Chapter 8

Impacts and adaptation

In this chapter, we discuss the impacts of heat and cold waves and adaptation strategies to cope up the adverse impacts of heat and cold waves.

8.1. Heat wave Impacts:

Heat waves affect human health and air quality, increase energy consumption, reduce crop yields, increase water loss and intensify droughts. In addition, exposure of crops to temperatures beyond a critical threshold can lead to crop failure. Heat waves also increase temperatures in buildings and cities (urban heat islands), cause disruptions in critical infrastructure networks, affect the economy through lower labour productivity, and exacerbate the impacts of other climate-related hazards such as droughts or forest fires.

Heat waves have claimed more lives in India than other natural hazards, with the exception of tropical cyclones. In March and June, they also lead to dry weather with lower humidity. However, heat stress due to increased humidity and temperatures can significantly endanger human life. Unfortunately, there is not much research on such heat stress episodes in India. Jaswal et al. (2017) made such an analysis of heat index over India. Heat Index (HI) known as apparent temperature, combines air temperature and relative humidity to determine how hot it actually feels. It has been shown that changes in the HI resulting from increases in atmospheric moisture can account for a considerable fraction of the total increases in the HI. The risk of heat-related illness becomes greater as the weather gets hotter and more humid. The human body normally cools itself by perspiration, or sweating, in which the water in the sweat evaporates and carries heat away from the body. However, when the relative humidity is high, the evaporation rate of sweat is reduced. This means heat is removed from the body at a lower rate, causing it to retain more heat than it would in dry air.

Im et al. (2017) examined the effects of heat waves and discussed the risks and vulnerability of people. Previous studies have shown that a wet bulb temperature of 35^0 C can be considered an upper limit for human survivability. Based on an ensemble of high-resolution climate change simulations, the study found that wet bulb temperature extremes in South Asia are likely to approach and exceed this critical threshold in a few places by the end of the 21^{st} century under the business-as-usual scenario of future greenhouse gas emissions. The greatest risk from extreme heat waves is in the densely populated agricultural regions of the Ganges and Indus river basins. Climate change, without mitigation, poses a serious and unique risk to South Asia, a region that is home to about one-fifth of the world's population, due to an unprecedented combination of severe natural hazards and acute vulnerability.

Heat waves have significant impacts on a number of aspects such as health, infrastructure performance, energy demand, building design, water quality and costs (Zuo et al. 2015). These impacts are significant and some of them even interact (e.g. costs and energy consumption). The study by Azhar et al. (2017) examined heat wave vulnerability over India. Their study revealed that of the total 640 districts considered, 10 districts are vulnerable in very high-risk category and 97 districts in high-risk category. The districts with higher heat vulnerability are located in the central parts of the country. These are less urbanized and have low rates of literacy, access to water and sanitation and presence of household amenities.

Zachariah et al. (2021) made a probabilistic assessment of extreme heat stress on India wheat yields under climate change. They showed an increase in magnitude, frequency and areal extent of heat stress episodes in the Indo-Gangetic Plains region during 1967-2018. Probabilistic estimates of below-average wheat production under scenario-averaged heat stress conditions are expected to rise by 8%–27% under the SSP5-8.5 climate change scenario, with Punjab showing the largest increase. Quantitative links between heat stress indicators and loss of crop yield highlight

increased agricultural vulnerability in India under climate change. The 2022 Indian heat wave impacted key geographies of wheat production in northwestern and central India (Sidhu, 2022). In 2022, due to strong heat wave activity, wheat production was expected to have fallen by 4.5 per cent, in some regions losses could be up to 15 per cent.

Anel et al. (2017) discussed the impact of cold and heat waves on the energy production sector. Cold and heat waves represent a significant problem for the electricity generation sector. The disruptions cold and heat waves can cause in power production are beyond their consumption impacts through, for instance, higher peak demand.

Nori-Sarma et al. (2019) addressed the impact of heat waves on mortality in northwest India. They found that even in areas with extreme high temperatures, heat waves present health risks for mortality. Their results indicate that relationships generated for temperature and mortality from developed country settings may not accurately characterize such relationship in the global south. The findings of differential impact depending on heat wave definition have critical implications for policymakers and merits additional study. Continued development of local data resources to assess the relationships between temperature and health in developing countries such as India, is important to accurately assess current health effects, as well as to inform future heat wave alerts globally under a changing climate.

Some of the main impacts of heat wave on human health are given below. Heat waves can impact health, agriculture and energy.

1. Heat exhaustion and heat stroke: Heat waves can cause heat exhaustion and heat stroke, which can be life-threatening if not treated promptly. Symptoms include nausea, dizziness, headache, rapid heartbeat, and confusion.
2. Dehydration: High temperatures can cause dehydration, particularly if people are not drinking enough fluids. This can lead to headaches, fatigue, and other health problems.

3. Respiratory problems: Heat waves can exacerbate respiratory problems such as asthma, as high temperatures can cause air pollution to accumulate and irritate the lungs.

4. Cardiovascular problems: High temperatures can also increase the risk of cardiovascular problems such as heart attacks and strokes, particularly for people with preexisting cardiovascular conditions.

5. Mental health: Heat waves can also impact mental health, leading to increased stress and anxiety, particularly for those who do not have access to air conditioning or other cooling measures.

Overall, heat waves can have significant impacts on human health, particularly for vulnerable populations. It is important to take precautions during heat waves, such as staying hydrated, staying indoors in air conditioning if possible, and avoiding strenuous activities during the hottest part of the day.

Overall, heat waves can have a significant impact on agriculture in India, with potentially serious consequences for food security and the livelihoods of farmers.

1. Crop failure: Heat waves can cause crops to wilt and die, leading to reduced yields or even total crop failure. The high temperatures can also cause damage to plant cells, reducing their ability to photosynthesize and produce food.

2. Reduced soil moisture: High temperatures can lead to increased evaporation of water from soil, reducing soil moisture levels and making it more difficult for crops to grow. This can lead to drought-like conditions, which can be devastating for farmers.

3. Pest infestations: Heat waves can create ideal conditions for pests and insects to thrive. This can lead to increased damage to crops and the need for more pesticides, which can be costly for farmers.

4. Livestock health: Heat stress can be a significant issue for livestock, causing reduced milk production, lower fertility rates, and even death in extreme cases. Farmers may need to take extra precautions to protect their animals during heat waves.

5. Water scarcity: Heat waves can exacerbate existing water scarcity issues, as water sources dry up more quickly and demand for irrigation increases. This can lead to conflicts between farmers and other water users, and can make it difficult for farmers to grow crops.

Heat waves also can have significant impacts on the energy sector, affecting the reliability of the energy grid, increasing costs, and potentially leading to power outages and other disruptions. The following impacts are very important.

1. Increased demand for electricity: During heat waves, demand for electricity tends to increase as people use more air conditioning and fans to stay cool. This can put a strain on the energy grid, leading to blackouts or brownouts if supply cannot keep up with demand.

2. Reduced power generation: High temperatures can reduce the efficiency of power plants, particularly those that rely on water for cooling. If water temperatures are too high, power plants may have to reduce their output or shut down altogether, leading to reduced electricity supply.

3. Transmission and distribution issues: Heat waves can also cause transmission and distribution equipment to fail, particularly if it has not been designed to handle high temperatures. This can lead to power outages and reduced reliability of the energy grid.

4. Increased risk of wildfires: Heat waves can increase the risk of wildfires, which can damage or destroy energy infrastructure, including transmission lines and power plants. This can lead to power outages and a need for costly repairs.

5. Increased energy costs: During heat waves, energy prices may increase as demand for electricity rises and supply becomes more constrained. This can lead to higher energy bills for consumers and businesses.

8.2 Adaptation to Heat Waves

The most effective way to reduce the negative impacts of a heatwave is to develop a comprehensive response plan that combines individual strategies into an integrated approach and includes cultural, institutional, technological and ecosystem-based adaptations. For example, the institutional plan could include weather forecasting, monitoring, and education and awareness. Appropriate education can ensure the health and safety of urban residents during heat waves, especially vulnerable groups such as older adults, children, people working outdoors and low-income communities. Zuo et al. (2015) found that structural/institutional and technological factors attract the most attention in the literature, while cultural/behavioral factors receive less attention. It is worth noting that these mechanisms are complementary and ultimately aim to improve the resilience of the urban and built environment to climate change. Indeed, an appropriate combination of these mechanisms can lead to more effective measures to cope with heat waves and their associated impacts. The effectiveness of these measures varies and depends on contextual factors such as cultural background, level of economic development, etc.

It is crucial to make adaptation choices to reduce the impact of these heat waves. Here are some of the adaptation choices that can be made for heat waves in India:

1. Increasing public awareness: One of the best ways to adapt to heat waves is by increasing public awareness. People need to know the signs of heat stroke and how to protect themselves from the sun's harmful rays. Government agencies can launch awareness campaigns through various media to educate people on the dangers of heat waves and the precautions to take during these times.

2. Improving the built environment: India needs to improve the built environment to make it more heat-resilient. This can be done by incorporating better insulation and ventilation systems in buildings, planting more trees, and increasing the green cover in cities. Such measures will help to reduce the urban heat island effect, which is a phenomenon where cities are much hotter than surrounding areas.
3. Providing cool shelters: Providing cool shelters is another adaptation choice for heat waves. The government can set up public cooling centers and shelters in public spaces where people can go to cool off during extreme heat. This can be especially useful for vulnerable populations such as the elderly, homeless, and those with chronic health conditions.
4. Changing work schedules: The government can implement policies to adjust work schedules during heat waves. For example, working hours can be shifted to the early morning or late evening when temperatures are cooler. This can help to reduce the risk of heat stroke and other heat-related illnesses in workers.
5. Developing early warning systems: Developing early warning systems can help people prepare for heat waves. The government can issue heat wave warnings through various media, including television, radio, and social media. This will help people take the necessary precautions to protect themselves from the heat.

It is important to note that these measures must be implemented on a large scale to make a significant impact and reduce the impact of heat waves in India.

Recurrent heat waves, already a problem in the rapidly growing and urbanising countries of South Asia will most likely worsen in a warming world. However, coordinated adaptation measures can reduce the negative health impacts of heat. Across India, state and district governments have responded by creating Heat Action Plans (HAPs) that prescribe a variety of preparedness activities and heat wave response measures across government departments to reduce the impact of heat waves (Aditya

Valiathan Pillai and Dalal 2023). To address this problem in Ahmedabad (Gujarat, India), a coalition was formed to develop an evidence-based heatwave preparedness plan and early warning system. Knowlton et al. (2014) discussed the details of developing and implementing South Asia's first Heat Health Action Plan in Ahmedabad (Gujarat).

Aditya Valiathan Pillai and Dalal (2023) published a report critically analyzing 37 heat action plans at city (9), district (13) and state (15) levels in 18 states. They identified several opportunities to strengthen India's HAPs. They also documented a wide range of solutions (covering 62 different types of interventions) prescribed in these HAPs, from promoting green roofs to federal school awareness programmes. The HAPs provide for a balanced mix of short- and long-term measures, although it is unclear to what extent these measures will be implemented. Long-term transformational measures such as climate-sensitive urban planning and changing cropping patterns are likely to have higher implementation costs than immediate measures, but could significantly reduce heat stress in the long term and facilitate the implementation of HAP. They found that most HAPs are not tailored to the local context and have an oversimplified view of the hazard. Almost all HAPs are inadequate in identifying and targeting vulnerable groups. HAPS are underfunded, lack transparency and have a weak legal basis.

In a recent study, Debnath et al. (2023) addressed the issues of heat wave impacts on public health, agriculture and other socio-economic and cultural systems. They argue that these impact can hinder or reverse the country’s progress in fulfilling the sustainable development goals (SDGs). The existing Climate Vulnerability Index (CVI) developed by the Department of Science and Technology, Government of India may underestimate the impact of heat waves on the country’s developmental effects. Linking Heat Index (HI) with CVI identifies more of India’s vulnerability and provides an opportunity to rethink India’s climate adaptation policies through international cooperation in designing holistic vulnerability assessment methodologies. They conclude that there is an urgent need to improve extreme weather impact assessment by

combining multiple layers of information within the existing climate vulnerability measurement frameworks that can account for the co-occurrence and collision of climate change events and non-climate structural SDG interventions.