicated that there were about 21,531 students attending schools or institutes in 2016. Of this 17,934 are attending school and the remaining 3,597 are engaged in vocational training institutes.

Road Network, Vehicles, and Public Transport: As the oldest city in Bhutan, Thimphu city was not planned for the growth is experiencing now. A total of 78.6 km road in the city is convoluted and is mostly clogged by during rush hours leading to increased emission. Emission is further exacerbated by the increasing vehicle ownership (NSB, 2015). Public transport sector needs significant improvement

to reduce the number of privately owned cars on the road. Future transport also must adopt greener technologies such as electric buses or trains.

Informal settlements: Like any city in the world, Thimphu city has its own share of informal settlements. It is difficult to establish who exactly constitutes this segment of the population because some residents choose to live in poor dwellings despite having reasonable incomes. As they illegally occupy land they are reluctant to improve the buildings and they have no legal right to demand provision of municipal services. Also, people move into and out of poverty in response to shocks such as loss of a job. Sustainable use of environmental resources can help poor communities to break out of the poverty trap. At the same time, poor communities may engage in activities detrimental to the environment and society such as deforestation and poor waste management in order to survive.

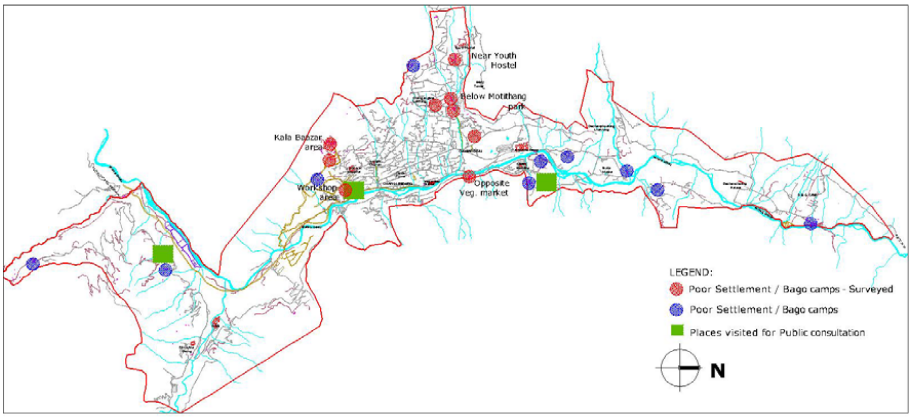

Figure 1. Locations of Slum Areas in Thimphu

Source: Royal Society for the Protection of Nature.

Land Use: Given its topography, availability of land for urban development is a major constraint. As a result, in contravention to the land act (Royal Government of Bhutan, 2007) which forbids conversion of agricultural fields to other land uses, most urban development including expansion of Thimphu city has consumed the gentle valleys which were the bastions of agriculture. Thimphu city consists of a mixture of residential, commercial, light industrial (mostly for automobile workshops), and government buildings with supporting infrastructure such as water, energy supplies, sanitation, and transport. Most of the land currently under cultivation lies in small and isolated pockets along the main river valley. More than 50% of the area is unbuilt, being under forest, agricultural, orchards, water, and vacant. Peripheral areas surrounding the city limits are forested (19%) mostly with conifers (*Pinus, Picea, and Abies* species) with cool broadleaves (*Quercus, populous, willow* species) in certain areas. The second major land use is residential, accounting for nearly 18% of the total area. Land under agricultural use accounts for more than 15% of the area of Thimphu city, and land under orchards (mostly apple orchards) accounts for another 11%.

Water resources: The availability of water in Bhutan is dependent on heavy rainfall, glaciers or snow, and land-use practices and demand. A reduction in the average flow of snow fed rivers and streams combined with an increase in peak flow and sediment yield continues to impact hydropower generation, urban water supply, and agriculture. Overall, Thimphu city receives about 675mm of rainfall (RSPN, 2006). Most rainfalls occur during monsoon seasons and occasional snow during peak winter months of January-February. Drinking water for the city is mostly sourced from springs and streams that emerge from watersheds high in the hills. Water from rivers supplements these sources especially for agriculture purposes.

Water supply by the City Corporation is mostly limited to the core city leaving a major portion of the extended areas relying on rural water supply system and some communities rely on untreated stream water. Water quality is fairly good as they originate from springs from watersheds. However, traces of pollutants in the streams and rivers is a growing concern. Water supply in areas with or without municipal supply lines is one of the priority concerns as communities with municipal lines also feel the supply most certainly could be improved.

Sewerage system: The existing sewerage system of Thimphu City functions completely on the gravity system and covers mainly the core city with one 225mm branch catering to the national referral hospital and the area around it, and the other branch serving the Tashichho Dzong and the ministry offices. The unserved areas mostly rely on private septic tanks and soak pits. The wastewater treatment plant located at Babesa functions on the "waste stabilization pond" principle. This infrastructure is challenged with increasing population and buildings and as such its carrying capacity is already exceeded. Heavy rainfall frequently leads to flooding of these systems. Some areas which are not served by this system discharge their wastes into wasteland or open drains exposing residents to bad odor and diseases.

Solid waste disposal: City Corporation has a system of collecting the solid waste from door-to-door, largely in areas where there is a motorable road access. Where there is no direct road access either there are common bins or the citizens have their own method of disposing the solid waste, either by burning or by burying. The waste is collected in compression trucks and transported to the waste disposal site located on a hill outside the city.

Others: Street lighting currently is limited only to the main roads and the secondary and tertiary roads are excluded from the street lighting system. Recently, the street lights along the Babesa expressway has been upgraded to LED lighting system imported from China and is expected to save energy consumption. Use of such energy saving technologies must be promoted to reduce carbon foot print of Thimphu city. Most of the citizens either have a landline or a mobile phone. Only the economically upper class has personal computers with internet connection and this is mostly concentrated in the core area.

3.2 State of the Urban Environment

Biodiversity: Due to its position at the intersection of two major bio-geographic realms (the Indo-Malayan and the Pale-artic) coupled with elevational variation Bhutan is endowed with rich biodiversity (RGoB, 1995). It is part of the eastern Himalayan biodiversity hotspots and a critical corridor between east and west Asia.

Bhutan's ecosystem boasts of a wide variety of plants, many of which have high conservation significance. There are three main eco-floristic zones: the alpine zone, the temperate zone, and the sub-tropical zone. Towns and cities currently occupy only a small portion of the total land area. Trees and shrubs are planted extensively within urban areas around the country and are an important part of the urban environment. Thimphu city falls in the temperate zone with coniferous forests dominated by blue pine (*Pinus wallichiana*). Riparian vegetation, marshland vegetation, and paddy fields are the dominant types of vegetation within the valley. A number of ornamental plants and trees such as willow, poplar, juniper, *Cryptomeria*, *cupresses* (local and imported species), beech, and hibiscus have been planted along streets, the river, and in open spaces, significantly to the city's appeal. Areas of the city are designated as preserved areas to protect the indigenous flora and fauna.

The forests within and surrounding the city harbor a few wild life species such as, the Himalayan black bear *(Ursus tibetanus)*, sambhar deer (*Cervus unicolor*), tigers (*Panthera tigris*), leopards (*Panthera pardus*), and wild dogs (*Cuon alpinus*). The forested area between Langjophaka and Taba, and along the eastern banks of *Wangchu* act as corridors for bears and leopards. The city valley served as a bird's paradise in the past. Increases in population and reduction in vegetative cover and open spaces has significantly changed the bird populations. Some common bird species that can be spotted within the city currently are choughs, crows, sparrows, doves, pigeons, wagtails, hopoe, and white throated laughing thrushes. Common species found in marshy areas and along the river are black tailed craig, rudy craig, wood snipe, ground diper, and Ibis bill.

Parks and Open Spaces: The Forest and Conservation Act of 1995 prohibits the felling of trees within a 30-meter corridor of the river or any streams to protect the watercourses. This law is not applied within the city limits. The policy of the Thimphu Thromde prohibits any type of construction along the boundaries of rivers and streams in order to have a green buffer zone along the streams and the river. The city currently has only one children's recreational park (Coronation Park), Nature Park (Kuensel Phodrang Nature Park), and the Takin Preserve.

4. General Climatic Conditions

Climate data available in Bhutan only dates back to 1994. Given its variation in elevation, topography, and altitude, in a relatively limited area, Bhutan climate varies from humid and subtropical on the southern plains and the foothills to temperate in the Himalayan valley and alpine in the higher mountains. The climate is hot and humid in the southern foothills, with temperatures ranging from 15^{o} to 30^{o}C throughout the year and precipitation between 2,500mm and 5,550 mm (Wang et al., 2017).

The inner Himalayas, which rise to 3,000m, constitute, with their broad valleys, the economic and cultural heartland of the Kingdom. The inner Himalayas are characterized by a cool temperate climate with annual average precipitation of 1,000 mm. The higher Himalayas constitute the northernmost and highest mountain ranges with elevations up to 7,550m. These northern regions, under perpetual snow, are sparsely populated and have an alpine climate with average annual precipitation of 400mm. Thimphu city is located in the temperate region and enjoys warm summers and cold winter. On average, summer temperature ranges from 15^0C to 30^0C and while in the winter it ranges from 5^0C to 15^0C. It is to be noted that sometimes temperature drops below freezing (upto -10^0C) during some cold winter months. Rainfalls patterns are becoming erratic and unpredictable in recent years with early arrivals, and late withdrawals with heavy rainstorms at times. On average the city receives 500 to 1000 mm rainfall. Heaviest rainfall was recorded in 2002 with the Thimphu river rising up to 3 meters submerging a lot of infrastructure and paddy fields along the river valleys. However, climate change is most noticeable if snowfall and temperature rise are indicators of it.

4.1 Climate Related Threats

Given its topography, narrow range of ecological zones, and steep terrain, Bhutan remains very vulnerable to the impacts of climate change and climate variability. Impacts are manifested mainly in the form of floods, landslides, Glacial Lake Outbursts, forest fires, etc. Thimphu city in particular has been identified by International Institute of Environment and Development (IIED, 2009) as one of the 15 most vulnerable cities to climate change. However, for a variety of factors, there has been no modeling of future climatic conditions for Bhutan let alone Thimphu city. Mountain regions are characterized by complex topography and rapid changes in temperature and precipitation over short distances. There have been few attempts at modelling future climate change conditions in mountain areas because of the costly computing requirements for fine spatial resolution to accurately reflect topography and climatic parameters (IPCC Report, 2007). Regional Circulation Models (RCM), such as PRECIS, have a 50km horizontal resolution and preferably run a 30-year simulation. Inner valley projections over mountainous regions would require much higher resolution (MEA, 2004).

Bhutan falls within IPCC's South Asia sub-continental region which stretches to latitude 50°N. Averaged temperature and precipitation changes are derived from a dataset of 21 global models. For the A1B scenario, the models show a median increase of 3.3°C by 2100, with increases in daily minimum and maximum temperatures. The largest warming will take place at higher altitudes, for example over the Himalayas, as surface albedo will decrease with the melting of snow and ice. A 5% decrease in precipitation is projected in the dry season, and an 11% increase for the rest of the year. In summary, the IPCC climate change projections to 2100 for the South Asia sub-continental region, including Bhutan, consist of the following:

- Increase in average temperatures with relatively warmer weather at higher altitudes and during the dry season;

- Increase in average annual precipitation and with a higher relative increase in the wet season and a decrease in the dry season;
- No conclusive indication of changes in climate variability and occurrence of extreme weather events;
- Continued spatial variation in temperatures and precipitation due to complex local topography.

Floods and landslides: Floods and associated landslides occur annually in the southern and eastern foothills of Bhutan. The monsoon brings torrential rains from June to September, as the clouds originating in the Indian Ocean are blocked from further travelling northward by the Himalayas. The topography of the foothills characterized by steep narrow gorges and river valleys makes them prone to local flash floods of high volume and short duration. Landslides and floods may lead to the unstable formation of natural dams and lakes, which later burst as their structure fails. The south-eastern monsoon floods of the year 2004 affected some 1,500 households, 300 hectares of farmland, and damaged or destroyed 160 houses. The maize, rice and potato crops were lost to the floods in the affected areas, which also washed away 2,000 orange trees. Given Bhutan's population size and cultivated land area, these losses are significant on a national scale. Thimphu city has also been impacted with flooding that has caused economic and human losses. The city experienced its heaviest rainfall in 2002 with Thimphu river rising 3 meters. Flooding has and is continuing to clog the existing storm and sewer drains thereby exposing residents to health risks. Storm drain areas prone to flooding has also been identified and mapped. Heavy rainfall coupled with steep slopes with scanty vegetation leads to frequent landslides in the city. The slides sometimes clog streams and gorges creating artificial dams which causes flooding during heavy rains.

Dry winters and forest fires: Rural livelihoods depend on rain fed agriculture and the timely pattern of seasonal precipitation. Because of its steep topography, windy climate and abundant vegetation cover, the country is naturally prone to forest fires. Fire outbreaks usually occur in the dry winter months from November to April, and have been mainly caused by human behavior (burning of agricultural residues, carelessness, land conversion, and sometimes intentionally by herders to encourage new grass). Thimphu city is located in a conifer-dominated area, which are particularly susceptible to forest fires especially during dry winter months. Recent data on forest fires are not available from the city, but records indicate that the city suffered 9 cases of forest fires from 1978 to 2007 (DoFPS, 2015). Prolonged dryness, change in precipitation, sun-facing location has increased its susceptibility to fires. The effect of observed and predicted climate change on relevant sectors is described in the Table 1 below:

Table 1. Effect of Observed and Predicted Climate Change on Relevant Sectors

Sector	Effects/vulnerabilities
Agriculture	- Crop yield instability/loss of production and quality (due to variable rainfall, temperature, etc.) - Decreased water availability for crop production/Increased risk of extinction of already threatened crop species (traditional crop varieties) - Loss of soil fertility due to top soil erosion and runoff/Loss of fields due to flash floods, landslides and rill & gully formations/Soil nutrient loss through seepage - Crop yield loss (flowers & fruit drop) to hailstorms/Deteriorated produce quality (fruit & vegetables) by untimely incessant heavy rains and hailstorms - Delayed sowing (late rainfall)/Damage to crops by sudden early (paddy) and late spring (potato) frost (ref. seasons shifting) - Outbreak of pests and diseases in the fields and storages where they were previously unknown - Damages to road infrastructures (access and food security)
Natural resources	- Drought in combination with increased lightning risks triggering forest fires - Change in phenological characters of plants/Loss of endemic species - Change in migratory pattern of wildlife - Possible increase of vector-borne disease in wildlife due to warming
Energy	- Temporal & spatial variation in flow, affecting notably electricity production/exports due to disruption of average flows for optimum hydropower generation
Water	- Increased sedimentation of rivers, water reservoirs and distribution network - affecting notably irrigation schemes' productivity/agricultural crop yields - Reduced ability of catchment areas to retain water/increased runoffs with enhanced soil erosion (deterioration of environment) - Deterioration of (drinking) water quality (see also Health sector)
Health	- Loss of life from disasters (e.g. frequent flash floods, GLOF and landslides (recent Trashigang floods and landslides)) - Spread of vector-borne tropical disease (malaria, dengue) into more areas (higher elevations) with warming climate - Loss of safe (drinking) water resources increasing water borne diseases
Infrastructure	- Industrial estates/infrastructures - Human settlements: urban, sub-urban and rural settlements - Historical and cultural monuments: dzongs, monasteries, chortens, etc. Public utilities: roads, bridges, and communications

	-	Public utilities: roads, bridges, and communications
Tourism	-	Reduced aesthetics for enjoyment
	-	Disease outbreaks discouraging tourist from visiting
	-	Damage tourist facilities reducing the capacity of the city to receive tourists

4.2 Non-Climate Related Threats

Urbanization coupled with increasing immigration is putting pressure on the already stressed urban ecosystem which is the source of livelihoods for large number of urban poor. Climate change is further exacerbating these non-climates related threats thereby putting the vulnerable population at greater risk. These threats are described below:

Pressure on natural resources: Thimphu city is located in a narrow river valley surrounded by steep hills which also harbors city's precious water reserves. This limits the size of urbanization to just gentle slopes and flood plains along the river. Rapid urbanization and high immigration is putting additional stress on the carrying capacity of the city's land areas and natural resources including water. Unsustainable use of natural resources by the urban communities especially the vulnerable groups are unintentionally destroying urban ecosystems on which their very livelihoods depends. Deforestation and de-gradation is impacting vital sectors such as water, agriculture, fuel wood availability, etc. Unsustainable use of natural resource has resulted in: i) increased soil erosion/landslide; ii) reduced water infiltration into soils and water quantity and quality; iii) reduced food availability.

Threats causing soil erosion and landslides and reduction in food availability: De-vegetation and ecosystem degradation renders land especially on slopes for soil erosion and landslide as detailed below:

- The vegetation covers of trees, shrubs, and grasses is reduced due to excessive and unsustainable collection of natural resources and the trampling by humans and livestock such as goats. The regenerative capacity of the natural ecosystems is exceeded resulting in a negative cycle of degradation.
- The loss of vegetative cover that regulates infiltration of precipitation especially during rainy seasons exposes soil to direct impact by rain drops. This results in clay dispersion and soil crusting leading to increased run off and soil erosion.
- Reduced amount of root systems in the soil (due to loss of vegetation) allows rain water to penetrate shallow depths which gets quickly evaporated during sunny days. This reduced infiltration coupled with increased run off reduces the ability of the soils to retain water affecting water flows.
- In a mountainous situation like Thimphu city, this situation can lead to devastating landslide including collapse of hill sides especially during heavy rains.
- Landslides can not only damage properties, lives, and agriculture lands, but can form temporary lakes which when bursts lead to catastrophic flood damages downstream.

- Eroded soils and landslides reduce the effectives of hydropower and irrigation projects.
- Poor soils with poor yield coupled with ineffective irrigation system threatens food productivity and security.
- Overall, these threats can further increase the dependence of urban communities on natural resources thereby placing increased pressure on already degraded ecosystems.

Poverty: Urban poverty is increasing the vulnerability of the urban poor to climate change impacts due to limited adaptation capacities. This situation is further exacerbated due to rapid urbanization, immigration, and lack of livelihood opportunities, which forces urban poor to rely heavily of natural resources. Such a situation involving excessive and unsustainable harvesting of natural resources reduces their regenerative capacity. This in turn reduces livelihood sources to urban poor and retains them in poverty.

Limited institutional capacity: Along with Good Governance, Cultural Preservation, and Sustainable Economic Development, Environmental Conservation is one of the four pillars of Bhutan Developmental Philosophy, the Gross National Happiness. This is translated into declaring 51% of the country as national parks and biological corridors with the Constitution of the Kingdom of Bhutan requiring that Bhutan maintain at least 60% of the country under forest cover for all times to come. While ecosystem conservation programs are implemented in the national parks and government reserve forest, urban cities are pretty much left out of these national programs. In particular, there is limited institutional capacity at both national and city levels to implement EbA interventions.

Limited infrastructure: The infrastructure plan of Thimphu Thromde was not built to cope with current level of urbanization and immigration. Although there is a booming real-estate business these houses remain unreachable to majority of the low-income families who resort to semi permeant houses or slums exposing them to natural and man-made disasters including fires. Most of these places also do not have access to proper facilities including roads, electricity, water supply, sanitation, etc. In fact, the sewer lines even in the core of the city are not adequate enough and often floods during rains exposing citizens and visitors alike to health risks.

4.3 Opportunities for Strategic Ecosystem Based Adaptation Responses

Strategic adaptation responses are a pre-requisite to reducing threats and improving social and ecosystem resilience. Ecosystem based Adaptation (EbA) interventions allow the use of biodiversity and ecosystem services to improve socio-ecological resilience to help people adapt better to the adverse effects of climate change (CBD, 2008). Since its introduction into the international policy arena by UNFCCC in 2009 (Colls & Ash, 2009; TNC, 2009) EbA has received increasing acceptance. Stakeholder consultation in Thimphu city to identify preferred solutions to build climate resilience of poor urban communities by catalyzing large-scale implementation of Ecosystem-based Adaptation include building institutional, technical, and individual capacity to plan and implement EbA across urban cities in Bhutan.

Top response identified by stakeholders is to build Institutional, technical, and individual capacity of city management authority and relevant organizations (such as National Environment Commission, Department of Agriculture, Department of Forest and Park Services) including vulnerable communities enhanced to manage ecosystems sustainably under conditions of climate change. Such capacities would allow the city planners and management to use current and past knowledge reinforced by multi-stakeholder discussion to customize and integrate EbA into development planning and management of ecosystems. Such EbA activities will target to protect ecosystems, alleviate poverty, and formalize informal settlements.

Stakeholder consultations also identified potential EbA response interventions such as urban agriculture that would not only improve food security and earn extra incomes, but also improve community vitality and cooperation through self-help group formation. In addition, urban agriculture is expected to improve vegetative cover and soil quality thereby reducing erosion and facilitating infiltration of water. Plantation along riparian/river banks, empty spaces, and in resettlement areas will improve ecosystem services and reduce health problems. Resettlement of vulnerable households from slums will greatly reduce direct contact and pressure on natural resources through income generation, availability of basic facilities, and huge health costs. Relevant sectors such as department of agriculture and department of forest and park services must provide technical backstopping and in kind support (such as crop seeds, tree saplings, green houses, irrigation technology, etc.) to make EbA interventions cost efficient and contribute towards achieving the goal of improving resilience. Research capacity to monitor, evaluate, document best practices, and backstop Thimphu Thromde and its sister Thromdes in scaling up EbA has also been prioritized as a need to make adaptation more efficient and effective.

4.4 Barriers to Implementing EbA Responses

The study also identified some major barriers to achieving the implementation of urban EbA which include:

Lack of capacity to plan and implement EbA: Currently, the city management authority and the government lack adequate capacity to manage ecosystems to successfully adapt to climate change impacts and future climate change risks. Individual staff members have not been trained on EbA and as such are not able to integrate EbA into planning and implementation.

Insufficient funds to implement EbA: Thimphu Thromde has never been financially self-sustainable. Its own revenue collection has always fallen short of the operating and establishment expenditure. Though the revenue deficit in each year is met out of budget (current) support provided by government, the mounting operating losses are matter of great concern. This restrains the Thimphu Thromde from venturing into little known world of EbA.

Limited understanding, research, and public awareness of the benefits of EbA: Current understanding of EbA especially among general public is quite limited. This is attributed to it being a new concept and limited on the ground examples, and resources available for research on EbA. While EbA is gaining grounds especially in urban areas of Europe and Singapore, it is still a relatively new field in

the region not to mention of Bhutan. As such there is no easily available awareness materials such as guide books, planning tools and guidelines, etc. to guide the general public and the decision makers.

5. Conclusion

A search for innovative ways of adapting to climate change at local level is a priority of every researcher, manager, and policy maker. Ecosystem based Adaptation is born of one such a quest and is quickly gaining grounds as a successful tool for integrating ecological concepts into adaptation strategies. This is a win-win strategy with both the ecosystem and society gaining at the same time. EbA provides an excellent opportunity to save our fast degrading cities by revitalizing its ecosystem thereby bringing biodiversity back and enhancing ecosystem services which are vital not just for livelihoods but also for spiritual well-being.

Cities often are full of artificial structures with cars, billboards and giant television sets and city dwellers are the most stressed people on the face of the earth. Yet urban cities are the backbone of many nations providing economic benefits and hence highly populated. However, many cities are not managed properly with no planning thus exposing the city to the slightest risk from nature or man-made hazards such a flooding, landslide, etc. Our study indicates that one group of cities that are neglected from scientific focus are the high-altitude cities which are increasingly threatened by climate change. These cities especially when located in developing countries lack the necessary infrastructure or the technical capacity to deal with climate change impacts. The study found out that while Thimphu city enjoys good quality drinking water from spring sources, the supply is not well managed and not all residents have access to drinking water. In addition, bad road network and poor management of traffic is leading to frustrated drivers and burning extra gas while stuck in traffic jams thereby increasing carbon footprint. Large population of city residents are concentrated in the core of the city, exacerbating pressures on services including ecosystem. As result infrastructures, such as sewer and storm drain systems are often flooded during summer rains exposing the city residents to waterborne diseases. Study also found out that while there is general awareness among the policy makers about the impacts of climate change and disparity in adaptation capabilities amongst the city residents, these have not been translated into plans and strategies. The city residents on the other side are not fully aware of climate related risks with people living in poorer areas remaining in absolute ignorance about the impacts of climate change. To adapt to these climate related threats, the study identified several ecosystems based adaptation options to mitigate these threats and recommended risk aversion pathways that will improve the resilience of urban city as well as that of ecosystem. City authority and policy makers are encouraged to integrate these EbA opportunities into the city development plans across the country. In addition, robust researches to assess vulnerabilities of high altitude land locked cities must be carried out to recommend effective adaptation and mitigation measures that are grounded in ecological and social sciences.

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