Climate change, Sustainable development concerns: North-Eastern Hilly Region, India

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ABSTRACT

Climate change has been a major issue for which many environmentalists, researchers, scientists and professionals directly or indirectly involved with, are working rigorously to understand, delay and minimise the impacts it is creating on human life. The major need for sustainability begins with the rise in global temperature which has created subsequent multifaceted problems. The UN has been working on various protocols to control the temperature change in the climate. But the climate changes are exponentially impacting areas and creating zones of vulnerable. The aim of this paper is to study the vulnerabilities of a hilly terrain to understand the issues that have arisen due to disruption in regular patterns in the climatic conditions. The changes considered over a period of years include livelihood, economic status, geographic conditions, climate, etc.

*Keywords*— *Climate change, Vulnerability, Global warming, environment, economic, socioeconomic aspects*

1. INTRODUCTION

Climate change is a term used to inform the changes in the climate at Global, regional and local contexts. It can be referred as the prevalent average climatic conditions of a place. Climate change includes the patterns of changes in rain, wind, temperature, humidity and precipitation. Climate patterns play a fundamental role in shaping natural ecosystems, and the human economies and cultures that depend on them. But in the past 2000 years, climate change has been progressively changing with disruptive impacts and the past is no longer a reliable predictor of the future. (ecy.wa.gov, 2016). Climate change can be understood as a gradual yet drastic change in the statistical distribution of weather patterns and the change should be observed for at least a few decades to be termed a change. Climate change is the result of factors like variations in the Solar radiation, plate tectonics, volcanic eruptions and biotic processes. But the recent extreme turn of events has also been identified with human activities, often referred to as **global warming**. As many systems are dependent on climate, a change in climate can affect these systems where and how people, plants and animals live, food production, availability of water and health risks. (ecy.wa.gov, 2016)

2. NORTH-EAST REGION, INDIA

In India, North-eastern region consists of a complex geographical terrain which includes mountainous region, eroded plateaus and valleys. The areas are segregated sharply from each other, physically and culturally, yet locational linked, so at some level it has to be treated together. The physiographic complexities of the hilly and plateau areas invited the dangers of annual flooding in the entire stretch of Brahmaputra valley which deters the overall progress. The North-east is a rich agglomeration of different cultural groups. The tribes are densely concentrated in the hills and plateaus. The main activity in the hills being agriculture, economy is based on peasant agriculture. Another economic revenue generation sector is tourism, which is still known as an unexplored paradise. (Ganguly, 1995).

The North East region, consists of eight states covering a geographic area of 26.2 million hectares and stretches between 21°50' and 29°34' N latitude and 85°34' and 97°50' E longitude. Its population is 40 million, with large rural population (82%) and 60% of the area is covered by forests. These seven sister states have many mountain ranges and hills which are home to wide range of flora and fauna. Some of the hilly areas in this region are Lesser Himalaya, Assam Himalaya, The Himalayas, Patakai Range, Lusai Hills, Khasi Hills, Garo Hills, Naga Hills, Jampui Hills, Chino Hills, Manipur Hills and Jantia Hills. It has low population density, having maximum percentage of indigenous tribal communities (34–91%). The region falls under two major river basins one is Brahmaputra and the other Barak. Larger population of this region are dependent on natural resources.
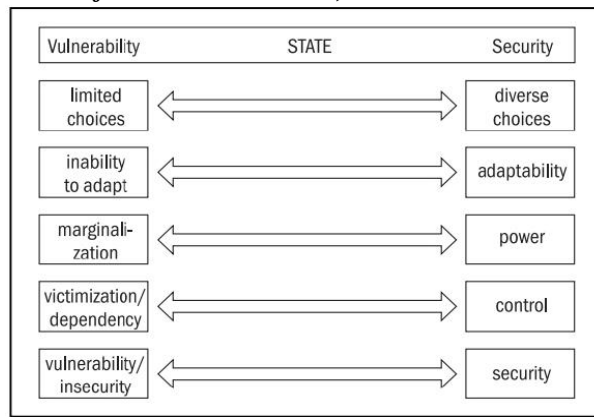
Fig. 1: Vulnerability-security continuum (UNEP,2002)

The region is also characterized by diverse climate conditions which are highly dependent on the southwest monsoon (June–September). Over 60% of the crop area is under rainfed agriculture, and so is in areas highly vulnerable to climate variability and climate change. (Rabindranath, 2011). Northeast India is full of natural beauty, amazing valleys, astonishing waterfalls, dense forest and great hills. The infrastructure development is not very good when compared to other regions of the country.

3. EVIDENCES FOR CLIMATE CHANGE IN NORTH EAST INDIA

Because of its fragility, North East hilly regions in India are prone to the impact of climate change. According to the previous research, the mean annual rainfall in the NE region is 1577 to 6002 mm(Parthasarathy *et al.* ,1995), the mean temperatures are in the range of 5 -30 °C and the mean relative humidity is 70% - 85% for most part of the year (Jhajharia et al. , 2009). It is projected that there will be a substantial decrease in winter rainfall by 2030 compared to 1970 with no additional summer rainfall whereas monsoon rainfall may increase slightly by 5%. (MoEF,2010). These impacts are not explored much when compared to other regions thus increasing the uncertainties of this region (Anup Das et al.,2009). Climate studies on this region indicates that there is no clear trend in rainfall during the season and it keeps on changing every time. The summer monsoon rainfall has been in downward trend in the last century at a rate of 11 mm per decade (Anup Das 2004, Mirza et al.,1998). Meteorology records predicts an increase in temperatures up to 3.5^0C and rainfall increase by 250-500mm in North East region. (Anup Das et al.,2009). Long term temperature data of this region has shown an increase in surface air temperatures and annual mean temperatures by 0.04^0C (Anup Das, 2004). Many regions of Assam state in North Eastern region have faced drought kind of situation during 2005-2006 which may be the result of changes in climate (IPCC,2007a). Precipitation during this period has decreased by 40% in most of the states in the region. Himalayas are retreating at an average rate of 15 meter per year, an impact of climate change. This is consistent with the higher temperatures recorded at the climate stations in Himalayan region for the past 50 years. For example, it is observed that the Gangotri glacier has been receding at a rate of 28 meter per year. This phenomenon may lead to increased water flow during summers and excessive flooding initially for a few decades. The water flow will be reduced after that as the river feeding glaciers recede and disappear from the headstreams.

3.1 Vulnerability

"Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." (IPCC, 2007a). Vulnerability to climate change can be defined as the adverse impacts of climate change on the geophysical, biological and socio-economic systems (Füssel and Klein, 2006). As explained in the United Nations Framework Convention for Climate Change (UNFCCC), vulnerability assessments lead to mitigation and adaptation. "Since, vulnerability and its causes play essential roles in determining impacts, comprehending the dynamics of vulnerability is as important as understanding climate itself" (Handmer et al. 1999). So, understanding the vulnerabilities associated with climate change pertaining to a location is crucial. Key vulnerabilities may be associated with various systems linking to climate sensitivity. Some of the factors of vulnerability are population, land degradation, over dependence on environmental sectors like forestry, agriculture and fisheries, economic condition, health, infrastructure, ecosystems, inequities regarding access to wealth and resources among groups, etc.

3.2 The "Three" Impacted Sectors
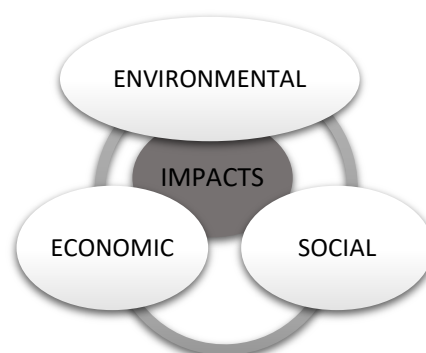
Fig. 2: Three Impacted sectors

Whenever any study, mitigation or development is proposed in terms of sustainable development, three spheres are inter-linked and inter-dependent, based on which, all impacts are assessed and necessary measures are undertaken. Those three spheres are namely, environment, economy and society. If any of it is affected, negatively or positively, the other two if not taken into consideration prior to the implication of changes, are also affected. This is when a planned modification is proposed. But when climate change impacts any of the sectors, catastrophic outcomes prevail due to unprecedented implications of climate.

3.3 The Vulnerabilities
According to Füssel, climate change vulnerabilities of a place are dependent on domains like social-economic factors, technology, natural processes, etc that can be arranged in a matrix as follows:

	Domain	
Sphere	Socioeconomic	Biophysical
Internal	Household income, social networks, access to information	Topography, environmental conditions, land cover
External	National policies, international aid, economic globalization	Severe storms, earthquakes, sea-level change

Table 1: Examples for each of the four categories of vulnerability factors classified according to the dimensions sphere and knowledge domain. Source: [**Füssel 2007**]

3.4 Vulnerability Assessment
The assessment of vulnerability is defined by IPCC in to two streams (i) contextual vulnerability assessment and (ii) the outcome vulnerability assessment. The contextual vulnerability assessment is undertaken with the help of survey and case studies to assesses vulnerability in a constructional approach. Whereas the outcome vulnerability assessment uses quantitative technique such as modelling known as reductionist approach for its assessment. The current method of vulnerability assessment, the index-based approach, is an outcome-based vulnerability measurement.

3.5 Index based approach towards assessing vulnerability
Formal indices are constructed for each of the components of vulnerability. Methods of aggregating the vulnerability have been developed across sectors and scales. Construction of vulnerability index for each sector involves the methodology as below.
1. Identifying and defining the indicators: Indicators are selected according to assumptions, baseline considerations and limitations for each sector.
2. Quantification of indicators: Indicators are quantified based on secondary data sources, observations or measurements and stakeholder perceptions.
3. Normalization: For aggregation purposes, each indicator is normalized to render it as a dimensionless measure or number:

$$S_{i_{normalized}} = \frac{S_i - S_{i_{min}}}{S_{i_{max}} - S_{i_{min}}},$$

Where S_i is the ith indicator value.
4. Principal component analysis (PCA): In this step, we identify the significant indicators and eliminate non-significant indicators from a set of inter-related indicators. It involves a mathematical procedure that transforms a number of possibly correlated indicators into a smaller number of uncorrelated variables called components. Each component is a geometric combination of the indicators. In a PCA, a set of components are extracted using a criterion, whereby eigen value of each component that is extracted is than 1. Generally, indices are created out of an arithmetic and geometric combination of the indicators that are present in the extracted components.

5. Aggregation and categorization: Indicator set for each sector are aggregated with appropriate weights to obtain the vulnerability index,

$$VI = \frac{\sum_i^N K_i S_i}{K_i},$$

Where K_i is the weight assigned for indicator S_i.
VI is normalized further to get a value on a scale of 0-5.

$$VI_{normalized} = 5 \left(\frac{VI - VI_{min}}{VI_{max} - VI_{min}} \right).$$

The normalized vulnerability indices are categorized across vulnerability classes (very low, low, moderate, high and very high). The assignment of vulnerability scales across the index values are as follows:
- Very low: $0 \leq VI_{normalized} < 1$,
- Low: $1 \leq VI_{normalized} < 2$,
- Moderate: $2 \leq VI_{normalized} < 3$,
- High: $3 \leq VI_{normalized} < 4$,
- Very high: $4 \leq VI_{normalized} < 5$.

The method is to have a thorough study upon the main points like water, forest, and agriculture. The method will be as following:

1. Water vulnerability index.
2. Forest vulnerability index
3. Agriculture vulnerability index

3.6 Climate change induced vulnerabilities in NE India and Sustainable development

The impacts of climate change on NE India are not much explored making this area more vulnerable to environment induced risks. Studies on rain fall pattern in this region as a whole indicate that there is no clear rainfall pattern (Anup Das,2004). But in certain areas, there is significant changes in the seasonal rainfall has been observed. Because of climate change and Global warming, Himalayan glaciers are retreating at a rate of 15m per year since 1970s (Anup Das et al.,2009). As a result of increasing surface temperatures, these mountains are expected to melt increasing water flow in to the rivers below. But soon after, there is a danger of these glaciers being disappeared slowly further reducing water flow in to the rivers originating from the Himalayas. As a consequence, water scarcity may be an expected outcome in the rivers like Ganga and Brahmaputra etc. Further the changes in these glaciers may have impacts like altering the hydrological conditions in Brahmaputra river basin, intense rainfall and flash floods etc. in the region. Some of the areas are expected to become rain shadow regions and water scarcity will become a major concern for the people living in those areas. Fragile environmental conditions and not so well economic conditions in NE region become a reason for its vulnerability for climate change impacts. vulnerability towards water and climate induced disasters will make this region environmentally insecure in the future unless strong counter measures are taken up to reduce the impact.

3.7 Environmental Vulnerabilities

Climate Change is causing irregular precipitation patterns due to which the whole agricultural cycle has become unpredictable and ultimately leading to extreme conditions of flood or drought. These occurrences lead to improper agricultural yield and cause major soil erosion. In hilly areas, soil erosion leads to landslides. Landslides in hilly areas result in damages to lives and property. Buildings in the hilly areas are highly prone to landslides when there is excessive rainfall, which in turn claims lives and destruction, leading to road blocks, which ultimately affect infrastructure and pose a setback to the development of the region. Excessive irregular formation of rain in clouds cause cloud bursts which have the capability to destroy property, lives and resources within large chunks of territories. Since impacts of natural catastrophes don't have any boundaries, many a times not just the origin place, but various surrounding areas are also affected by it. The Meghalaya cloud burst of the South Garo Hills in 2014, submerged many villages under water. And the trails could be seen in many parts of Assam, particularly Kamrup and Goalpara districts, where lakhs of people were affected. The downpour of flash flood, which swept through, high as a wall washed away huge vehicles and highway townships on the NH37. (The Indian Express, 2014) In the West Garo Hills, where the damage was maximum, around 80% of a village, which was located near a tributary of the Brahmaputra River, was destroyed and now due to the erosion and silt deposition, the course of the river has changed and it now runs through the village. (PTI, 2016)

3.8 Economic Vulnerabilities

Earlier hilly area houses were made of local materials suitable to the topography. Recent times have seen multi-storeyed R.C.C. constructions in the hills, but without effective measures of building retaining walls; hence due to irregular precipitation patterns, wherein after major rainfall, as monsoon after effect it still keeps drizzling, water seepage to the soil makes the foundation weak and soil erodes, ultimately leading to landslides. Another scenario is, when such buildings are located at higher levels, the habitants in the area staying at lower altitude needs to be evacuated as precautionary measures to minimise risk on life toll. Because when the weather dampens out of monsoon period, it is difficult to even work on the construction and make amendments. The implications of climate change on economy, environment and society are interlinked. Referring to the Meghalaya cloud burst, the devastation caused pulled back progress of the state by 10 years. The progress made over a decade was washed away by 72 hours of severe unprecedented rainfall. (PTI, 2016).

3.9 Socio economic Vulnerabilities

The level of exposure to advancement is always lesser as compared to the central flatlands. When the environment and economy is further destabilised due to climate change, it is even harder to presume the impacts it will have, because it has been a newer phenomenon as compared to natural calamities. Now climate change itself is giving rise to a lot of natural calamities as mentioned in section 4.1, which is affects the economy in the process.

And society being the core of it all, cannot go unaffected and hence receives a back-pull on the path of development. When natural resources are affected, many hill tribe's livelihood gets affected, due to which migration occur, when houses are swept away along with the economy being affected, the social conditions are also hindered. Many people become homeless, lives are lost, and livestock and properties are damaged. In urban hills, network systems are damaged and shut down and curfew like situation prevail.

Northeast India has a great scope of tourism. All these undulations can prove as major vulnerabilities and affect the sector hence bringing down the whole process of development. This is a region filled with ample scope for community based NRM approaches, which can help empowerment of the people. Due to the hilly terrains already, it is difficult to progress at a pace that mainland areas are progressing at. When the unprecedented weather conditions affect it further, the socioeconomic conditions are further held back.

3.10 Forest vulnerabilities

The North East region has about 143,360 sq. km of forests covering around 61% of land area which is one of the highest forests covers in India. Much of the dense forests of Assam, Nagaland and Arunachal Pradesh are part of Himalayan biodiversity hotspot, as per the norms defined by conservation International. For assessing vulnerability of forests, four factors were taken in account which are following:

- Disturbance: it is an indication of disturbance caused by human beings in forests of a specific district. More the disturbance, higher

the forest vulnerability.

- Fragmentation status: it is an indication which shows how the forests of a district are fragmented. More the fragmentation status, higher the forest vulnerability.
- Biological richness: It indicates the diversity species of flora and fauna per unit area in a forest. It is been based on the ecosystem uniqueness, biological value, terrain complexity and disturbance regime. Higher the biological richness, lower the forest vulnerability.

3.11 Water vulnerability
- Water vulnerability shall be assessed for both Brahmaputra and Barak River basins in this region.
- Water Availability: Amount of water available per unit of area. Higher availability shows lower vulnerability.
- Crop water demand (evapotranspiration): This is an indicator of adaptive capacity. The amount of water used by standing crop during the crop growing season per unit area (mm). Higher crop evapotranspiration implies higher yield and lower vulnerability.
- Drought Indicator: This is an indicator for exposure. This is based on weekly soil moisture availability during June- September (monsoon months) used for the assessment of drought severity. Higher the drought indicator, higher the vulnerability.
- Flood discharge: Flood discharge frequency is the number of extremely high stream discharge events and is calculated as the magnitude of flood peaks above 99 th percentile.

3.12 Agricultural vulnerabilities
The pattern of agricultural growth has been uneven across the crops in this region. Food production in rainfed conditions of this region is highly subjective and based on climate variability. Climate change will be an additional stress and will have direct consequences on food production systems and indirect impacts on food security. It is estimated that 305 million hectares is under rainfed rice cultivation in this region, which accounts for 30% of the total area under cultivation. Most of the districts in the North East face problems like fragmented and uneconomical land holdings, lack of proper irrigation facilities, lack of adequate infrastructure and modern agricultural technologies, poor transport and communication system and lack of institutional credit.

3.13 Strategies for mitigating Climate Change vulnerabilities in NE region
In the wake climate change and its impacts are visible in this region, there is a need for assessment of various practices in agriculture and conservation of natural resources. Afforestation programme must be undertaken by the Govt and various other organizations including NGOs. Some of the resource conserving interventions suitable for the region are-
- Agricultural practices which conserves natural resources should be given importance
- For improving hydrology, planting of multipurpose trees and multipurpose crops have to be encouraged.
- For maintaining the soil condition well, recycling of nutrients and integration of animal and fishing industries agricultural practices has to be encouraged.
- Rain water harvesting systems have to be encouraged well.
- Degraded lands have to be restored for the conservation of moisture in soil
- Alternative crop varieties have to be encouraged as per the changes in the pattern in rainy seasons.
- For improving the economic conditions of the people, employment opportunities have to be created.
- Alternative means of livelihood has to be promoted among the people to reduce the cultivation types which are deteriorating the air quality.
- Training and awareness programs have to be conducted about better water policies, cultivation methods for improving the quality of water and soil.
- Setting up of more public sector organizations can reduce the unemployment and thereby increasing the quality of life.

4. CONCLUSIONS
Hilly areas are climatologically very vulnerable and face hindrances in development, impacting environment, economy and society. Measures have to be taken at the planning level focussing on the overall development of the region. Hill town planning laws should be properly implemented. Integrated watershed management programme (IWMP) is another approach which on maintaining ecological balance along with focus on livelihood generation and social and infrastructural development and the new way is to integrate planning of hill town areas around watershed management techniques. As water is not a stagnant element and it flows from higher to lower levels it can be said that the result or impact of the vulnerabilities faces by the urbanised hilly areas is not restricted to the geographic boundary of those areas and in fact affects the low-lying plain areas also. Technology can be used in mitigating the impacts of climate change. Artificial intelligence is one such technology can be used to track and tackle the climate change in the following ways:
- Machine learning is being used for improved grid networks that are more predictable and efficient, and the use of renewable energy.
- Smart sensors and metres can be used to gather real time data and to track, analyse, and optimise natural resources.
- Machine learning algorithms are now being used in smart transportation, such as Google Maps and Waze, to improve routing, enhance protection, and provide knowledge about geographical aspects of the terrain.

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