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Inequality and Autonomous Adaptation to Climate Change

National Institute of Advanced Studies

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Inequality and Autonomous Adaptation to Climate Change

Abstract

This note intends to pave a conceptual and methodological frame for an inaugural multidisciplinary scholarship on the inequality and autonomous adaptation to climate change in the Indian scenario. It begins with providing a brief background on climate change responses and uncovers the disconnect in the existing climate change knowledge in social sciences. It argues that the knowledge on climate change in social sciences-especially on inequality, vulnerability, and adaptation, lacks the discourses from the ground. This disconnect perhaps take a toll on the existing adaptation policies. Therefore, it argues that the intuitive and spontaneous responses of people and communities towards coping and adapting to climate change known as autonomous adaptation has potential scope for improving the adequate and equitable resilience policies and 'governances of adaptation' in the regime of climate change. It also raises the need for shifting our attention and scholarly engagements towards investigating autonomous adaptation to climate change as potential scope for bridging the existing disconnect in climate change knowledge. It further presents the geographical locations in India which are more exposed towards the effects of climate change as an appropriate site for ethnographic inquiry on the process and other dynamics of autonomous adaptation. Besides, it draws the theoretical and methodological approaches emerging in different disciplines in social sciences such as economics, political science and anthropology to move forward to study both inequality and autonomous adaptation to climate change.

Introduction

Inequality has become a persistent theme in the climate change discourse in social sciences. It is now recognized that 'climate change and inequality are inescapably linked both in terms of who contributes to climate change and who suffers the consequences'.[1] In this aspect of inequality of climate change, which is widely referred to as 'carbon inequality',[2] developed countries by their level of consumption contribute more to climate change and the developing and less developed countries too often face the difficulties of the crisis.[3] In addition to rising carbon inequality on a global scale, climate change also exacerbates inequalities that exist within the country, at a regional or local level. While climate change affects everyone irrespective of their social and economic status, it widens existing inequalities and produces more vulnerabilities. The poor and disadvantaged populations often find climate change has added new challenges in their everyday life in the form of livelihood crises, resource scarcity, homelessness, and health hazards. Skoufian noted that climate change impacts 'tend to be regressive, falling more heavily on the poor than the rich'.[4] The Intergovernmental Panel for Climate Change (IPCC), has stated that the socially and economically disadvantaged and marginalized people- small farmers, coastal communities, and native people are disproportionately affected by climate change.[5]

A somewhat less discussed difference, with its implications for inequality, is in the realm of knowledge. There is a growing disconnect between the official discourse on climate change and the discourse that determines the local responses to it. The official discourse relates to a variety of aspects of policy. These range from strategies to control the extent of climate change, to reduce its adverse effects and to determine the distribution of the costs of these actions between nations. The local response, and the inevitable local discourse around it, is more concerned with the strategies to adjust to changing climate, ranging from modifying cropping patterns to migration to areas less adversely affected by climate change. Given the distance between the larger debates on climate change and local knowledge, it is important to explore how local communities understand and address the changing climate that they are forced to deal with on their own, or what has been termed autonomous adaptation.

This note aims to lay out the broad parameters of such an exploration, identifying the conceptual issues involved, the most effective methodologies, and the locations that are likely to provide the best insights into that process. It will begin with a brief background of the nature of climate change and provide a brief history of climate change response on the global level, particularly the engagements of IPCC. It will go on to discuss a case to study autonomous adaptation. Then it will peek into the regional dimension of different effects of climate change in India while identifying particular locations with higher exposure to multiple climatic events. In the end, it will then define an appropriate methodology- the multidisciplinary approach to study climate change response.

The Backdrop

Climate is 'average weather or the statistical description of the mean and variability of meteorological quantities over a long period'.[6] The unprecedented shifts or the frequent variations of average weather in a specific location, region, or planet is generally called climate change. Climate Change is defined as, 'a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (decades or longer)'.[7] The Physical Science basis of climate change is explained through the concept of Earth's 'energy budget'.[8] The Earth partially absorbs the radiation it receives from the Sun and re-radiates the remaining back into space. Some gases present in the atmosphere absorb these radiations and re-radiate them into the atmosphere, thus making the earth's surface and lower atmosphere warmer. This process of trapping heat on the earth is called the 'Greenhouse Effect'. The gases which enable the greenhouse effect include water vapor, carbon dioxide, methane, CFCs, ozone, etc., and are referred to as Greenhouse Gases (GHGs). The natural Greenhouse Effect makes the earth habitable; without this, the earth would have been much colder.[9]

Any alteration in the aforesaid mechanics of earth's climate system, that is any change in the radiation received from the Sun or lost to space or any change in the redistribution of energy within the atmosphere, and between the atmosphere, land, and ocean, affects climate. This alteration could be caused due to natural factors or anthropogenic (human-induced) factors. The natural causes could be changes in the sun's intensity, volcanic eruptions, changes in naturally occurring greenhouse gas concentrations, variations in the earth's orbit, and so on. Earth has gone through warm and cool phases in the past, much before human existence. However, these changes took place over a long period. Climate change has been much faster since the beginning of industrialization. Such fast change cannot be explained by natural causes and so anthropogenic factors need to be analyzed. The human-induced changes in climate, widely referred to as anthropogenic climate change or Anthropocene climate change, have caused a drastic transformation of climatic balance on the planet.[10]

Greenhouse gas emissions generated by human beings are found to be the leading cause of climate change. Concentrations of carbon dioxide, methane, and nitrous oxides have increased to unprecedented amounts in recent decades. The atmosphere's share of carbon dioxide has risen by 40 percent since preindustrial times. It is estimated that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in GHG concentrations and other anthropogenic forces. Sources of such anthropogenic emissions include burning of fossil fuels (coal, oil, gas for electricity, heat, and transportation), deforestation and other forms of forest degradation, fertilizer use (emitting N2O), livestock production (emitting CH4), certain industrial processes (emitting fluorinated gases), agriculture, road construction (affecting reflectivity of earth's surface) and so on. Earth has natural carbon sinks (forests, oceans) but it can't keep up with such a high rise in emissions.

The terms 'Climate Change' and 'Global Warming' are often used interchangeably, but global warming is only one aspect of climate change. Global warming is the long-term heating of Earth's climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities and is measured as the average increase in Earth's global surface temperature.[11] Climate change encompasses global warming, but it refers to the wider changes happening on the planet, like rising sea levels, accelerating ice melt, shrinking mountain glaciers, and shifts in flower/plant blooming times. While a lot of these changes are caused by global warming, climate change includes changes caused not only by shifts in temperature but also by precipitation and wind patterns. Climate change transforms global systems, thus affecting everything including land, water, and air. According to IPCC climate change has an impact on (1) types of terrestrial and aquatic ecosystems (deserts, mountain ecosystems, coastal ecosystems, forests, rangelands, oceans, lakes, streams and wetlands, cryosphere); (2) Hydrology and water resources; (3) Food and fiber (agriculture, forest products, fisheries); (4) Human infrastructure; and (5) Human health.[12] To understand this impact it is important to study some crucial climate change parameters.

Climate change indicators are required to demonstrate the range and pace of climate change. Some of the indicators are changes in global and regional surface temperature, atmospheric water vapor, greenhouse gases concentration, precipitation, cryosphere (glaciers, ice), sea-level changes, ocean acidification, changes in land use/vegetation, changes in frequency and severity in extreme weather conditions such as hurricanes, heatwaves, wildfires, droughts, floods, etc.[13] Different organizations have enlisted different sets of climate change indicators, and hence the above list is not exhaustive. The US Environmental Protection Agency has categorized indicators into six broader categories: indicators of greenhouse gases, weather and climate, oceans, snow and ice, health and society, and ecosystems.[14]

Climate change has diverse manifestations on the planet. It alters the physical geography and threatens the existence of biodiversity. 'Humans and animals face new challenges for survival because of climate change. More frequent and intense drought, storms, heatwaves, rising sea levels, melting glaciers and warming oceans can directly harm animals, destroy the places they live, and wreak havoc on people's livelihoods and communities.'[15] Thus, climate change has been considered as the 'biggest threat that modern humans have ever faced.'[16]

Climatologists had observed the signs of anthropogenic climate change and its negative impacts on the planet at the beginning of the twentieth century.[17] However, serious efforts to understand the growing issues of anthropogenic aspects of climate change have increased since the late 1970s. The first World Climate Conference convened by World Meteorological Organization (WMO) in collaboration with various organizations associated with the United Nations, held in Geneva in 1979, the establishment of World Climate Program, an outcome of the first World Climate Conference, the Villach Conference in 1985 and the SCOPE 29 report on 'the Greenhouse Effect, Climatic Change and Ecosystems' published in 1986, the world conference on the Changing Atmosphere: Implications for Global securities, also known as the Toronto conference held in Toronto, Canada in 1988 have inevitably led to the formation of the IPCC in 1988 jointly by the WMO and the United Nations Environment Program (UNEP).[18] The IPCC was formed 'with the mandate to assess scientific information related to climate change, to evaluate the environmental and socio-economic consequences of climate change, and to formulate realistic response strategies.'[19] The scientific engagements of IPCC accelerated the scientific and political concerns on the climate change issues globally since 1990.

The IPCC published its first assessment report in 1990. The report provided rigorous scientific knowledge and presented data on global warming, greenhouse gases, and its effects, sea-level changes, the effects of climate change on the ecosystem, and the history of changing climate on the planet.[20] It paved the foundation for scientific, political, and economic discussions and negotiations that later contributed to international climate policymaking. The first IPCC Assessment Report concluded that 'continued accumulation of anthropogenic greenhouse gases in the atmosphere would lead to climate change whose rate and magnitude was likely to have important impacts on natural and human systems'.[21] The report played a key role in the creation of the United Nations Framework Convention on Climate Change (UNFCCC), an important international treaty against climate change. The UNFCCC was created at the United Nations Conference on Environment and Development (UNCED) also known as Earth Summit, held in Rio de Janeiro in 1992. Ever since the creation of UNFCCC, it has played a major and indispensable role in achieving a global consensus- both political and social, on climate change.

The Second Assessment Report (SAR) of the IPCC was submitted in 1995. The SAR provided the scientific basis for framing the Kyoto Protocol, which was adopted in 1997. The Third Assessment Report (TAR) of IPCC, submitted in 2001, raised the question of 'how vulnerable are agriculture, water supply, ecosystems, coastal infrastructure, and human health to different levels of change in climate and sea level? What is the technical, economic, and market potential of options to adapt to climate change or reduce emissions of the gases that influence climate?'[22] The Fourth Assessment Report (AR4) of the IPCC, submitted in 2007, 'illustrates the impacts of global warming already underway and to be expected in future, and describes the potential for adaptation of society to reduce its vulnerability; finally, it presents an analysis of costs, policies, and technologies intended to limit the extent of future changes in the climate system'.[23]

The Fifth Assessment Report (AR5) of the IPCC was finalized between 2013 and 2014. The AR5 contains a more comprehensive assessment of climate change. It laid the scientific foundation for the Paris Agreement, a legally binding international treaty on climate change, aiming to limit global warming to well below 2, preferably to 1.5 degrees Celsius, which was adopted by 196 countries at COP 21 in 2015 and entered into force on 4th November 2016. The IPCC has finalized the Working Group 1 contribution of the Sixth Assessment Report (AR6) on 6th August 2021. The Working Group 1 report presented updated scientific knowledge on three important fields of climate change discourses. It updated the status of the present climate and its possible futures on the planet and life. It provides climate information for risk assessment and regional adaptation, and a new strategy for limiting climate change.

The report says that 'global surface temperature is now higher by 1.07°C since that pre-industrial era'[24] and 'human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5'.[25] The report also 'expectedly project an increase in climate extremes due to global warming, with heatwaves, extreme rainfall events, and occurrence of extreme sea levels all expected to intensify and be more frequent'.[26] The report also underlined that extreme and unpredictable climate change events are already happening and they will be increasing in the future in South Asia and India specifically. The report further emphasized the need for adaptation strategies in addition to mitigation within our communities, both large and small, to limit climate change and reduce the climate change vulnerabilities.

The case for Autonomous Adaptation

Adaptation and mitigation have been considered the two measures in the climate change resilience policies.[27] IPCC 2014 defines mitigation as 'a human intervention to reduce the sources of greenhouse gases or enhance the sinks (those processes, activities, or mechanisms that remove greenhouse gas from the atmosphere) and adaptation as the process of adjusting to actual or expected climate and its effects'. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to the expected climate and its effects.[28] In the early years, the climate change response policies were given more emphasis on mitigation, but later it is observed that the mitigation can't alone bring radical transformation in the growing issues of climate change. Thus, adequate adaptation policies came to the fore in climate change responses.[29]

The IPCC report says that 'building adaptive capacity is crucial for effective selection and implementation of adaptation options'.[30] 'Adaptation planning and implementation can be enhanced through complementary actions across levels, from individuals to governments'.[31] It further observed that the 'indigenous, local and traditional knowledge systems and practices, including indigenous peoples' holistic view of community and environment, are a major resource for adapting to climate change, but these have not been used consistently in existing adaptation efforts. Integrating such forms of knowledge with existing practices increases the effectiveness of adaptation'.[32] Indeed, the adaptation, on an individual and collective level, against climate change also happens naturally. Primarily because human beings have the inherent capacity to adapt to the challenging environment.[33]

In the present anthropogenic climate change, adaptation exists in three major categories. Primarily the 'state-driven planned adaptation policies are playing a key role in reducing the climate change crisis across the world. The international agencies, various treaties, and the governments across the countries are the actors in implementing these state-driven adaptation policies. Secondly, the non-state involvement in climate change adaptation also plays a remarkable role'.[34] The non-state response to climate change happens at different levels. The civil societies, NGOs, academics, activists, communities, industries, and individuals do engage with planning and execution of short term and long term, but planned adaptation strategies become quite common in climate change scenarios. The role of these non-state actors who largely contribute to planning and implementing adaptation strategies are widely recommended in the IPCC assessment reports,[35] and the Paris Agreement has emphasized the same. The third category is that the people and communities who suffer the challenges of climate change may themselves tend to cope and adapt to the situation in more spontaneous ways, which is collectively termed as 'autonomous adaptation'.[36]

In practice the third category has tended to get less attention than it deserves. The gap in the knowledge about climate change between the intellectual elite and the communities that are forced to respond to the effects of this change can be quite wide. Many of those affected by climate change reside in relatively remote rural areas with limited knowledge of the still growing science of climate change. Yet as those worst affected by the phenomenon they cannot wait for the knowledge to trickle down to them. Instead, they have to respond on the basis of what they believe to be the correct response.

When considering the differences, bordering on inequality, between knowledge at the global and national levels, and local knowledge that drives local responses, there is a need to pay greater attention to the local, or autonomous adaptation. Whether these responses are in fact the best possible ones are not beyond debate. It is possible that local knowledge generates original responses that can later be validated by more scientific study, but it is possible for the opposite to also happen. It is thus imperative to examine the nature of such autonomous adaptation; to identify and understand the nature of these responses.

The IPCC fourth assessment report,[37] distinguishes between 'planned adaptation,' which results from deliberate interventions, and 'autonomous (or spontaneous) adaptation,' which is 'adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems.' According to this definition, autonomous adaptation might include practices such as altering agricultural inputs, diversification of livelihood, changing crops, changing property and land rights, use of innovation and new technologies, migration, changes in land-use patterns, altering cropping cycles, diversifying economic activities, etc. However, the scope and ability of spontaneous adaptation practices are rooted in a community's culture, tacit knowledge base, leadership, innovations, collective action, and experiential learning that are mediated by individuals and local institutions.[38] Studies have also classified autonomous adaptation into two categories: proactive adaptation strategies which include anticipating, precautionary, and change, and reactive adaptation strategies which include ad hoc, retrofitting, or perspective.[39]

The need for greater attention to be paid to autonomous adaptation also stems from the diverse manifestations of climate change in different local communities. Extreme weather produces multiple vulnerabilities, including livelihood crises, crop damage, agricultural issues, resource shortage, infrastructure issues, homelessness, mental and physical health issues, unemployment, and financial debt. Climate change tends to produce more threats and vulnerabilities to communities that have already been suffering social and economic inequalities, particularly indigenous communities, farming communities, fisherfolk, and slum dwellers. It also contributes to widening the category of the disadvantaged by its ability to force more people and communities into the category of disadvantaged and pushing more people and communities to the margins. Climate change threats also unequally affect people across class, caste, age, and gender differences. Jouni Paavola observed how inequalities have been prevailing when climate change impacts the health of the people in general.[40] Paavola argued that the 'health impact of climate change will not be the same for all because of the differential exposure, sensitivity, and the adaptive capacity of individuals and groups'.[41] Many of the coping and adapting strategies towards the threats of climate change available to the rich may not be affordable to the poor.[42] Similarly, gender and age are also often interlinked with the inequality discourses of climate change in social science.[43] To cite a term used by the IPCC, climate change is a 'threat multiplier'.[44]

Autonomous adaptation begins as a spontaneous response to a climate event to reduce the risks and vulnerabilities. Individuals and communities, depending on the sources and abilities they have, tend to use different strategies to cope and adapt to challenging situations. In most cases, the first response against these threats takes place in the ground itself. Local people use their individual or collective skills and experience to produce knowledge, networks, and strategies to reduce the risks of climate change. These strategies may also tend to diffuse from one person to another or one culture or society to another without any involvement of government or other established agencies. For example, when climate change produces crop failure in an area, people themselves tend to change the crops or the patterns, and people in other areas too tend to copy the adaptation strategy from them. There has also been some recognition that non-state responses – specifically 'autonomous adaptation', the 'action undertaken by the people without planned intervention'[45] – could be considered and supplemented with the planned forms of adaptation,[46] especially in developing countries.[47]

Autonomous adaptation may be a spontaneous response of local communities towards reducing the consequences of climate change, but it is a complex phenomenon involving a variety of strategies, techniques, and roles of actors. This complexity also varies across the socio-cultural, economic, and geographical dynamics. With around half the workers in India being dependent on agriculture, either as cultivators or as agricultural labor, there is a widespread sensitivity to droughts, floods, and other elements of climate change. A warming of the sea changes the patterns of marine life and the availability of resources for the fishing community. There are also issues of reaching out to those who are affected, especially the Adivasis who account for 8.61 percent of the population and are not always fully integrated with the mainstream. This complexity demands the attention of researchers, especially in social sciences, to explore how people and communities across diverse geographical, social, cultural, and political settings respond and prepare autonomous adaptation strategies against the climate change vulnerabilities. It is also important to observe and understand how the different forms of existing inequalities in society are reflected at the various levels and stages of the autonomous adaptation process. The output of those scientific engagements can contribute to framing adequate climate change adaptation policies and also strengthening the 'governance of adaptation'.[48] It is also important that the investigation on these aspects of inequality, and autonomous adaptation of climate change demands the conceptual and methodological contributions of different disciplines in social science.

Autonomous adaptation is an individual or a collective local agency to cope and resist towards climate change threats. Many social, cultural, political, and economic factors closely and directly determine the capacity of autonomous adaptation of people and communities. The community response portfolio towards impacts of climate change may include both short term and long-term responses[49] and it also adheres to the fact that certain events which might be larger in scope and scale which pose an indirect/direct impact on a community might not even gain the same response that few other climate hazards which trigger the subconscious climate response. Therefore, it is important to understand the adaptive capacity of the population, to estimate the vulnerability and the exacerbation of the inequality caused by climate change. However, the existing discourses and knowledge on the social impact of climate change are ignored or did not recognize the significance and the agency of autonomous adaptation in the Indian scenario. As an inaugural move towards conceptualizing the methodological as well as a theoretical frame for studying the autonomous adaptation process in the Indian scenario, in the following section, we attempted to map the most climate change-affected regions in India. The parameters for identification of the most climate change-affected regions are taken strictly based on the scope for studying the autonomous adaptation. Therefore, more importance is given to long-term climate change effects like rainfall and temperature variability than just looking at extreme weather events which are isolated events like 24-hour heavy rainfall events. The following section initially presents an overview of observed and predicted changes in key climatic parameters in the Indian context, then will eventually venture into the elaborate analysis to map down to the locations in India highly exposed to multiple climate change indicators.

Observed impacts of climate change in India

Key climate change indicators deemed most pertinent to the Indian region (including Indian land area and the surrounding ocean) by a compiled report by the Ministry of Earth Sciences (MoES) include Warming over India and the Indian Ocean, Monsoon Precipitation, Droughts and Floods, Sea-level rise in the North Indian Ocean, Tropical Cyclonic Storms, and the Himalayan Cryosphere.[50] The key climate-related observed and projected hazards to look out for in Asia as reported by IPCC include rising average temperatures, more frequent extreme temperatures, changing rainfall patterns (temporally and spatially), a projected increase in the frequency of various extreme events (heatwave, floods, and droughts) and sea-level rise.[51]

While human-induced climate change has a severe impact on all aspects of life on Earth, the increasing heat extremes and changing monsoon patterns pose a threat to the lives, livelihoods, infrastructure, and health of people and communities in many regions of India. Climate variations like variation in monsoon have an enormous socioeconomic impact in tropical regions, particularly in India and neighboring countries.[52] Future predictions for the regional climate in the Indian region made under different climate change scenarios indicate strong changes in the mean, variability, and extremes of some key climatic parameters including land temperature and precipitation, monsoons, tropical cyclones, Indian Ocean temperature, and sea level, and the Himalayan cryosphere.[53] The Indian region is also found to be prone to climate extremes and severe weather events including floods, droughts, heatwaves, tropical cyclones, thunderstorms, etc. Therefore, it is of great importance to understand the changes in extreme weather events for better adaptation and disaster management practices.[54]

To understand and adopt climate change adaptation and mitigation measures, it is important to have a comprehensive knowledge of the observed climate variability and change. Knowledge of specific climate change-related scientific observations and the implications of changes in climatic parameters singularly and collectively will help inform and shape relevant responses to regional climate change issues. In tracing the specific effects of climate change the focus is typically on two major sets of changes: temperature and rainfall.

Temperature

The impact of climate change on temperature has several dimensions. The main effect of climate change is, arguably, a significant change in surface air temperatures, both increases and decreases. The sustained increase in temperatures can at times lead to an increase in the frequency of heatwaves.

Changes in Surface Air Temperature

The climate summary of India 2015 suggests that there has been a significant positive trend over most parts of the country between the period of 1901-2015 in the mean annual temperature anomalies and the positive trend ranged between 0.5^0 c to 1.5^0 c at 95% significance level.[55] The IITM-ESM historical simulation finds that from 1901 to 2018, the average temperature of India has risen by around 0.7°C. This rise has been attributed to GHG-induced warming, anthropogenic aerosols, and changes in land use and land cover. In the thirty years from 1986 to 2015, the temperature of the warmest day has risen by about 0.63°C and that of the coldest night has risen by around 0.4°C.[56] A larger pattern of warming has been observed over the North and Northwest parts of India during 1951-2014.[57]

Changing temperature patterns are observed through a study of trends in maximum, minimum, and mean temperatures both annually and seasonally. Seasonal division for temperature is winter (January-February), pre-monsoon (March-April-May), monsoon (June-July-August-September), and post-monsoon (October-November-December). The annual mean, maximum, and minimum temperatures averaged over India during 1986–2015 show a significant warming trend of 0.15 °C, 0.15 °C, and 0.13 °C per decade, respectively (high confidence). Pre-monsoon temperatures displayed the highest warming trend followed by post-monsoon and monsoon seasons. Also, the frequency of warm extremes over India has increased during 1951–2015, with accelerated warming trends during the recent 30-year period 1986–2015 (high confidence).[58]

A study of the changing temperature patterns during 1985-2015 over the agro-climatic zones of India found a significant increase in annual maximum temperatures in India has taken place in parts of northern states of (erstwhile) Jammu and Kashmir, Himachal Pradesh, and Uttarakhand, in all North-eastern states, in Eastern states of Odisha, Jharkhand, and Chhattisgarh, in Maharashtra in the West, and parts of Southern states of Karnataka, Telangana, Andhra Pradesh, Kerala, and Tamil Nadu. Significant reduction in maximum temperatures has taken place in parts of Rajasthan, Uttar Pradesh, and Tamil Nadu. A significant rise in annual minimum temperatures is seen in most parts of the Northern and Central states, in the Eastern States of Bihar, West Bengal, and Sikkim, and parts of Southern states of Karnataka, Kerala, and Tamil Nadu.

Heatwaves

Rising extreme temperatures also lead to an increase in heat waves. A Heat Wave (HW) represents the rise of maximum temperature at a given place by a certain amount from its climatological value.[59] Heat Waves in India are usually observed during March to July, with extreme events mostly observed in the middle of this period, i.e., during the hot weather season from April to June (AMJ). Abnormally high-temperature events have a severe effect on the human body in terms of physiological stress. Thermal stress affects human mortality, and during unusually hot or cold wave episodes, deaths increase significantly.[60] An analysis of deaths due to heatwaves in India during the period 1971-2010 revealed that the number of deaths was the highest between 2001-2010 compared to previous decades.[61]

Temperature change projections for India[62] suggest that average temperatures over India will rise by approximately 4.4°C by the end of the twenty-first century (relative to the 1976-2005 average temperature). At that time, the temperature of the warmest day is projected to rise by 4.7°C approximately and that of the coldest night is projected to rise by 5.5°C approximately. It is projected that the frequencies of warm days and warm nights will increase by 55% and 70%, respectively. In effect of rising temperatures and the increasing frequencies of warm days and nights, the frequency of summer (April to June) heatwaves and their average duration are also projected to increase. By the end of the twenty-first century, heatwave frequencies are expected to be three to four times higher compared to the 1976-2005 reference period. The average heatwave event duration is also projected to approximately double. Amplification of heat stress due to a rise in surface temperature and humidity is expected all over India, but specifically over the Indo-Gangetic and Indus River basins.[63]

Except for Northeast India and large parts of Peninsular India, most parts of the country have experienced an average of two HW days per AMJ season from 1961-2010. This region has been referred to as the "core HW zone"[64], or CHZ, and it includes the states of Punjab, Himachal Pradesh, Uttarakhand, Delhi, Haryana, Rajasthan, Uttar Pradesh, Gujarat, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, West Bengal, Odisha, and Telangana, and the meteorological subdivisions of Marathwada, Vidarbha, Madhya Maharashtra, and coastal Andhra Pradesh. It is found that the two decades 2001–2010 and 2011–2016 marked the beginning of an even warmer global climate. A study of HW during 2010-16 reveals the most frequent HW in Jammu and Kashmir, Himachal Pradesh, Punjab, West Rajasthan, East Rajasthan, East UP, West UP, East MP, West MP, Vidarbha, Odisha, and Coastal Andhra Pradesh. In addition to this, entire Rayalaseema and some parts of Karnataka and Tamil Nadu, the areas that showed no or very few heatwave events in the previous decades experienced HW during 2010-16.[65]

Rainfall

Alongside changes in temperature, major transformations in patterns of rainfall are seen as another major consequence of climate change. The change in climate can cause either an increase or a decrease in rainfall. The increase in rainfall can at times lead to extreme rainfall events as well as floods. The long-term decrease in rainfall can contribute to sustained droughts. In addition, there are episodic extreme climate related events in the form of cyclones.

Changing Rainfall Patterns

Global warming has a direct influence on precipitation. Monsoon rains occur through complex interactions between land, ocean, and atmosphere, and so changing rainfall patterns are an important indicator of changing climate. The Indian summer monsoon forms an important component of the global climate. Changing rainfall patterns are studied both on annual and seasonal levels. The seasons for which rainfall patterns are studied include pre-monsoon (MAM), monsoon (JJAS), post-monsoon (OND), and winter (JF). While most of India receives a major share of its annual rainfall during the summer monsoon (also called the Southwest monsoon), a part of India also depends on the Northeast monsoon in the post-monsoon period, and the western Himalayas receive a significant amount of precipitation due to the Western Disturbances during winter and early spring period.[66] Summer monsoon (JJAS) contributes about seventy percent of annual mean rainfall in India and is the backbone of the Indian economy as it plays a crucial role for the sectors like agriculture, water resources, and power management. Changes in the monsoon rainfall thus have far-reaching impacts.

The summer monsoon precipitation (June to September) over India has declined by around 6% from 1951 to 2015, with significant decreases over the Indo-Gangetic Plains and the Western Ghats. There has been observed a decrease in summer monsoon precipitation over Central India during 1951–2014. A north-south pattern of monsoon rainfall decreases over Central India and an increase over the equatorial Indian Ocean has also been observed. This observed weakening of the southwest summer monsoon post-1950s has been attributed to anthropogenic aerosol forcing, regional land use, land cover changes as well as rapid warming of the equatorial Indian Ocean sea surface temperature (SST).[67] It is projected by climate change model CMIP5 that the mean and variability of monsoon precipitation, as well as daily precipitation extremes, will increase by the end of the twenty-first century[68] Based on high-resolution gridded data for 1901–2015, statistically significant decreasing trends were found in annual as well as seasonal rainfall over Kerala, the Western Ghats, and some parts of central India including Uttar Pradesh, Madhya Pradesh, and Chhattisgarh as well as some parts of the northeastern states. Whereas rainfall over Gujarat, Konkan coast, Goa, Jammu and Kashmir, and east coast shows a significant increasing trend.[69]

Extreme Rainfall Events

While the trend in the annual, as well as the summer monsoon, mean rainfall during 1951–2015, has been decreasing, at the same time, locally the frequency of heavy rain occurrences over India has increased.[70] For the period 1901-2010, there is a decrease in frequencies of lower intensity rainfall and an increase in higher intensities (heavy to very heavy rainfall) during the southwest monsoon season over most parts of India.[71] The All India Summer Monsoon Rain (AISMR) for the period 1871-1993 has seen a significant decreasing trend over central and major parts of North India for annual frequency of rain, rainy and heavy rainfall days, and increasing trends over Peninsular India for annual frequency of rain, rainy and heavy rainfall days.[72] The findings also indicate that generally, the area coverage of very heavy rainfall events is more during the recent 55 years (1961-2015) compared to 6 decades before that. The decline in SM rainfall from 1990 (to 2015) is associated with a decrease in the frequency of wet days, an increase in the frequency of dry days, a decrease in the frequency of little, moderate rainfall days, and an increase in extreme rainfall days.[73] It was also found that there has been a significant increase in extreme rainfall events during Southwest monsoons during 1901-2010 over West Bengal, Assam, Tripura, Uttar Pradesh, Punjab, Jammu and Kashmir, Maharashtra, Orissa, Andhra Pradesh, Karnataka, Goa, and Tamil Nadu.[74] With the rising number of extreme rainfall events, a substantial increase in hazards related to heavy rain over central India in the future is also expected.[75]

Floods

A flood is 'the overflowing of the normal confines of a stream or other body of water or the accumulation of water over areas that are not normally submerged'.[76] Floods have regional characteristics and usually occur over shorter periods ranging from several hours to days. Floods may be classified as riverine (extreme rainfall for longer periods), flash (heavy rainfall in cities or steep slopes), urban (lack of drainage), coastal (storm surge), and pluvial (rainfall over a flat surface) flooding. Regions prone to frequent floods mainly include river basins, hilly, coastal areas, and cities.[77] Floods may result from extreme rainfall events (though not all such events lead to flooding), and also from other factors like antecedent soil moisture, storm duration, snowmelt, drainage basin conditions, urbanization, dams, and reservoirs, and also proximity to the coast.[78]

Climate change influences many of the factors affecting floods (such as precipitation, soil moisture content, vegetation, sea level, snow cover, glacial lake conditions, etc.), thus changing the flood characteristics.[79] Developmental activities like the building of dikes, reservoirs, or changes in land use can also affect floods. However, it is difficult to distinguish between climate-driven floods and other drivers due to limited evidence, and so there is low confidence in the signs of climate-driven changes in flood magnitude and frequencies. However, anthropogenic climate change has influenced components of the hydrological cycle that may go on to affect flood trends. Limited flood records making it difficult to ascertain increasing flood trends to anthropogenic climate change.[80]

It is suggested with medium confidence that the projected rise in heavy rainfall events will lead to an increase in local flooding in some regions.[81] It is also found with high confidence that increased frequency of localized heavy rainfall on sub-daily and daily timescales has enhanced flood risk over India.[82] Many major cities in India, including Mumbai, Bengaluru, Chennai, Ahmedabad, and Kolkata, have witnessed urban floods since 2000 attributed to climatic shifts, urbanization, cyclones, and sea-level rise for coastal cities, and other regional factors. The major river basins of India including the Brahmaputra, the Indus basin, Narmada-Tapi, Godavari, Ganga, Mahanadi, etc. have experienced increased flooding. River floods may be a result of excessive rainfall or the flow of glaciers and snowmelt into the river. Regional climatic factors and remote forcing influence the flooding of river basins.[83]

An abrupt surge in extreme floods has been seen since the year 2005 (in a study of floods for the period 1970-2019) in India.[84] Between 1974 and 2004, there was an average of three extreme floods per year, affecting 19 districts on an average. Post-2005, this number has gone up to eleven extreme floods per year, and 55 affected districts on an average. The year 2005 registered the highest frequency of 18 extreme flood events, where 69 districts were affected. The year 2019, in comparison, registered a total of 16 extreme flood events, with 151 districts being affected. So, the frequency, intensity, and spatial spread of extreme floods in India have risen abruptly over the last few decades.[85]

Droughts

Droughts are defined as 'an extended period of unusually low precipitation, that produces a shortage of water, and operationally it is defined as the degree of precipitation reduction that constitutes a drought, that varies by locality, climate, and environmental sector'.[86] Droughts are categorized into four major types[87]: (1) meteorological drought, as a deficit in precipitation; (2) hydrological drought, as a deficit in streamflow, groundwater level, or water storage; (3) agricultural drought, as a deficit in soil moisture; and (4) socio-economic drought, incorporating water supply and demand. All these four categories of droughts usually start with a deficiency in precipitation. Several drought indices are used to examine meteorological droughts. These include Percentage of Normal Precipitation (PNP), Standard Precipitation Index (SPI), Standard Precipitation Evapotranspiration Index (SPIE), etc. SPI and SPEI are the most widely used drought indices.[88]

Droughts cause severe water scarcity as a result of one or more of the mechanisms of insufficient rainfall, high evapotranspiration, and over-exploitation of water resources.[89] Droughts, extended over a long period have significant impacts on water availability, agriculture, and socio-economic activities. They cause a reduction in the water table, lowering reservoir storage, and crop failure. Severe droughts highly affect agricultural output and effectively the GDP of the country. Droughts can cause a loss in agricultural yield, and even if the total rainfall is adequate, water shortage during critical periods affects the yield.[90] The decrease in summer monsoon rainfall in the last seven decades has led to an increase in droughts in India. It has been found that the frequency and spatial extent of droughts over India have increased significantly during 1951–2015. During this time the area affected by droughts has increased by 1.3% per decade. Particularly, Central India, Southwest coast, Southern Peninsula, and Northeast India have had on an average more than two droughts per decade during this period.[91]

It is predicted by IPCC[92] that the frequency of meteorological droughts (less precipitation) and agricultural droughts (decrease in soil moisture) is likely to increase in currently dry regions due to climate change by the end of the twenty-first century. This in turn is likely to increase the frequency of short hydrological droughts (decrease in surface water and groundwater) in these areas. Droughts in some seasons and some regions are projected to become longer, or more frequent, or both due to reduced rainfall, or increase in evaporation, or both. In India, it is projected that drought frequency is likely to increase with more droughts occurring per decade by the end of the twenty-first century. The intensity of these droughts and the area under drought is also projected to increase as a result of increased variability of monsoon rainfall and an increase in demand for water vapor in a warmer atmosphere.[93]

Tropical Cyclones

Cyclones are defined as 'a tropical storm originating over tropical or subtropical waters. Cyclones are characterized by a warm-core, non-frontal x-scale disturbance with a low-pressure center, spiral rain bands, and strong winds. Depending on their location, tropical cyclones are referred to as hurricanes (Atlantic, Northeast Pacific), typhoons (Northwest Pacific), or cyclones (South Pacific and the Indian Ocean).'[94] The cyclonic activity over the North Indian Ocean (comprising the Bay of Bengal and the Arabian Sea) makes both the East and West coasts of India prone to destruction by cyclones.[95] Tropical cyclones are extreme weather events occurring in coastal areas, causing large-scale destruction to life and property. The primary peak of cyclone frequency over the North Indian Ocean is during the post-monsoon season (October to December) and the secondary peak is during the pre-monsoon season (March to May).[96]

In India, a significant reduction in the annual tropical cyclone frequency over the North Indian Ocean has been observed since 1951 (to 2018). On the other hand, the frequency of very severe cyclonic storms (VSCSs) has significantly increased during 2000–2018, with more than one event taking place per decade during the post-monsoon season.[97] Before 2005, on average eight districts were affected annually by tropical cyclones in India. Post-2005, this number has risen to 28 districts.[98] Climate simulation models have also projected a rise in tropical cyclone intensity over the North Indian Ocean basin in the twenty-first century.[99] However, there is only medium confidence in attributing this increasing number of cyclones to human-induced climate change.[100]

The coastal regions of India are most prone to tropical cyclones. The districts in India found to be cyclone hotspots are Puri, Chennai, Nellore, North 24 Parganas, Ganjam, Cuttack, East Godavari, and Srikakulam.[101] There is found to be a significant decline in tropical cyclone frequency in the North Indian Ocean per decade for the times periods 1891-2018 and 1951-2018. A rising trend in tropical cyclone frequency in the Bay of Bengal region has been observed, during November and May particularly.[102] The annual frequency of cyclonic storms and severe cyclonic storms has significantly declined in the Bay of Bengal region during 1951-2018, while an upward trend for both has been observed in the Arabian Sea region on both annual and seasonal scales for the same period, during the post-monsoon season.[103]

Identifying districts to study Autonomous Adaptation

While in the previous section we assessed the overall impacts of climate change faced by different regions in the country. The following analysis takes a comprehensive path to identify areas(districts) in the country affected by changes in specific parameters to facilitate the study of autonomous adaptation towards climate change. The focus on autonomous adaptation influences the factors that must be considered when choosing the areas that can provide insights into this process. These factors are different from those to be considered when focusing on the adverse consequences of climate change, at least in one important way. A focus on the adverse effects of climate change would require considerable attention to be paid to the vulnerability of the community that is affected. That is, it would consider not just the intensity of climate change, but also the ability of the community to absorb the costs of this change. A study of autonomous adaptation, on the other hand, would focus only on the responses of local communities, irrespective of their ability to bear the costs of this change.

Changes in climatic factors do not occur in isolation from one another, rather they occur in combinations, and change in one crucial aspect of climate may lead to cascading of extreme events. For instance, while the change in mean temperatures is a sign of climate change, the most prominent effects are seen in changes in extreme temperatures which have varied effects on agriculture and allied activities, human health, energy and water resources, and natural ecosystems. The rise in extreme temperatures also contributes to a rise in heat waves which severely impacts human health. In changing rainfall patterns, we observe that overall average monsoon and annual rainfall have decreased in most parts of India, but a pattern of extreme rainfall events has been observed. The reduced number of rainy days and the rising temperatures have led to more droughts on one hand, while the increasing number of heavy and extreme rainfall events has led to an increase in floods on the other. Other climatic factors like the increase in cyclones and sea-level rise also lead to flooding and cause major disruption to human ecosystems.

The effects of climate change are varied, both in terms of their intensity as well as the possibility of being affected by more than one aspect of this change. In the review of climate change indicators in the previous section, we narrow down to seven important climate change criteria that have been observed pan-India. These include changing temperature trends, rising heatwave trends, changes in rainfall patterns, increase in droughts, rises in extreme rainfall events, floods and cyclones. Out of these seven, changes in temperature and rainfall patterns refer to significant changes in climatic parameters that normally remain stable over long periods. The other five criteria- rising trends in heatwaves, extreme rainfall events, droughts, floods, and cyclones - are the extreme weather events with growing frequency and intensity. Each criterion has different parameters that indicate change, like maximum/minimum or annual/seasonal changes in temperature, annual/seasonal rainfall patterns, frequency and intensity of droughts and floods, and so on.

From the review of various elements of climate change in India, we realize that changes in long-term trends of climate are insidious, unlike the extreme weather events that are more visible. As the long-term changes are gradual, people experience and adapt to such changes first before science detects them or governments respond to them. Extreme events garner more response from authorities of the state because of their overt nature. Hence to study autonomous adaptation, it is imperative to focus primarily on the long-term changes in climatic parameters. So, as a first step we looked at the districts that are affected by changes in mean variations in climate parameters, and then looked at the effect of extreme events in the subsequent steps to identify the most severe climate change-affected districts. To do this, we developed a matrix by collating district-wise trend analyses of the selected criteria from different sources. District-level analyses done at an all-India level were identified for each criterion to maintain uniformity of period and methodology. However, in cases where such trend analysis was missing from the all-India studies, the gaps were filled by other relevant studies. The details of the sources referred to and the corresponding period for each are presented below, followed by the maps representing the findings of the matrix.

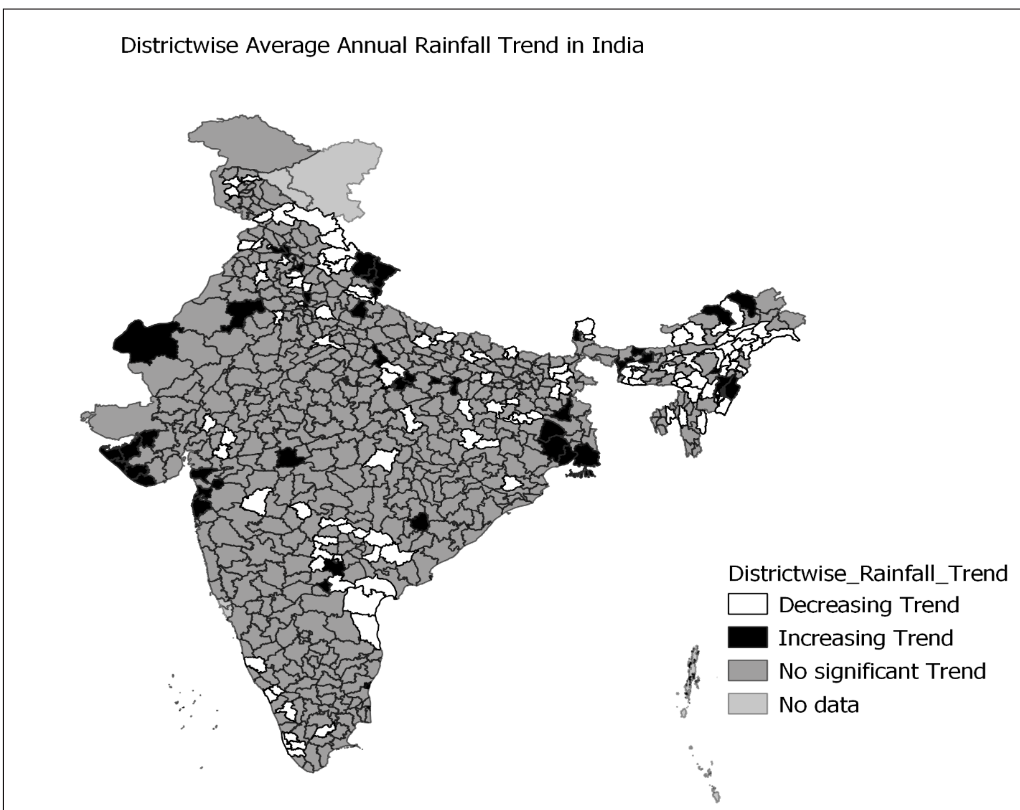
The Matrix: district-level exposure to multiple climatic events

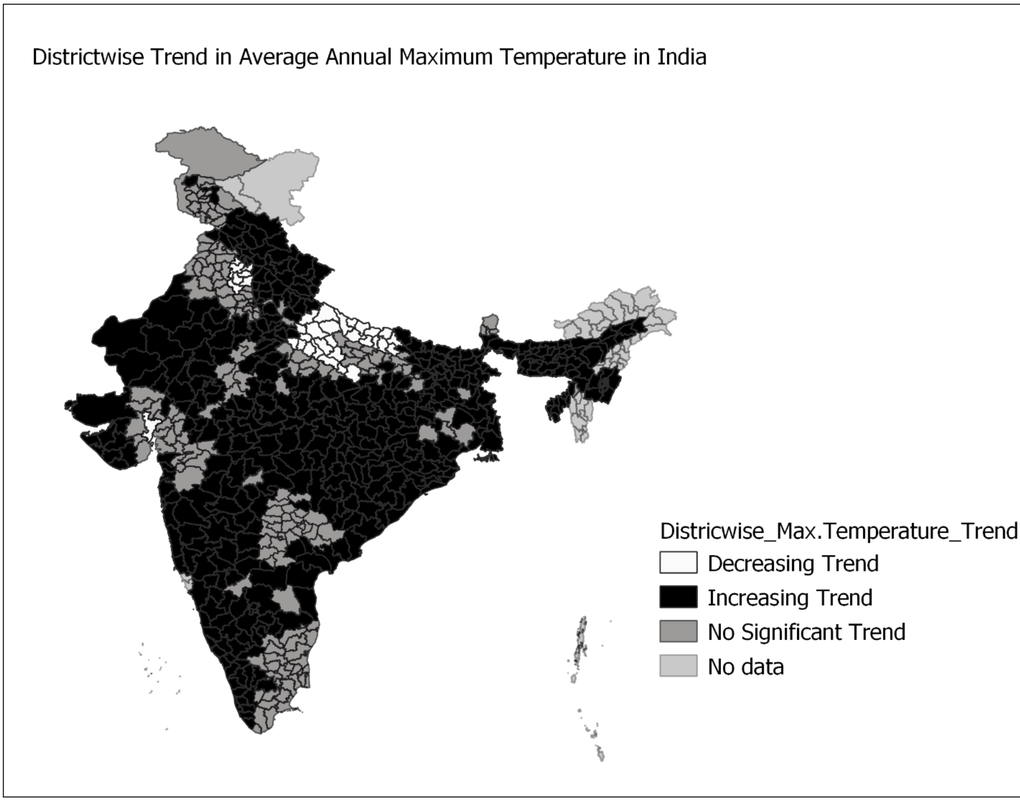
To identify the locations in India with higher exposure to certain major climatic events a matrix is developed in three different stages. These stages were classified based on the characteristics and dynamics of the climatic parameter and the variations in their spatio-temporal magnitude. In the matrix, when a district is found to have been exposed to effects of a particular climatic parameter with a significant (either increasing or decreasing) trend then those districts were assigned with the value 1, and the districts with no significant trend were marked with the value 0. The different stages of the matrix and the results are explained below.

Stage 1: Key indicators

To evaluate the effects of the climate change at the district level at the first stage of the matrix the key indicators considered in our study were the temperature (maximum and minimum) and precipitation, as the long-term variability trends in these two parameters could act as a base to indicate the variability of climate in a broad-sense and also could legitimize the existence of the effects of other associated climatic events which depends on these variabilities. The following thresholds of these two parameters were considered while mapping their long-term trends:

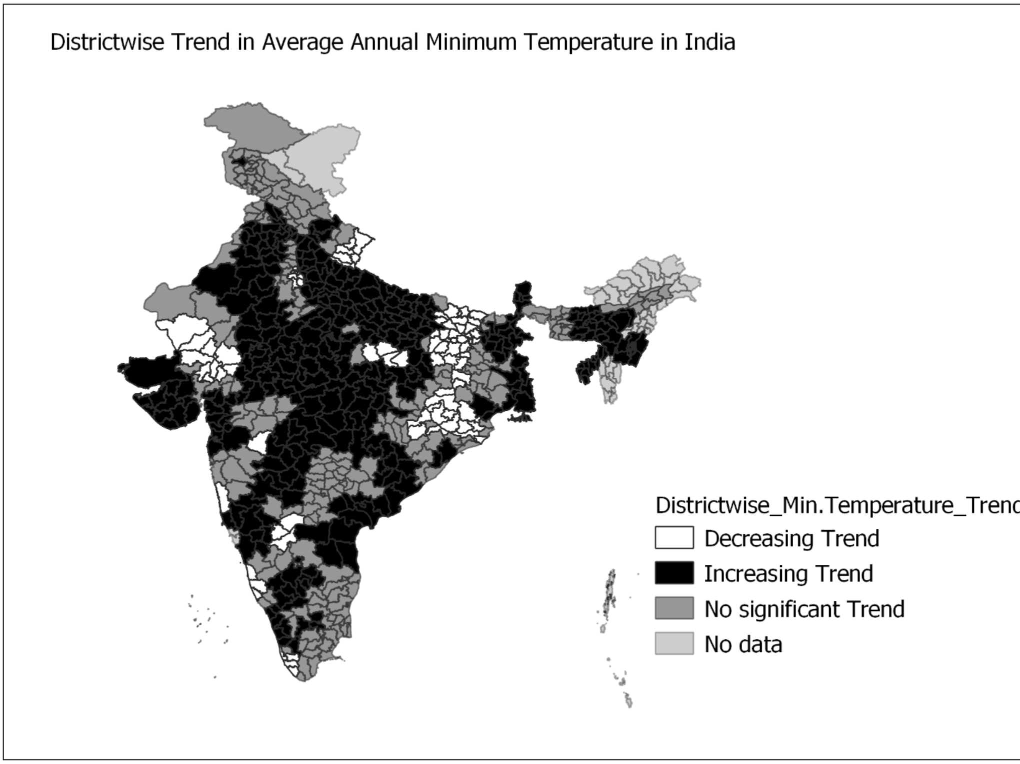
Rainfall: For the increasing and decreasing rainfall patterns, district-wise





trends were obtained from the analysis of observed rainfall variability and changes done by IMD for each state. The reports for each state were retrieved from the IMD website. A uniform methodology and period have been chosen to analyze trends for all districts. Daily Rainfall data from 1989 to 2018 is considered for analysis of trend, variability, and mean rainfall patterns. Districts showing trends at a 95% significance level were marked in the matrix. The trends in the rainfall indicated that 121 districts in the country were facing a significant decreasing trend in annual average rainfall while only 45 districts showed an increasing trend. The map representing the trends in district wise average annual trend in rainfall is as follows:

Temperature: District-wise long-term trends in the annual average maximum and minimum temperature were retrieved from the maps developed by Climate Prediction and Monitoring Group, published by Indian Meteorological Department (IMD), Pune. These maps have been found to represent temperature



trends based on the historical data ranging between the period 1901-2015. The districts showing significant positive departure or negative departure (at 95% significance level) from the average annual maximum/minimum temperature (Normal) (1981-2010), were marked in the matrix.

In terms of the district-wise long-term trend in the annual average maximum temperature. A total of 423 districts in India represented an increasing trend while a mere 35 districts were found to be exposed to a decreasing trend. The map depicting the above-mentioned trends in maximum temperature is as follows:

On the other hand, 344 districts seem to have been exposed to an increasing trend in the annual average minimum temperature while 88 districts have shown a significant decreasing trend.

At the end of stage 1 into the development of the matrix, when we inquired into the cumulative impact of all these three key parameters (Rainfall, Maximum temperature and Minimum temperature), it was found that a total of 78 districts in the country were found to be affected by changes in all these three parameters.

Stage 2: Associated climatic events

Taking the results of the stage one to further explore the impacts of associated climatic events in these 78 districts, the matrix was further extended to accommodate the events like Floods, Droughts and Heat waves. These events were chosen based on the facts like the occurrence of these events largely depend on or sensitive to the variability and trends of key indicators analyzed in stage one. The criteria involved in this stage to infuse these events into the matrix are as follows:

Floods: For floods, the district-wise data to represent the magnitude of incidence and intensity were derived from the web portal called thinkhazard.org, which is a hazard screening tool developed by Global Facility for Disaster Reduction and Recovery (GFDRR). This tool translates and represents the intensity, frequency, and susceptibility of the scientific parameters of hazard in the form of probabilistic data to communicate the probable frequency at which a particular location may sustain a hazard. Based on the damaging intensity and frequency threshold the probabilistic hazard data is mainly classified into three categories: low, medium, and high. The districts which fell under the higher probability to the incidence of the hazard with higher damaging threshold and lower end of the return period were mapped in the matrix.

Heatwaves: The data on heatwave trends were taken from a study of the changing trends in heatwaves for 103 stations in India, which we extrapolated to the districts that those stations belong to, to get a district-wise heatwave trend. Here, the normal climatological value used is for the base period of 1971-2000. An analysis is done for the daily maximum temperature data of 103 stations uniformly distributed over the country for the period 1961-2010. The definition of heatwaves used by this study is the one used by IMD, as follows:

- Heatwave need not be considered till the maximum temperature of the stations reaches at least 40 °C for plains and at least 30 °C for Hilly regions

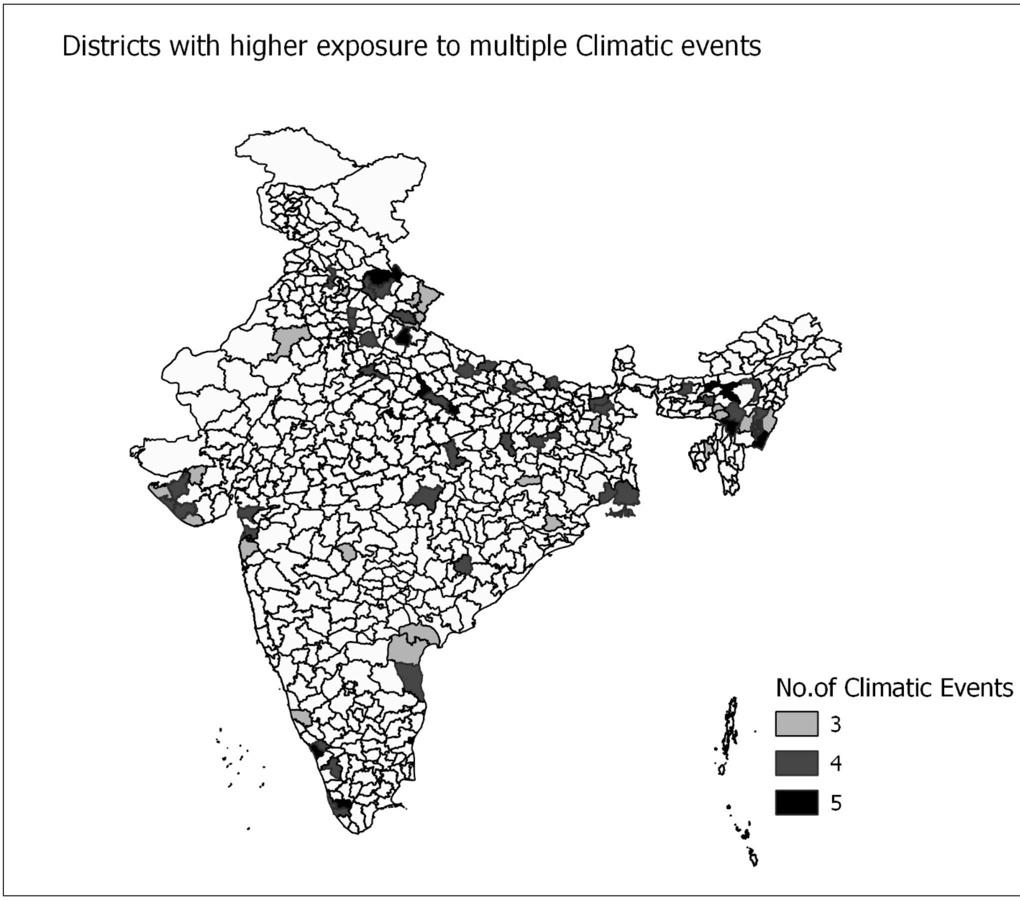
When the normal maximum temperature of a station is less than or equal to 40 °C

- Heatwave: Departure from normal is 5 °C to 6 °C
- Severe heatwave: Departure from normal is 7 °C or more

When the normal maximum temperature of a station is more than 40 °C

- Heatwave: Departure from normal is 4 °C to 5 °C
- Severe heatwave: Departure from normal is 6 °C or more

When the actual maximum temperature



remains 45 °C or more irrespective of normal max. temperature Heatwave should be declared

- For Coastal stations, if the maximum temperature of 40 °C is reached "Heatwave" may be declared.

Droughts: The district-wise trend of increasing droughts in India was taken from a study that analyzes the long series of monthly rainfall data of 640 districts of India for 115 years (1901–2015) has been used in the study. The standardized precipitation index (SPI), a probability-based indicator that depicts the degree to which the cumulative precipitation of a specific period departs from the average state, was used to analyze drought trends. SPI values under three categories of 'moderately dry' (SPI between –1.49 to –1.00), 'severely dry' (–1.99 to –1.50), and 'extremely dry' (SPI –2.0 or less) were used to classify droughts. The districts showing a significant decreasing trend in cumulative SPI were considered as the part of this analysis and the significance level is 95%.

The stage two in total has 6 parameters in consideration, with 3 parameters being carried over from the stage one for these 78 locations (Rainfall, Maximum temperature and Minimum temperature) and the 3 more parameters examined at this stage namely Floods, Droughts and Heatwaves. The results at the end of stage 2 analysis of the matrix revealed that 10 districts in the country are exposed to 5 out of all six parameters. These districts are- Nagaon, Cachar, Darrang (Assam), Pathanamthitta, Kozhikode (Kerala), Chandel (Manipur), Kanpur Nagar, Bareilly, Kaushambi (Uttar Pradesh), and Uttarkashi (Uttarakhand). All these districts were largely affected by long-term changes in by floods and droughts.

Stage 3: Extreme Events

This stage of the matrix is a supplementary analysis to further narrow down on the locations with higher exposure to multiple climatic events. Here, the impact of two more events which are episodic or highly extreme in nature namely Extreme rainfall events and Cyclones were considered and their trends in 10 districts identified as the part of stage 2 analysis were investigated. The following criteria were involved while considering these parameters as a part of the stage 3 of the matrix.

Extreme Rainfall Events: For mapping the district-wise annual extreme rainfall events the data points up to 2012 were obtained from the IMD report on Extremes of Temperature and Rainfall and the occurrence of extreme rainfall events after 2012 were derived from annual climate summary reports published by IMD. These events do not represent any specific long-term trends, the rainfall event with the highest magnitude which has ever been recorded at a particular station for 24 hours is marked in the matrix.

Cyclones: The district-wise data on Cyclones were derived from the web-portal called Thinkhazard.org, which is a hazard screening tool developed by Global Facility for Disaster Reduction and Recovery (GFDRR). Similar to floods in stage 2, the districts which fell under the higher probability to the incidence of the hazard with higher damaging threshold and lower end of the return period were mapped in our study.

The results of this stage of the matrix further gave the clarity that two districts- Cachar and Kozhikode- were found to be affected by both, extreme rainfall events as well as cyclones and five districts- Nagoan, Pathanamthitta, Chandel, Kanpur Nagar, and Bareilly- were found to be additionally affected by at least one of these extreme events.

Limitations with data: While a large proportion of the data is obtained from the above-mentioned sources, the trend analysis data for certain climatic parameters were missing for the districts of a few states. Those data gaps were filled by acquiring trends analyzed by other research studies that contained long-term data covering different periods. The rainfall trends for the districts of Manipur are for the period 1901-2000. The temperature trends for the districts of Uttar Pradesh are for the period 1971-2013. The trends were originally for agro-climatic zones of the state. To create the district-wise matrix we extrapolated the trends of corresponding agro-climatic zones to each of the component districts within it. The temperature trends for the districts of Madhya Pradesh are for the period 1951-2013. District-wise trends were obtained from the spatial map of temperature trends given in the study. The temperature trend for the districts of Sikkim is from 1978 to 2009. The temperature trend for the districts of Tripura is for the period 1969-2014. Here, only the data for Agartala and Kailashahar stations were available. The annual minimum temperature trends for the districts of Himachal Pradesh are for the period 1951-2013. District-wise temperature trends for the states of Arunachal Pradesh, Mizoram, and Nagaland could not be found.

Way Forward: Towards a multi-disciplinary approach

In the previous section with specific locations in India being identified to have been exposed to multiple climatic events could mean the responses towards them could vary dynamically based on the local conditions. In terms of autonomous adaptation as the response by local communities is subconscious towards the effects of climate change, the methods to study such response require an amalgamation of different approaches to thoroughly inquire upon the processes involved in it. Here the discussion delves into the requirement for a multi-disciplinary approach in the study of autonomous adaptation. Indeed, existing studies on climate change-specifically the impacts, responses, and inequality aspects of climate change traverse across disciplinary boundaries in social science. Economics, political science, and anthropology have already contributed knowledge, perspectives, and methodological approaches to investigate these aspects of climate change.

Historically, the growth of Greenhouse Gas (GHG) emissions and its increasing stock in the atmosphere, the principal cause for climate change, and the subsequent physical and social catastrophes, has been driven by the human thirst for economic development.[104] Science tells us that economic activities contribute substantially to anthropogenic climate. Economics as a discipline has a potential role in determining the strategies for climate change. Energy economics has explored the sensitivity of climate change to energy choices. Development economics has had to deal with the impact of climate change on livelihood strategies, resource availability, and other similar issues at the global and local levels. Economic tools have also helped to assess the damage caused by climate change. The multiplicity of these dimensions has contributed to the emergence of larger economics of climate change.

The bargaining around the costs of climate change and who should bear them has increased the focus on the politics of climate change. The immediate concern of political scientists was international climate change policies and the global governance of climate change negotiations. However, the political instability that climate change impacts have produced in global and local politics, and the rising inequality during the process of climate change, have directed attention to the political nuances of climate change, beyond the politics of international negotiations and the formation of treaties. Political conflicts between the states and within the state that have been caused by climate change, and have become a larger concern of political scientists.[105]

In this context, new political ideas such as deep democracy and bio democracy have become more prevalent in addressing both rising inequality and other socio-political issues generated by climate change. Both these ideas bring a radical paradigm shift in the way conventional democracy has been imagined and practiced to resolve the issues of inequality and ecological crisis. As Arjun Appadurai has observed, the new conceptualizations of democracy 'recognize that non-governmental actors are here to stay and somehow need to be made part of new models of global governance and local democracy'.[106] Deep democracy, in that way, it is an awareness of diversity, an attitude for 'everyone and every feeling must be represented'.[107] Climate change activists in the US have raised slogans like ‘deep democracy is the cure for climate change and inequality’.[108]

It is also important to note that deep democracy does not need a constitutional or an electoral procedure to perform, instead it can perform well on the ground through policies that incorporate equity and alliances between local people, governmental and non-governmental agencies to uplift the life of poor and marginal people.[109] The concept of bio democracy anticipates an equitable balance between 'political and ecological democracy'. Bio democracy offers 'a conceptual realization that allows us to think of the political and the ecological as not separate or opposed'.[110]

It is thus quite evident that the impact of climate change is wide-ranging. It 'can undermine livelihoods, impel migration and weaken valued cultural expressions and practice'.[111] Anthropology, as a study of humans, their society, culture, and their changing relationship with the natural environment, has a significant role in contributing to the study of climate change- specifically the social and cultural dynamics of climate change impacts. Anthropologists were a part of the first IPCC assessment report, but their contributions did not get much attention in a field that was dominated by physical scientists.[112] However, in the later period, especially in the new millennium, anthropological contributions are noticed specifically in 'engaging research that has a concern with, resilience, vulnerabilities, adaptation, gender, migration, and displacement'[113] and also inequality and differences of experiencing the impacts and the adaptation strategies of climate change. Janson Antrosio and Sallie Han observed that 'in the age of Anthropocene, the importance and relevance of anthropology rests on its traditional strength: close empirical work that very often becomes a basis for the challenge to conventional wisdom and prevalent assumptions'.[114] Cultural awareness and social contexts are the two areas where anthropological contribution to climate change seems more significant. Climate Change Anthropologist Ben Orlove writes;

> 'Anthropologists more specifically bring awareness of culture to the climate change issue, which is important because people understand the world through their cultural lens. Anthropologists also bring awareness of social contexts through individuals making decisions and taking actions, they do so in the context of the other people with whom they have certain shared ideas and relationships.'[115]

Anthropology as a field science that often focuses more on local reality, offers different approaches and perspectives, to study the local responses of climate change, capture the knowledge from indigenous people on their way of autonomous adaptation, and also understanding the ground realities of exacerbation of inequality as a consequence of climate change.[116] Similarly, political ecology, and ethno-climatology, are the two concepts that emerged in anthropology in response to climate change. Political ecology 'is a critical field within anthropology and related disciplines that examines how and why economic structure and power relations drive environmental change in an increasingly interconnected world'.[117]

The concept of political ecology becomes a relevant conceptual frame to understand the structural inequality of climate change. Similarly, ethno-climatology focuses on the localized knowledge and practices generated by cultures or communities grounded in specific geographic contexts. Ethno-climatology offers methodological and conceptual frames to understand climate change through people's perspectives. Precisely, anthropology of climate change can produce much reflexive ground reality of climate change impacts and people's intuitive response to resist the climate change threat, and further contribute to the resistance and adaptation policies.

Conclusion

This note primarily looked into the existing disconnect in the climate change discourses in social sciences and resilience policies in general. It is found that, in recent times, adaptation has gained remarkable attention as a potential strategy to reduce and resist the climate change crisis. However, the existing knowledge and discourses on climate change in social sciences- especially on the inequality, vulnerability, and adaptation, have ignored the knowledge from the ground. The intuitive responses, and the knowledge that is generated on the ground, by people and communities to cope and adapt to the climate change threats, known as autonomous adaptation, has potential scope for framing adequate and equitable adaptation policies to reduce and resist climate change threats that people across the differences have been suffering across the world in the regime of climate change. It is found that the need for shifting our attention and concern towards autonomous adaptation to climate change has increasing significance in our time, to bridge the existing disconnect in climate change knowledge. The note further moved to identify the geographical areas in India that are most affected by climate change, to move the foot towards the inaugural scholarly engagement on the autonomous adaptation to climate change. This process of identification of location found that Kozhikode in Kerala and Cachar in Assam are the most affected districts by the effects of multiple climatic events in India. In the end, the note has presented a conceptual frame for a multidisciplinary investigation on the process and various dynamics of autonomous adaptation to climate change in the identified areas.

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This note explores multidisciplinary framework to study inequality and autonomous adaptation to climate change. It argues that the knowledge on climate change in social sciences lacks the discourses from the ground. It raises the demand for investigating autonomous adaptation to climate change for bridging this disconnect.

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