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EDITORIAL

Editorial to the special issue on environment and population dynamics in South Asia

Guest Editor: Sangram Kishor Patel

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This editorial belongs to the *Special Issue*: *Environment and Population Dynamics in South Asia*

In the last few decades (particularly after 1950), the world's population doubled from three billion to six billion-plus population. This increased the pressure on land use and resource depletion continued. Further, it fuelled with habitat destruction, loss of biodiversity, water scarcity and water pollution, air pollution, global warming, and climate change across the globe.

Climate change is a global trend impacting both developed and developing nations, ranging from wealthy to poor, marginalized communities from women, infants, the disabled to the elderly population. The World Health Organization (2018) notified that all populations will be affected by climate change, but some are more vulnerable than others, and areas with poor health systems – mostly in developing countries – would be the least likely to cope without preparedness assistance. South Asia is predicted as one of the worst affected regions from global warming and climate change because of geophysical factors and socio-economic and -demographic backwardness. The area is home to around 1.8 billion people in the world and a portion of the world's poor. The UN estimates that the population of the region will grow by 40% by 2050 (United Nations, 2019). It would have a very strong effect on the agriculture sector across countries in South Asia. The vast reliance of life on agriculture and natural resources makes this region's communities very vulnerable to climate change. South Asia is gravely threatened by rising sea levels and the growing occurrence of severe climate events such as floods, droughts, cyclones, storms, earthquakes, and monsoon irregularities. Countries in the Greater Himalayan Region, including Bangladesh, Bhutan, Northern India, and Nepal, are facing increased frequency and magnitude of severe weather events resulting in floods, landslides, property and infrastructure destruction, agricultural crop degradation, reduction in hydropower generation, and adverse human health impacts (Asian Development Bank, 2015). The coastal regions of Bangladesh, India, the Maldives, and Sri Lanka are at high risk from the expected rise in sea level, which could lead to the displacement of human settlements, the loss of agricultural land and wetlands, intrusion of saltwater, and negative impacts on tourism and fisheries. Agriculture is one of the most important sectors in South Asia. It provides stable food sources, income and livelihoods, and a social safety net for rural populations.

Large sections of the population of South Asian region lack basic human needs such as sufficient food and nutrition, clean water, adequate shelter, and access to education and health care. However, the current changing environment and frequent occurrence of extreme weather events posing a serious challenge to socioeconomic development, food security, livelihoods and health hazards among the population in the region along with the resilience mechanisms. Improved understanding of the impacts of climate change in agriculture and adaptation practices to cope with these impacts of climate change and natural disasters are therefore necessary to enhance agriculture's sustainability and to develop policies that reduce the vulnerability of poor farmers to climate change at South Asia. Hence, it is necessary to investigate these issues through the lenses of research, which may help in formulating better policies and programs at the local and regional level. We herein have invited researchers from the international community working in the areas of environment, climate change,

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and population dynamics to contribute to this special issue on "Environment and Population Dynamics in South Asia." This special issue has broadly covered the issues related to population dynamics and its relationship with various environmental issues (but may not limit to) such as climate change and resilience, natural disasters, disaster management, waste management, WASH, urbanization and air pollution, climate change and migration, and climate change and public health.

The first research article authored by Patel *et al*. explored the effects of, and resilience to, cyclones, floods, droughts, and heatwaves in Odisha, India, and identifies government strategies that help mitigate these natural disasters. The findings described that the impacts of natural disasters are calamitous – affected the communities in a different way, particularly on livelihoods, food security, health, water, and sanitation. There is an urgent need to focus on reducing people's underlying vulnerabilities by taking proactive measures, engaging the community in decision-making, and generating alternative and sustainable livelihoods. The second research article authored by Patel and Pradhan aimed to estimate urban exposure level and examine the inequalities in the availability of infrastructure and the provision of services in million-plus cities in India by using the data from the 2011 Census for 40 million-plus cities. This study pointed out that population, health, educational infrastructure, and built environments contributed the most to the inequalities in a million plus cities. Unless addressed urgently, these inequalities in infrastructure and services will affect the sustainability of these million-plus cities and may hinder the country's achievement of Sustainable Development Goal (SDG) 13 on climate change. The third research article authored by Acharya and Das attempted to comprehend the impact of climate vulnerability on household nutrition status through agriculture production systems in Odisha, India. The study suggested that climate vulnerability has a much greater role in influencing household nutrition status, particularly with women and child nutrition through the agriculture production system. Appropriate policy level measures for climate-sensitive and adaptive action are the need of the hour to make agriculture production ecosystem contributes positively to nutrition status. The fourth research article authored by Taneja and Taneja tried to draw important lessons and a deeper understanding of issues and challenges in planning and implementing scientifically simulated Earthquake Damage Scenario (EDS) and Shakeout exercises in a highly populous developing country like India. The study highlighted that scientific EDS exercises followed by mega shakeout exercises not only helped the community up to some extent but also helped administration, government agencies in generating awareness of earthquakes and their possible risk. The fifth research article authored by Arora conducted life history interviews and focus group discussions with community members to examine social values and their linkages with climate adaptation decision-making among Raika community in Rajasthan, India. The findings demonstrated that the community's livelihood, health, and social cohesion are severely affected by environmental change, entwined with social, economic, and political stressors. There was a parallel change taking place in their social values. New adaptation options, such as urban migration, have emerged. The sixth review article authored by Patel *et al*. attempted to understand the impact of natural and man-made disasters on the people of Jammu and Kashmir and Ladakh region in India as well as examines resilience mechanisms. The review suggested that the region is afflicted not only by multiple natural disasters such as floods, earthquakes, avalanches, and landslides but also by the terrorism and violence, which had adversely affected most aspects of life and development in the region. To mitigate the risks, effective disaster risk reduction and management plans, early warning systems and infrastructure need to be strengthened along with community engagement needs to enhance to design of sustainable development programs. The seventh and last review article authored by Patel, Agrawal, and Mathew tried to understand the linkages between natural disasters and their impacts on the mental health of people as well as associated resilience mechanisms in India. The review documented the different pathways for disasters to adversely affect mental health, particularly among vulnerable populations. This research also outlined that better policies need to be designed for prevention, services, and psychological counseling of mental health problems due to disasters.

This special issue has covered a wide range of research on natural disasters, man-made disasters, and climate change in South Asia with a special focus on India. Along with climate change, the main natural disasters explored in this special issue are floods, cyclones, hurricanes, droughts, heatwaves, earthquakes, avalanches, landslides, and lightning. These pieces of research in the special issue have explored the impacts of these disasters on livelihoods, employment, food security, nutrition, physical health, mental health, education, water, sanitation, roads, infrastructures, etc. Along with the impacts, these studies have also tried to cover the resilience mechanism adopted by the communities, as well as the government measures to these effects. This special issue indicates that climate change and natural disasters have impacted the population of South Asia, socioeconomically, physically, and psychologically. There is an urgent need to focus on reducing people's underlying vulnerabilities by taking proactive measures, engaging the community in decision-making, and generating alternative and sustainable livelihoods. It is also apparent that the state-driven policies and strategies should be conceived and designed in accordance with the framework of SDGs to ensure a better and healthy life for all.

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RESEARCH ARTICLE

Voices of rural people: Community-level assessment of effects and resilience to natural disasters in Odisha, India

Sangram Kishor Patel*, Bincy Mathew, Ankit Nanda, Biswajit Mohanty, Niranjan Saggurti

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Abstract: Globally, natural disasters have caused a large scale of damage and destruction every year, affecting millions of people, the economy, and development – and developing countries are the most severely affected. Odisha is one of India's most disaster-prone states. This study explores the effects of, and resilience to, cyclones, floods, droughts, and heatwaves in Odisha, and identifies government strategies that help mitigate these natural disasters. We mainly used primary data collected through a qualitative study undertaken from April 2017 to June 2017 in three districts of Odisha. We conducted in-depth interviews and focus group discussions with community members and key stakeholders at different levels. In addition, our study analyzed secondary data on natural disasters using DesInventar, a disaster information management system data source. The findings show that floods, cyclones, and drought in recent years, along with heatwaves and lightning, have severely affected the people of Odisha. The impacts of these natural disasters are calamitous – particularly on livelihoods, food security, health, water, and sanitation. These natural disasters, which have affected agriculture, fisheries, prawn cultivation, roadside vendors, and daily wage laborers, have both short- and long-term effects on the livelihoods of people in Odisha, leaving them with scarce employment opportunities. The vulnerable and marginalized sections of the population have been the most severely affected, and common coping mechanisms have included selling off livestock, borrowing food, taking loans and mortgages, and migration. The government's measures/programs, such as an Early Warning System, Public Distribution System, Multipurpose Cyclone Rehabilitation Centers, Seasonal Residential Care Centers, and Indira Awas Yojana, play a major role in mitigating the effect of disasters among rural communities. Our study indicates that natural disasters have impacted the population of the state socioeconomically, physically, and psychologically. The effect on livelihoods, directly and indirectly, exacerbates income, food security, and health. There is an urgent need to focus on reducing people's underlying vulnerabilities by taking proactive measures, engaging the community in decision-making, and generating alternative and sustainable livelihoods.

Keywords: Climate change; Effects; India; Natural disasters; Odisha; Resilience

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1. Background

Natural disasters count among the prominent events that devastate populations, economies and impede development both in developed and developing countries. On a global level, over 98 million people were affected and US$66.5 billion in economic damages were incurred in 2015 alone due to natural disasters (UNISDR, 2016). India, one of the most disaster-prone countries, supports around one-sixth of the world population on 2.4% of the world's landmass. The country has experienced multiple disasters and has 40 million hectares of land that is susceptible to floods, a long coastline

prone to cyclones, and 68% of its agricultural land vulnerable to drought. In addition, the annual mean temperature is on the rise (an increase of 0.86°C between 1901 and 2014) (GOI, 2004; Radhakrishnan *et al*., 2017). About 330 million people in India were affected by droughts in 2015 and 2016, the greatest number affected by a natural disaster (Guha-Sapir *et al*., 2016). In India, heatwaves have proved deadly, with 3028 lives claimed in 1998, over 2000 lives claimed in 2002 (NDMA, 2017), and 2248 deaths in 2016 (UNISDR, 2016). Nearly 6500 people lost their lives in floods in India in 2013 (UNISDR and CRED, 2015). In 2013, cyclone Phailin displaced approximately 1 million people (IDMC, 2014). These disasters wreck every aspect of people's lives, destroying their livelihoods, harming their health, and causing damage to the ecosystem and infrastructure. Natural disasters not only affect physical health but also cause many psychosocial outcomes and considerable stress among the population. It has been evident that heatwaves have become more intense and frequent in recent decades and claim the lives of people each year (NDMA, 2017; UNISDR, 2016).

Odisha features among the states in India most vulnerable to climate change and the occurrence of natural disasters, including floods, cyclones, drought, and heatwaves (Ray Bennett, 2009; GOI, 2012; GOO, 2016; Patel, 2016). The geographic location and climatic conditions of Odisha have led to multiple disasters over the years (GOO, 2002). Floods are the most frequent natural disasters in Odisha due to its long coastline and multiple rivers. With the state receiving 80% of its rainfall in 3 monsoon months, any variation in rainfall can lead to droughts and affect the majority of the population that is dependent on agriculture (GOO, 2016). Cyclones have claimed lives and destroyed infrastructure in Odisha and have proven destructive especially for the people living along its coastline. Increasing levels of pollution, deforestation, and industrialization have made the heatwaves common in parts of the state, with the deadly heat wave of 1998 claiming over 1000 lives in the state (GOO, 2016). Odisha has been affected by disasters for 90 of the past 100 years (Sharma *et al.*, 2016). The socioeconomic profile of the state, its dependence on agriculture and other nature-based livelihoods, and a population more than two-thirds under the poverty line make it ripe for natural disasters (Mishra, 2015). This combination of extremely disaster-prone geographical location, low socioeconomic indicators, and changing weather patterns resulting from climate change make it the disaster capital of India (Sharma *et al.*, 2016).

Although many studies in Odisha have focused on mapping and vulnerability assessment for disasters, few studies have provided an in-depth understanding of the effect of natural disasters on rural communities. To add to the limited literature on the effect of natural disasters and resilience at the community level in Odisha, our study examines the cumulative effects of natural disasters in Odisha from 1970 to 2014. In addition, it explores people's perceptions of the effects of, and resilience to, cyclones, floods, droughts, and heatwaves identifies government strategies that are helping communities mitigate these natural disasters; and provides recommendations to strengthen responses to natural disasters in the state. We believe that this comprehensive study will be useful in strengthening the state's policies and programs, as well as helping the population.

2. Data and Methods

This study used data from both a secondary source (quantitative data) and primary research (qualitative data) to answer the key research questions:

- What are the mechanisms through which disasters affect the livelihood, food security, health, and other socioeconomic conditions of people?
- What are the community responses, and the approaches of the different departments and public policy to prevent or address the natural disaster impacts?

2.1. DesInventar: A Disaster Information Management System

This study analyzed the secondary data on natural disasters and their impact on socioeconomic dimensions and infrastructures in Odisha using DesInventar, a disaster information management system data source. DesInventar is an open database of natural disaster events reported in the media between 1970 and 2014 in 89 countries (UNDRR, 2015). DesInventar is a conceptual and methodological tool for the generation of national disaster inventories and the construction of databases of damages, losses, and, in general, the effects of disasters. These methodologies and software packages have been developed by the DesInventar project team with support from the following institutions and partners: UNDRR (United Nations Office for Disaster Risk Reduction), UNDP (United Nations Development Programme), LA RED (The Network of Social Studies on Disaster Prevention in Latin America), OSSO (Corporacion Observatorio Sismológico del Sur Occidente), RobotSearch Software, and Apache Software Foundation.

2.2. Primary Qualitative Study

2.2.1. Study design and settings

This study is mainly based on the primary data collected through a qualitative study. The study was conducted in three districts (i.e., Jagatsinghpur, Nuapada, and Sundargarh) of Odisha, India from April 2017 to June 2017. The primary data on effects and resilience to floods, cyclones, droughts, and heatwaves were collected from the community members at the panchayat level (e.g., panchayat consists of a village or a group of villages divided into smaller units called "wards"), and different stakeholders at the panchayat, block, district, and State Level in Odisha. For the study, one district highly vulnerable to cyclones/floods (e.g., Jagatsinghpur), droughts (e.g., Nuapada), and heatwaves (e.g., Sundargarh) was randomly chosen from the list of respective disaster-vulnerable districts of the state. In the second step, one highly vulnerable block was chosen purposively in each selected district. In the third step, two rural panchayats were randomly chosen from the selected block in the selected district.

2.2.2. Study participants

The qualitative data were collected using in-depth interviews (IDIs) and focus group discussion (FGD) guidelines. Qualitative data were collected among community members (i.e., farmers, women with children, young women (18-21 years), daily wage laborers, older persons, and disabled individuals) using both IDI and FGD guidelines, and among stakeholders (i.e., panchayat level, district emergency office, district medical office, and district agriculture department) using IDI guidelines. In addition, government officials were interviewed using IDI guidelines at the state level (i.e., Odisha State Disaster Management Authority, State Meteorological Department; State Agriculture Department; and State Directorate of Health). A total of 62 IDIs with different stakeholders and 6 FGDs with adult populations were conducted in the state. A detailed outline of the qualitative interviews is given in Table 1. Issues explored during the data collection were: (i) Effect of natural disasters on: Livelihood, food security, water and sanitation, health, and other socio-economic conditions; (ii) disaster resilience (coping and adaptation strategies at the community level); and (iii) government measures on disaster management.

2.2.3. Ethical statement

Overall study design, study tools, and consent processes were reviewed and approved by the Institutional Review Board (IRB) of the Population Council in New York. Written consents were obtained from all participants before participation in the IDIs and FGDs, and steps were taken to ensure their confidentiality. For this study, male or female adults aged 18 years or older who had experience with or exposure to natural disasters or extreme weather events in their life were recruited as participants, and the information was collected accordingly. No names and addresses were recorded. Participants were not provided any compensation for their time in the study.

2.2.4. Data collection and analyses

Qualitative data for the study were collected by trained Population Council researchers. Interviews were audio-recorded and conducted in the local language (Oriya), and then directly transcribed by the researcher into English. Qualitative data analysis was done using ATLAS.ti (6.1 version) software and based on the themes; codes were prepared.

Table 1. Description of qualitative interviews conducted by districts, Odisha, 2017.

Qualitative interviews	**Districts**		
	Sundargarh	**Nuapada**	**Jagatsinghpur**
FGDs (Total=6) – with adult community members (18+years) 1 with adult females in each district 1 with adult males in each district	2	2	2
IDIs (Total=62)			
Community members at panchayat level	13	13	14
Stakeholders at panchayat level	2	2	2
Stakeholders at block/district level	4	4	4
Stakeholders at State Level (Total=4)	-	-	-
Total IDIs at the district level	19	19	20

IDIs: In-depth interviews; FGD: Focus group discussion.

3. Results

3.1. Cumulative Effects of Disasters in Odisha

Out of different natural disasters that have occurred in Odisha from 1970 to 2014 (Tables 2 and 3) (data showed here in percentages), floods have affected people the most, both directly (63%) and indirectly (72%), followed by cyclones (36% vs. 21%). In addition, flooding was the deadliest disaster in terms of damaged houses (50%), damaged roads (in meters) (63%), lost cattle (76%), missing people (25%), and economic losses (92%, approximately 22,022.2 million INR). The results also show that the cumulative effect of cyclones was highest in terms of deaths (37%), houses destroyed (46%), people evacuated (57%), and damaged educational centers (80%), and hospitals (49%) as compared to the total natural disasters that occurred between 1970 and 2014. Drought has been the leading cause of crop loss (50%), damaging 12,046,254 ha of crops. Over the years, heatwaves have also been affecting people, causing health concerns, and deaths.

3.2. Effect of Disasters on Livelihood, Food Security, Health, and Other Socioeconomic Conditions

According to the participants in our study, floods, cyclones, droughts, heatwaves, thunderstorms, and lightning are the most prevalent disasters in the state. The findings show that natural disasters had immense health and socio-economic consequences for rural people in Odisha. In Jagatsinghpur, participants pointed out that essential services such as electricity and water supply were suspended during floods and cyclones, and transportation and communication were disrupted leading to a delay in the distribution of relief. The problems persisted for 2-3 months, and the period of recovery lasted up to 4 months. The study also traced changes in the impact of cyclones over the past two decades. According to the participants, while the super cyclone in 1999 led to deaths and destroyed houses with thatched roofs, people were much more prepared during subsequent cyclones, although it was still devastating for them.

> *"Our house was completely washed away, and there were no remains of it. Our paddy crop was also destroyed completely. We had nothing except clothes. We stayed under a polythene hut for more than 6 months. In 2013, the main house did not collapse but the thatched roof was destroyed, the kitchen and the cattle shed collapsed, there was no food to eat for 2-3 days after cyclone Phailin. The crop was badly affected. The fish pond was submerged and all the fishes were lost. The entire lot of paddy seeds were destroyed. The tube well also broke as tree branches fell on it. So in 2013 cyclone, the accumulated loss was over 2 lakhs INR."* (Unmarried female, 20 years, IDI)

Participants in rural communities in Nuapada, Jagatsinghpur, and Sundargarh pointed out that natural disasters impacted children's education. When cyclones hit, schools remained shut because they were used as shelters for a long

Table 2. Cumulative impacts of natural disasters on population, Odisha, 1970-2014.

Natural disasters	Deaths	Injured	Missing	Directly affected	Indirectly affected	Evacuated
Cyclone	21,112	943	143	941,902	27,905,612	2,218,588
Flood	3545	138	176	1,636,685	93,352,240	1,555,800
Drought	2217	223	NA	20	3,486,756	NA
Heatwaves	1033	285	NA	0	723	NA
Total*	57,306	86,154	716	2,600,441	130,524,600	3,900,450

Source: DesInventar; NA: Not applicable; *total includes impacts from cyclones, floods, droughts, heatwaves and other natural disasters.

Table 3. Cumulative impacts of natural disasters on socio-economic factors and infrastructure, Odisha, 1970-2014.

Natural disasters	Houses destroyed	Houses damaged	Education centers	Hospitals	Crops damaged (in hectares)	Lost cattle	Road damaged (in meters)	Losses in INR
Cyclone	885,218	1,919,219	8,128	191	4,050,726	946,327	27,366	13,973,002,737
Flood	391,124	1,965,313	1683	178	6,742,742	3,019,943	47,031,973	220,220,434,423
Drought	NA	NA	NA	NA	12,046,254	NA	NA	288,650,000
Heatwaves	NA	NA	NA	NA	NA	NA	NA	11,800,000
Total*	1,943,679	4,017,795	10,202	389	23,773,643	3,993,510	74,801	239,470,830,605

Source: DesInventar; NA: Not applicable; * total includes impacts from cyclones, floods, droughts, heatwaves, and other natural disasters.

duration. During drought situations, children of migrants often dropped out of school. Being in school beyond 9 am became difficult during heatwaves as the school building was made of concrete and there were no fans.

It was observed that these disasters affected agriculture, although with varying impacts. According to the majority of participants in the study sites, the changing climate, irregular rainfall, and recurrent disasters reduced crop productivity. Farmers had to contend with constant crop loss due to recurrent floods. Most participants in Jagatsinghpur said that floods and cyclones led to submergence of agricultural fields and saline water inundation, rendering agricultural fields uncultivable in subsequent years. When broken embankments were not repaired in time after the floods, the possibility of cultivation was delayed further. According to participants in Jagatsinghpur, the livelihoods of people engaged in fishing and prawn cultivation was affected due to the damage caused by cyclones to boats, fishing nets, fishponds, and prawn hatcheries that led to financial losses. The cultivation of tiger prawns reportedly stopped after the super cyclone in 1999.

> *"Here, the cultivation and the plantation are not possible due to saline water. Over the years, the production has gone down in our area."* (Housewife, 35 years, IDI)

Participants in Nuapada noted that groundwater depletion and water scarcity were characteristics of the present drought situation. Along with this, their major dependence on scarce rainfall and lack of adequate irrigation facilities led to crop loss. Farmers were not able to secure loans from formal sources for agriculture purposes if they failed to repay earlier loans. Farming had increasingly become an unviable occupation in recent years, rendering people engaged in the sector highly vulnerable. Droughts affected the prospects of sharecroppers and small and marginal farmers. Agricultural laborers were also affected due to the lack of farm work.

> *"Farmers are largely affected by drought. As there is no agriculture and production, we don't have any earning. Because of this, we are not able to send our children to school and always encounter problems in feeding our family and providing clothes to family members. We are not even able to provide treatment when our children have any health problems…. There is no money with us for our sorrow and happy time, and for treatment…. Usually, food and work are available when paddy is harvested. If there is no rain, then there is no paddy and no work is available in our area. Due to this, older people like us face more problems."* (FGD participant, Nuapada)

Most participants in Sundargarh said they had experienced temperature increases up to 50°C during March–June in the last decade. Participants observed that heatwaves had become more intense in Sundargarh and affected the livelihoods of roadside vendors, small businessmen, rickshaw pullers, and daily wage laborers. Heatwaves affected cattle rearing due to a lack of vegetation during the dry season. With the rising temperature, the cattle died roaming in the heat due to lack of water; hence, people were no longer interested in keeping them. The rising temperatures made it difficult for people to work in the scorching heat, thus hampering their limited income-earning opportunities. Heatwaves also had an impact on people's routines, because they were unable to go out in the extreme heat and eat or sleep properly.

> "*It is very difficult to go outside after 10 am and the heatwave persists up to 4 pm in the daytime. After 1 pm the hot wind blows, and it is difficult to stay home in the afternoon. I usually go to the shade of a mango tree near my home. For me, it is difficult to move because my left leg and left hand are affected by polio. So, I move by an old tricycle. Riding tricycles on a bad road in this scorching heatwave is really challenging for me. I have to hold the tricycle only in one hand, which requires a fair amount of energy, and due to this I feel tired quickly. Every day, I have to go to the pond which is around 500 m away from my home to perform daily activities like toilet and bath."* (Person with disability, 18 years, IDI)

Participants from the three study sites experienced the effects of natural disasters on their food security. Participants in Nuapada described the changes in food security concerns that have occurred over the decades. While thousands died of starvation as a result of the droughts in the 1980s, the government response to drought at present was said to be much better. Participants pointed out that when droughts occurred for consecutive years, the challenge to meet food requirements became arduous, as food grains were not stored beyond a year. Income loss in Sundargarh posed similar challenges for food security. In Jagatsinghpur, participants noted that the food stock got depleted within 10 days after floods and cyclones. Stored food grains were washed away, and shops did not open for weeks. Another challenge that emerged was that standing crops and farm vegetables were damaged during floods, affecting the availability of food. Some participants recounted the debts that were incurred in trying to meet food requirements in a large family.

As per the participants, natural disasters affected the quality and accessibility of drinking water, sanitation, and irrigation in the study sites. In Jagatsinghpur, the invasion of saline water in the land area affected drinking, cultivation, and daily life. The scarcity of water during droughts and heatwaves affected drinking, bathing, sanitation, daily household uses, irrigation, and cultivation, particularly for the disabled and older population. In some places, it was also reported that women had to travel far to fetch water, and in a few places, the waiting time at tube wells had increased by up to half an hour.

"Water scarcity leads to low productivity in the land, and livestock do not get sufficient water. We are always facing problems for bathing, washing, and drinking water." (Housewife, 27 years, IDI)

Other water sources, such as ponds, had dried up, and the water level in the river had also reduced. Participants in Sundargarh stated that the lack of water disrupted the supply of electricity, which resulted in the irregular supply of drinking water. Heatwaves and droughts have become more intense in recent years in Odisha as a result of less rainfall and extreme temperatures in the area.

Communities reported multiple health problems resulting from natural disasters. Participants in Sundargarh particularly noted an increase in incidence of sunstroke and deaths related to heatwaves. Participants listed a number of signs and symptoms of health issues related to heatwaves such as dehydration, heat cramps, heat exhaustion, sweating, swelling, fainting, dizziness, headache, body ache, vomiting, fever, and diarrhea. Heatwaves also created health problems for people who worked outdoors to earn a living. School and college-going students experienced head reeling (vertigo) and weakness, while pregnant women reported feeling uneasiness during heatwaves. Participants in Nuapada described suffering from a number of ailments, such as malaria, anemia, malnutrition, diarrhea, and weakness during drought periods. Participants reported that the health of migrants returning from destination states was affected. They also reported that malaria was highly prevalent in the area, and an average of 30 patients were admitted to the hospital every month.

According to participants in Jagatsinghpur, floods, and cyclones caused diarrhea, malaria, jaundice, pneumonia, vomiting, fever, cold and skin infection, and even led to deaths following an outbreak of diseases. With the inundation of water, often contaminated with the presence of dead bodies and open defecation, people contracted diseases, and snake bites. Other impacts of disasters included mental health problems. Some people developed psychological problems because they did not have jobs and struggled to make ends meet as a result of droughts and heatwaves. Cases of post-traumatic stress disorder (PTSD) and trauma have also been reported, particularly after the 1999 super cyclone in Jagatsinghpur.

"Many severe mental health problem cases were observed at that time. Many people were in mental trauma or post-traumatic disorders after the 1999 cyclone. Some people did not even recognize their family members. We had seen people in our area that could not recognize their family members, and when they saw us they called us by their daughter's name or some even said you are my daughter. The situation was so sad, you can't imagine. It happened due to the shock of super cyclone." (FGD participant, Jagatsinghpur)

Psychological trauma, stress, and depression have also been reported, linked with continuous losses in agricultural livelihoods due to natural disasters in the study sites in Odisha. People in Nuapada, Jagatsinghpur, and Sundargarh faced financial hardship in seeking treatment and traveling to reach government hospitals. Although they received free medicine from government hospitals for small ailments, in many cases, they said they had no option but to do medical tests and purchase other medicines from private pharmacies/shops. The burden of extreme events exacerbated their debt, and out-of-pocket health expenditures worsened their financial position. It was also seen that health facilities were not equipped, and hospital staff was inadequate during cyclones and floods as large numbers of people visited hospitals at that time.

3.3. Community Resilience and Government Measures to Mitigate Natural Disasters

3.3.1. Community coping and adaptation strategies

Qualitative results showed that many coping and adaptation mechanisms were taken by communities to protect or mitigate the natural disasters in the study areas (Figure 1). This figure described that natural disasters are reported to affect agriculture, food security, livelihood, health, drinking water and sanitation, and the infrastructure of the state. However, the governmental initiatives such as crop insurance, weather forecasting, compensation schemes, health camps, etc. together with individual/community strategies such as changing diet, storing food grains, crop diversification, etc. could build the resilience systems or cope with negative effects caused due to disasters.

Participants in Sundargarh undertook a variety of strategies to adapt to the rising temperature. They ate cucumber and watermelon and drank water, rice water, lemon water, soft drinks, curd water, *jaljiraa* (spice drink), *aam panna* (mango drink) and oral rehydration solution (ORS) supplied by *Anganwadis* (child-care centers). In rural Odisha, they poured water on their heads to keep themselves cool, stored water in earthen pots, and wrapped vegetables in wet clothes. People used fans/coolers, put up *khus-khus* (mats made of the woven roots of this perennial grass can keep out heat when bound with cords and hung in the doorway), and damped the door screens; and if there was no electricity in the afternoon, they damped their cotton mattresses. Some other coping mechanisms included covering asbestos roofs with straw, sprinkling it with water, and repairing tiles to keep the sun out. Those with cattle sprayed water on the roof of their cattle shed when the temperature rose. Participants mostly avoided venturing out during the scorching heat. If it was essential to

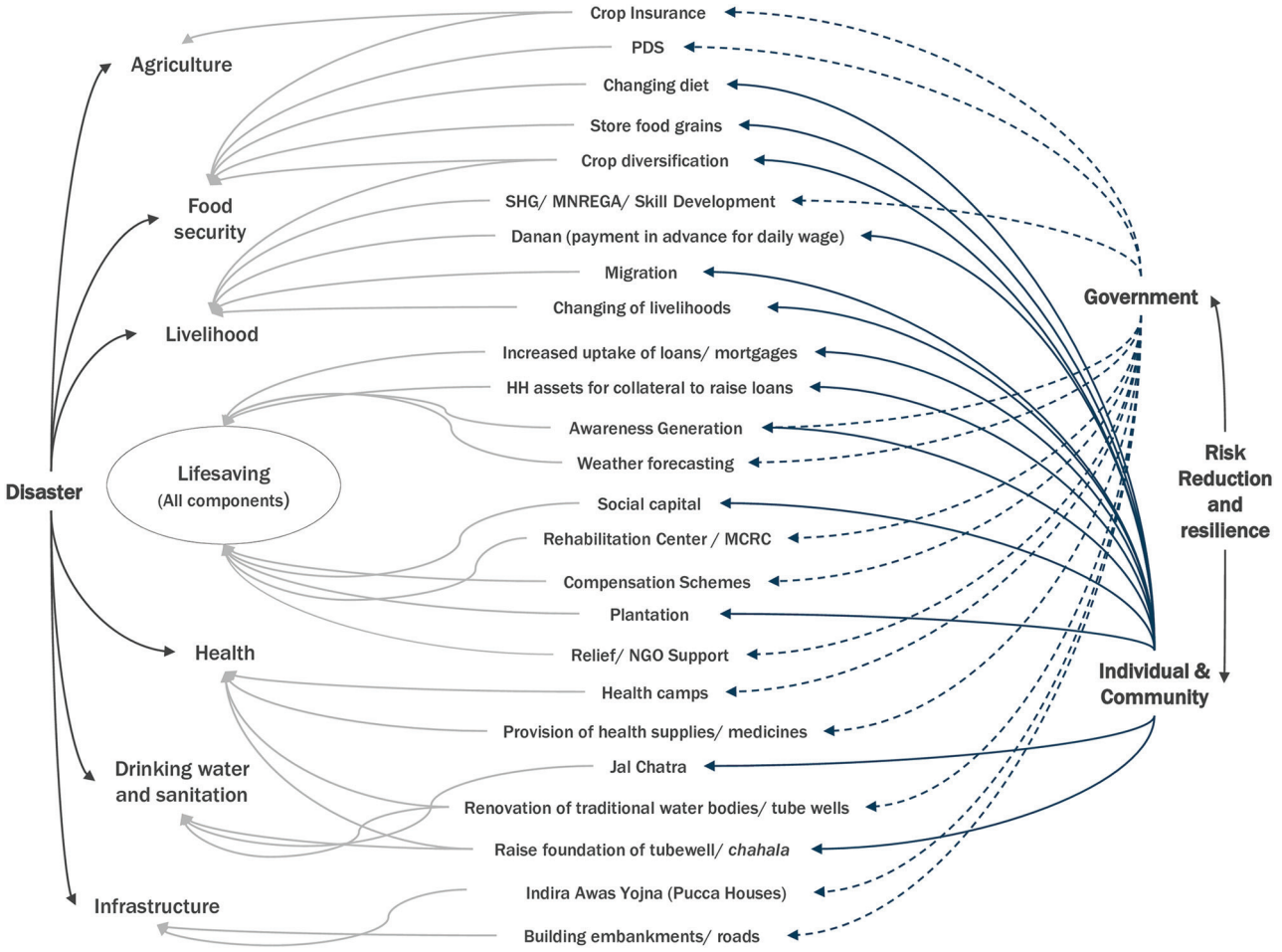

Figure 1. Pathways of effects, coping, and adaptation to natural disasters in rural communities in Odisha, India.

go out, participants carried water bottles, wore wet clothes, hats, and slippers, and used an umbrella. Often people were compelled to engage in labor work for their survival in the scorching heat as they had no other choice for earning, but they tried to avoid working during the peak heat hours.

> *"Before heat wave begins, I put straw on the asbestos and make the room cool and reshuffle the tiles. These activities are done in March. Water is sprayed on the roof of the cattle shed when the heatwave increases. I damp the door screen and by this way make the room cool and the children can sleep. Sometimes I use wet cotton mattress after 12 noon if there is failure of electricity to keep the room cool."* (Farmer, 51 years, IDI)

To cope with income shortages resulting from natural disasters (particularly in drought situations), people in Nuapada migrated for work to nearby towns and other states, changed their occupation, borrowed food from neighbors, and also depended on remittances. Participants in Nuapada stated that they took food on credit from shops and repaid their debts after they had earnings from migration. Sometimes people bought rice from shopkeepers by exchanging forest products or millet. Further, many rural participants stated that the Public Distribution System (PDS) was useful in an emergency, although insufficient. The results suggested that in many instances, people had to compromise on the food they ate due to the effect of disasters. Participants recalled that in the past, they stored surplus food grains to cope with droughts; however, they had to resort to other alternatives at present (e.g., migration). Migration (to work as bonded laborers [*Pathuria or Dadan* system] in neighboring states) had repercussions for individuals and their families, particularly in Nuapada. Participants further added that often migrants were unable to repay their debt.

> "*Earlier, people used to cultivate Mandia (finger millet), Suan (little millet), and Gurji (fox-tail millet) and stored these items in their home for future use, so when there was a drought they used the stored millets to manage their families. In case of emergency or shortage of food, people used to borrow or lend from the local money lender. Now*

people in our area prefer to migrate for work outside in cases of drought or any family emergency. Earlier people feared going outside for work, but now people do not want to stay in trouble but prefer to migrate and earn to maintain their families." (FGD participant, Nuapada)

Social capital was a key factor in the community response to cyclones and floods in Jagatsinghpur. Communities often took the first initiative to help, through family and community groups, with the government subsequently providing support. After the super cyclone in 1999, participants said that the community itself was the first to provide immediate help or shelter, and the government stepped in thereafter and offered support through rescue and relief activities. According to participants, there was a strong sense of community feeling during floods. People carried sticks and torchlights to rescue others onto river embankments and other areas. They also said that people ate rice left soggy after floods and green coconut to cope with food shortages in the immediate aftermath of cyclones or floods. Similar to Nuapada and Sundargarh, people in Jagatsinghpur skipped meals, and food was distributed equally among family members (particularly among children and elderly persons) during the aftermath of natural disasters.

After the 1999 super cyclone, community preparedness for cyclones was scaled up. Participants said that mechanisms to save human lives and cattle were given priority. People became proactive in taking preventive measures, such as storing flattened rice, jaggery, biscuits, potatoes and other vegetables, stoves and kerosene, and drinking water. When floodwater increased beyond a danger line, people moved to a higher place (e.g., stable *pucca* houses of neighbors, or public buildings such as multipurpose cyclone rehabilitation centers (MCRCs) and/or schools) with dry foods. Many villagers have built pucca houses with raised foundations. In their houses, they built a shelf (plank) for keeping important documents safe. The platforms of tube wells were raised, and toilets were built higher off the ground. Preservation of coastal mangroves to protect villages from the effects of cyclones was emphasized, and people grew plants locally that could shield homes from strong winds. Community members kept themselves updated and informed about impending cyclones and floods through television and newspapers.

"*We have built a semi pucca (cement wall and thatched roof) house now. We have also planted acacia, eucalyptus, casuarina near the house to shield ourselves from the wind. We purchased TV and newspaper in our home to know disaster-related information. We also raised the foundation of our house for protection from water, and constructed high-rise tube well in the house for drinking water. In addition, we keep polythene and rope in our home, store kerosene, keep important documents in a box for safety, store food from August onward because of the prevalence of cyclone, particularly in October and November*." (Unmarried female, 20 years, IDI)

For livelihoods and food security, participants reported that some people grew alternate crops such as black gram, some switched to cultivating white shrimp rather than tiger prawns, and others took up alternative occupations such as setting up cloth and eatery shops in Jagatsinghpur. In Nuapada and Sundargarh, people took up daily wage work and the sale of forest products as the survival mechanism from natural disasters.

3.3.2. Government measures, schemes, and policies

As noted by the state meteorological official, some of the strategies the government used to help people during cyclones and floods included early weather information and updates on natural disasters, communicated to the special relief commissioner, and the Odisha State Disaster Management Authority (OSDMA). The district collector and organizations such as National Disaster Response Force, Central Industrial Security Force, the Airport Authority, and hospitals were informed about the weather through text messaging. Regular weather updates were provided to the print and electronic media. Warnings were disseminated through a digital cyclone detection center. According to a key stakeholder with OSDMA, the preparedness of the district emergency officer, is crucial to coping with any disaster. Before a disaster, the district emergency office organizes a preparatory meeting with all the government departments. Rescue, operation, and first aid teams are formed. Most participants in Jagatsinghpur said that the establishment of MCRCs, in the wake of the destruction wrought by the super cyclone in 1999, has been useful for providing shelter to people during natural disasters.

"*During Phailin in 2013 and Hudhud in 2014, people had Indira Awas, cyclone rehabilitation center, and school buildings, so people stayed according to their convenience after they heard about the cyclone in the mike announcement. Due to the fear of super cyclone in 1999, people stayed in safe places and also stored dried food like flatten rice, biscuits with them. Because we knew of the difficulties encountered during super cyclone."* (FGD participant, Jagatsinghpur)

Government participants explained that the Shelter Management Committee carried out a vulnerability assessment exercise to map people in the community, to prioritize rescue and evacuation operations during disasters. Provision of pucca houses under the *Indira Awas Yojana* to below poverty line families was considered beneficial for people; however, the amount provided under different compensation schemes was found to be insufficient. According to the government participants, the state government in Odisha had introduced policies and adaptive measures to address challenges posed by

heatwaves and droughts, among other climatic issues. The State Nodal Officer, Climate Change, highlighted that the Odisha government had initiated pro-climatic policies and adaptation strategies for agriculture. *Chahala* (water holes) was dug in the riverbank for extracting water to drink during heatwaves. At community level hubs, *jal chatra* (large clay communal water pots kept under a shed) was set up to serve people water during the heat. Further, the government was said to be promoting self-help groups (SHGs) in the community to ensure that in times of different extreme climatic events families were secured financially and engaged in productive activities. According to government participants, SHGs were linked with banks for loans at lower rates of interest (7%) and subsidy (3%), and training was imparted to SHGs for vegetable cultivation, fisheries, mushroom cultivation, rice business, midday meals in schools, and other small-scale industries.

A government program in Nuapada that has been largely effective, Seasonal Residential Care Centers (SRCCs), has enabled children of many migrants to continue their education and prevented them from child labor. As per the government stakeholders in Sundargarh, some key actions taken by the government to help the community combat heatwaves included a change of working hours, particularly at Anganwadis and schools, sensitization about heatwaves by the medical officer on each block, and provision of ambulance facilities. Other measures included the establishment of sunstroke units at community health centers (CHCs) and district hospitals; beds, air conditioners or air coolers, ice packs, medicines, and ORS were arranged in these facilities. Under the *Gaon Kalyan Samiti* (Village Welfare Committee), water was distributed, and sheds were set up in different places so that people could take rest.

One drawback pointed out by participants on the part of the government was that it was not playing a leading role in implementing schemes, digging ponds, installing tube wells, establishing irrigation facilities, harvesting rainwater, and supplying seeds. Not all farmers received fertilizers and seeds distributed through government programs. Awareness generation on drought and cultivation by village-level workers was sporadic, and information was not provided at the right time for sowing seeds. Participants also highlighted that compensation on crop loss was insufficient. Many people who were not able to insure their crops due to poor financial status were not compensated, and additionally, it was observed that awareness of government schemes was less. According to participants in Nuapada and Sundargarh, the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) lacked proper implementation, as an adequate number of workdays was not provided under the scheme. Moreover, wages provided under the scheme were irregular and reportedly lower than the prevailing wage, and the entire amount was often not paid.

4. Discussion

This study highlights that floods, cyclones, and droughts are severely affecting the people of Odisha in various ways. Heatwaves and lightning are also slowly emerging as major disasters in Odisha due to the severity of impact in recent years. The study also reveals that there is uncertainty about the timing and duration of seasons in recent years due to sudden changes in climate. The impact of natural disasters on people's life is calamitous, particularly on their livelihoods, agriculture, food security, health, water and sanitation needs. The study shows that agriculture, which is the main source of livelihood for the majority of participants in the study, has become increasingly affected along with other livelihoods. Multiple disasters impacted agriculture in various ways, from complete submergence of fields and salinization of soil during cyclones and floods to loss of crops and reduced production during droughts and heatwaves.

Individuals in the study areas observed that these events may have become more intense in recent years, leaving scarce employment opportunities and having long-term effects on livelihoods and income-earning capacity. This is further substantiated by multiple studies that argue that agriculture, the primary source of livelihood for the majority of the population, is the most widely affected by multiple natural hazards (Mishra, 2007; Chhotray and Few, 2012; GOO, 2016; Duncan *et al*., 2017; Patel *et al*., 2019); however, the magnitude of losses in agriculture varies according to each disaster. For instance, between 1965 and 2008, droughts caused higher losses in crop production than cyclones and floods (Paltasingha and Goyarib, 2015). Droughts, while directly impacting agricultural production, also proved detrimental for farmers, laborers, and sharecroppers. Heatwaves made it difficult for people to work outdoors thus depriving them of basic sources of income, and this has disproportionately affected the poorer sections of the society who cannot afford to let go of their work. Another study corroborated our findings that heatwaves are anticipated to reduce the working capacity of people working in exposed conditions (Dash and Kjellstrom, 2011). Cyclones have also been detrimental to livelihoods other than agriculture (fisheries, and prawn cultivation) in Jagatsinghpur because they damage boats, fishing nets, and prawn hatcheries. Our findings are similar to the findings of other studies that showed that small landholders in coastal areas of Odisha turned a portion of their agricultural land (due to salinization) into prawn ponds but found cultivation of prawns to be unviable due to lack of credit and technical knowledge, and then they were unable to convert the land back for cultivation (Iwasaki *et al*., 2009; Chhotray and Few, 2012).

Disasters impacted most livelihoods in the area under study, and food security was recognized as a major concern. In the immediate aftermath of disasters, there is an extreme shortage of food and food security becomes a chronic issue. Other studies in Odisha and other parts of India support the argument that natural disasters have impacted the food security of people disproportionately (Ramakrishna *et al.*, 2014; Duncan *et al*., 2017; Mishra, 2017). With food insecurity and the unavailability of clean drinking water, multiple waterborne diseases such as diarrhea and jaundice have been diagnosed, and vector-borne diseases like malaria are rising; thus, health emerges as a major source of concern for people in these study areas. A study on the impact of climate change also highlighted that frequent flooding increased the spread of both vector-borne and diarrheal diseases (Mishra, 2017). Heatwaves, in particular, cause multiple heat-related ailments such as dehydration, headache, dizziness, and sunstroke, resulting in deaths in extreme cases.

The impact of natural disasters on health is not limited to physical health, and people in our study areas repeatedly talked about their mental and psychological concerns. Psychological disorders like PTSD are common after a disaster, with the chances of being affected directly related to the extent of exposure to the disaster (Galea *et al.*, 2005). In the aftermath of the 1999 super cyclone, studies showed that trauma and depression were widely prevalent among the population (Kar *et al*., 2004; Chhotray and Few, 2012; Patel, 2018a). Further, another study substantiates that apart from direct exposure to disaster, deaths of close ones, low socioeconomic status, and dissatisfaction with relief and rehabilitation efforts have made people more vulnerable to psychological disorders (Kar *et al*., 2004). A study by Shultz *et al.* (2007) pointed out that the psychological impacts are more expansive in scope, more extended in time, and frequently more debilitating in severity than the injurious physical impacts of natural disasters. An important finding of our study is the drawback of the public health system. People in all the study sites had to travel far to reach government hospitals, and the lack of all-weather roads revealed the shortcomings in infrastructure in rural Odisha and the challenge this poses during emergency situations in the event of disasters. Another study supports our findings by highlighting that the distance to a health facility makes people more vulnerable during the disaster (Sam *et al*., 2017). Heavy out-of-pocket expenditure and debts incurred in the process aggravate the community's financial burden and mental health problems. Expenditure on health care also leads to a decrease in consumption levels of households, as shown in Patnaik *et al*. (2016).

This study also highlights that the impacts on vulnerable groups such as the poor and older adults, and pregnant and widowed women are much more severe than impacts on other subpopulations. An important finding of the study is the challenge faced by disabled people. The income-earning opportunities for the poor, the tribal, agricultural laborers, and small and marginal farmers are shown to be affected vastly by natural disasters. Lack of resources, adaptive capacities, and alternate employment opportunities put these individuals at the forefront of desolation from natural calamities (Mishra, 2017). Paltasingha and Goyarib (2015) revealed that climatic extremes affect small and marginal farmers more than medium-scale farmers, and they find it difficult to cope. Another key finding of our study is the myriad ways in which children's education is also adversely affected by heatwaves, cyclones, droughts, and floods. The use of schools as shelters in the aftermath of cyclones and floods resulted in the disruption of education for a long period, whereas heatwaves resulted in changes to school hours. In addition, our study reveals that in drought-affected areas, the cases of children dropping out of school and becoming employed in brick kiln and construction sites at migration destinations are a serious concern.

Our findings also contribute to the existing literature on coping mechanisms (Mishra and Mishra, 2010; Chhotray and Few, 2012; Patnaik *et al*., 2016). With the increasing intensity and frequency of disasters, people have made an effort to adapt to natural disasters by undertaking short- and long-term measures. There has been better preparedness since the 1999 super cyclone (people have taken steps to protect their lives and property). In the study areas, people opined that even though starvation deaths have been averted in recent years, there is a struggle to meet food requirements through various means (borrowing from neighbors/moneylenders, buying from shops, the PDS, and alternate employment). Help and assistance provided to people by the community during the time of cyclones and floods is an essential coping mechanism. Often described as a social capital approach (Mancini and Bowen, 2009), communities tend to offer the first responses themselves, through family and community groups, with the government subsequently providing support. The importance of social capital in the event of disasters has been stressed further in other studies (Lo *et al*., 2015; Sanyal and Routray, 2016). In addition, our study shows that people take loans from local moneylenders, relatives, and self-help groups to recover from losses caused by disasters and incur debts in the process. Other studies show that due to the absence of the official credit system, fishermen have been forced to sell fish at low prices in return for loans (Vivekananda *et al*., 2014). In addition, selling livestock at low prices and taking up daily wage labor were other measures adopted by the farmers in the disaster-affected areas of Odisha (Patel, 2018a; Patel, 2018b). Our study furthermore highlights that the short-term alternate employment opportunities offered as part of government programs (e.g., MGNREGA) were not sustainable and need proper monitoring in the disaster-prone areas.

This study indicates that due to the paucity of sustainable employment opportunities locally during disasters, migration becomes a key coping mechanism for rural people. Other studies have shown that migration is a common phenomenon after natural disasters, with youth migration being the most commonplace (Mishra and Mishra, 2010; Jülich, 2011; Vivekananda *et al*., 2014; Patnaik *et al*., 2016). Migration was also described as a new phenomenon over the past two decades by participants in our study and was not prevalent earlier. Migration of the youth to urban cities and other states has also impacted the social fabric of the society because older adults are left behind to fend for themselves in the villages. However, the establishment of SRCCs in Nuapada has been one of the most successful government programs and has enabled the continuation of education for children of drought-affected people who migrate.

Other useful government programs/schemes highlighted by the community include an Early Warning System, PDS, MCRCs, SCRCs, and pucca houses provided under the Indira Awas Yojana. According to government participants, the Odisha government has also initiated pro-climatic policies and adaptation strategies for agriculture (e.g., flood- and drought-resilient crops); however, its implications need to be seen on a large scale. Some of the concerns raised by community participants were that the government was not proactive in the implementation of water-related efforts, irrigation, and awareness-generation relating to agriculture and insurance. The study points out that government schemes need to be scaled up with proper monitoring mechanisms put in place so that the communities can be made more disaster resilient in the process.

This study has some limitations. As disasters affected the selected areas over different points in time, the accuracy and precision of the information provided could have been affected, especially as some of the community members would have relocated, died, or forgotten certain vital events (particularly the incident of cyclone, as it is not frequent).

5. Conclusions

This study highlighted that multiple disasters have ravaged Odisha, particularly affecting poor, small and marginal farmers, sharecroppers, vendors, children, and the older population and women (due to their weaker adaptive capacities and lack of resources), and jeopardized government measures. The study has further enhanced our understanding of the ways, in which droughts, floods, cyclones, and heatwaves have challenged people's resilience. It suggests that while there has been an improvement both at the community level (e.g., social capital) and the government response (e.g., early warning systems) to the disasters over the past two decades, a lot more needs to be done on the resilience front. Government response to natural disasters requires a proactive and sustainable approach aiming at reducing people's vulnerabilities. Such a response will improve the adaptive capacity of the community, making it more resilient, and contributing to achieving Sustainable Development Goals (SDGs) and reducing poverty over the longer run. Measures also need to be taken for livelihood regeneration and the creation of alternate employment opportunities that are sustainable. Mechanisms need to be strengthened in developing a social capital approach in the context of resilience to all disasters, and the community needs to be engaged in devising policies and programs related to disasters and resilience at the local level. Furthermore, research and advocacy are required to highlight these issues both at the local and global levels.

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Authors' Contributions

Conceived and designed: Sangram Kishor Patel. Review of literature: Sangram Kishor Patel, Bincy Mathew, and Ankit Nanda. Contributed to tools/materials/data collection: Sangram Kishor Patel, Biswajit Mohanty and Niranjan Saggurti. Analyzed the data: Sangram Kishor Patel, Bincy Mathew, and Biswajit Mohanty. Drafted and wrote the manuscript: Sangram Kishor Patel, Bincy Mathew, Ankit Nanda, Biswajit Mohanty, and Niranjan Saggurti.

Conflicts of Interest

No conflicts of interest were reported by the authors.

Ethical Approval

Overall study design, questionnaires, and consent processes were reviewed and approved by the IRB of the Population Council, in New York.

Availability of Supporting Data

The secondary data "DesInventar: A disaster information management system" used in this study are publicly available at https://www.desinventar.net/DesInventar/.

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RESEARCH ARTICLE

Inequalities in urban exposure to infrastructure, services, and environment in million-plus cities of India

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Abstract: Unplanned spatial development, unregulated migration, and changing energy consumption patterns are likely to increase the vulnerability to climate change of populations inhabiting in urban areas. This study aims to estimate urban exposure level and examine the inequalities in the availability of infrastructure and the provision of services in million-plus cities in India. Using data from Census 2011 for 40 million-plus cities, this study measured urban exposure through the urbanicity scale ranging from 0 to 70 points. The urbanicity scores revealed a transparent gradient in the level of urban exposure across these 40 million-plus cities, with the scores ranging from 45.59 (the lowest, in Meerut) to 61.47 (the highest, in Delhi). The economic activity scores were similar for all the million-plus cities, whereas the health infrastructure scores showed a wide variation from 1.0 to 8.8 points. Population, health, educational infrastructure, and built environment contributed the most to the inequality. Unless addressed urgently, these inequalities in infrastructure and services will affect the sustainability of these million-plus cities and may hinder the country's achievement of Sustainable Development Goal 13 on climate change.

Keywords: Urban exposure; Environment; Urbanicity score; Million-plus city; India

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1. Introduction

Urban exposure, usually defined as the conditions found, especially in an urban area, influences the individuals residing in that particular area (Vlahov and Galea, 2002; Cyril, Oldroyd and Renzaho, 2013). An urban condition present at any given point in time determines the scope of urbanization in that area and is a strong predictor of future urban conditions. Cities or urban areas are densely populated and marked by the expansion of housing, transportation, infrastructure, and sanitation facilities. Unregulated migration, change in land use, and unplanned spatial development is likely to increase the vulnerability of the urban population to changes in weather and climatic conditions. Megacities stand out as the more visible face of urbanization due to their influence and economic importance and face a higher vulnerability to climate change (Reckien, Creutzig, Fernandez, *et al*., 2017). The growing number of small and million-plus cities will contain most of the world's population in the 21st century, facing inequalities in infrastructure and services created through different exposure levels and facing other severe challenges (Vlahov and Galea, 2002; UN-Habitat, 2016). In 2018, 55% of the world's population lived in urban areas compared to 43% in 1990 and this figure is expected to increase to 68% by 2050 (World Urbanization Prospects, 2018). Recent estimates reveal that 34% of the Indians reside in urban areas (United Nations, 2019).

The dynamics of the accumulation of individuals and the surrounding areas shape the pace of urbanization in particular areas (Kundu, 2006; Peng, Chen, Cheng, *et al*., 2011). The complexity of the urbanization process, however, makes it difficult to assess the

equality in infrastructure and services (Riha, Karabarinde, Ssenyomo, *et al*., 2014), more so in less developed countries, due to the inconsistent definitions of what constitutes an urban area and the lack of data (Montgomery, Stren, Cohen, *et al*., 2003). Urban exposure is an immediate means of studying the unique features of urban areas, their association with health, and their synergy with climate change (Allender, Foster, Hutchinson, *et al*., 2008; Novak, Allender, Scarborough, *et al*., 2012; Angkurawaranon, Wisetborisut, Rerkasem, *et al*., 2015). Several studies have focused on the urbanicity scale as a measure of urban exposure and its association with health (Novak, Allender, Scarborough, *et al*., 2012; Cyril, Oldroyd and Renzaho, 2013; Riha, Karabarinde, Ssenyomo, *et al*., 2014; Sothmann, Krumkamp, Kreuels, *et al*., 2015).

There is no scientific study assessing the inequalities in urban exposure, especially the availability of infrastructure and the provision of services in the million-plus cities of India. The present study aims to fill this research gap by estimating the urban city-scale for the million-plus cities. Efforts are also there to assess selected child health status and its association with available environmental indicators in some million-plus cities. The results are expected to be of use for urban planning and for understanding the possible long-term impact of climate change in the studied cities. The results may also be of importance in assessing the sustainability of these cities, providing real opportunities to mitigate and adapt to the effects of climate change, which is accepted by the United Nations as a sustainable development goal (SDG-13) to be achieved by 2030.

2. Data and Methods

2.1. Data

The present study used data from the towns directory, household files, and the Primary Census Abstract of the Census of India 2011 to construct the urbanicity scale. The Census of India is the primary official source of data on the urban population. It provides statistics on state and town- or city-level estimates of the urban population and also estimates on the availability of infrastructure and services in those localities. The 15th Indian National Census was conducted by the Office of the Registrar General, Government of India, in 2011 (ORGI, 2011). Census 2011 covered all the 28 states and seven union territories, including 640 districts, 497 cities, 5767 tehsils, and 640,867 villages. The Census was conducted in two phases – house listing and population enumeration. The house-listing and population census provide extensive information on the status of the population settlements, the housing characteristics, and the primary assets and necessities of the households. The Census of India provides information on a wide range of socioeconomic and demographic characteristics at the community, household, and individual levels. In addition to the census data, the present study used indicators of climate (mean temperature [maximum and minimum] and mean rainfall) for the selected cities as provided by the India Meteorological Department. Pollution data from the Central Pollution Control Board and the World Health Organization (WHO) Global Ambient Air Quality Database were also used to understand the climate conditions of some selected cities. There were 53 million-plus cities in India in 2011, but only 40 of them had more than one million population, whereas the rest had agglomeration population. The present analysis was restricted to the 40 million-plus cities.

2.2. Measurements of Exposure and Environments

2.2.1. Urbanicity scale measurement

The urbanicity scale was initially developed and used in the Philippines by Dahly and Adair (2007) and in India by Allender, Lacey, Webster, *et al*. (2010). Urbanicity, also called urbanness or urbanism (Dahly and Adair, 2007; Allender, Lacey, Webster, *et al*., 2010), is a broad concept that measures urban environments, health, and related issues. The urban exposure is influenced by the population composition, physical environment, social environment, availability of, and access to health and social services and all these are assessed through the urbanicity scale. The urbanicity scale helps highlight the differences and variations in the levels of urban exposure among the large million-plus cities. Following a review of the literature, we selected an existing multi-component urbanicity scale based on the availability of data. The scale used in the present analysis comprised of the following seven components: Population size, economic activities, built environment, communication, educational facilities, health facilities, and diversity. Specifically, information on population size; density; proportion of population involved in agricultural activities; availability of paved roads, sewage system, flush latrines, electricity, television sets, mobile phones, theaters, public phones, and public internet; literacy rate and availability of educational facilities; availability of health facilities, number of beds, doctors, para-medical staff; and households having good quality houses and tap water was used to construct the urban city scale.

The selected domains and variables for calculating urban city-scale were based on the literature review and availability of data from Indian Census. The scale scoring is modeled from Dahly and Adair (2007), Jones-Smith and Popkin (2010), and Novak, Allender, Scarborough, *et al*. (2012). At the final stage adopted the Riha, Karabarinde, Ssenyomo *et al*., (2014)

with some changes based on the data availability in Indian context. Summary statistics of the urbanicity scale are provided in Table 1. Each domain was assigned a maximum of 10 points, so the total score ranged from 0 to 70 points; further, these domains have variable information where these were equally divided points. For preparing the urbanicity scale, the additive method was used, where all the score values were added for each million-plus city to define the urban exposure level. The scoring algorithm and the characteristics of the urbanicity scale used for the present study are presented in detail

Table 1. The scoring algorithm used for the urbanicity scale.

Component	Score items	Scale scoring
Demographic characteristics	Population size	5.0
	1,000,000	0.5
	2,000,000	1.0
	3,000,000	1.5
	4,000,000	2.0
	5,000,000	2.5
	6,000,000	3.0
	7,000,000	3.5
	8,000,000	4.0
	9,000,000	4.5
	10,000,000	5.0
	Population density	5.0
	<5000	1.0
	5000-10,000	2.0
	10,000-15,000	3.0
	15,000-20,000	4.0
	More than 20,000	5.0
Economic activity	The proportion of the population involved in agricultural activities	10 points – 10*(proportion of the population involved in agriculture)
Built environment	Paved road	2
	Sewerage system (Open-0.67, closed-1.34, and both-2)	2
	The proportion of household with flush latrine	2*(proportion of household with flush latrine)
	Electricity	2
	The proportion of household with domestic electric connection	2*(proportion of household with electric connection)
Communication and entertainment	The proportion of household having a TV	2*(proportion of household having a TV)
	The proportion of household having a mobile	2*(proportion of household having a mobile)
	Population per theatre	2
	Public telephone	2
	Public internet	2
Education	Literacy rate	5*(literacy rate/100)
	Educational facilities: Primary, secondary and university	5
Health	Hospital per ten lakh population	2*Decile value/10
	Hospital alternative medicine per ten lakh population	2*Decile value/10
	Beds per lakh population	2*Decile value/10
	Doctors per lakh population	2*Decile value/10
	Para-medical staffs per lakh population	2*Decile value/10
Diversity	The proportion of having a good quality of houses	5*Proportion of good quality house
	The proportion of household with tap drinking water	5*Proportion of household with tap water supply

Table 2. Urbanicity scale characteristics for 40 million-plus cities in India in 2011.

Range	15.880
Minimum	45.589
Maximum	61.469
Mean	52.477
Standard deviation	4.043
Item variance	6.392
Sample variance	16.347
Cronbach's alpha	0.638
Count	40

in Tables 1 and 2. It is worth mentioning that all the different kinds of parameters used for the calculation of the urbanicity scale and the respective scores of the 40 million-plus cities are available in Appendix Table 1A and 2A.

2.2.2. Measurement of selected environmental indicators

The Air Quality Index (AQI) is an index for reporting air quality and tells the health effects one can experience after breathing the polluted air. The index is calculated by transforming the weighted values of individual air pollution-related parameters (e.g., SO_2, CO, visibility, etc.) into a single number or set of numbers (Central Pollution Control Board, 2014). The index has six categories, i.e., (i) good: 0-50, (ii) satisfactory: 51-100, (iii) moderately polluted: 101-200, (iv) poor: 201-300, (v) very poor: 301-400, and (vi) severe: >401. This study used the available AQI by Central Pollution Control Board for the year 2016, and PM2.5 (diameter of <2.5 mm) and PM10 (diameters 10 or <10 mm) were adopted from the published report of the WHO Global Ambient Air Quality Database (2018). In addition, information on temperature and rainfall during 1901-2000 in selected cities, available on the Government of India website, was used to assess the changing climatic condition and its possible effects on health and environment.

2.2.3. Measurement of selected health indicators

To assess the health status of children residing in selected million-plus cities under study, we used the data from the representative National Family Health Survey (NFHS)–4, 2015-2016. We estimated the children's nutritional conditions in terms of stunted (short for their age), wasted (thin for their height), and underweight (thin for their age). The proportion of children 0-59 months of age who have their height-for-age two standard deviations below the WHO (WHO, 2006) growth reference (HAZ <−2) was considered as short for their age. Similarly, the proportion of children 0-59 months of age whose weight-for-height and weight-for-age were two standard deviations below the WHO growth reference was considered as wasted and underweight, respectively. In addition, the information on the acute respiratory infection (ARI) for children under age 5 years in the past 2 weeks preceding the survey was used. The ARI symptoms consist of cough accompanied by (1) short, rapid breathing that is chest related, and/or (2) difficult breathing that is chest related.

2.3. Data Analysis

Statistical Softwares such as STATA (V16) and MS Excel were used for data analysis. Specifically, the NFHS-4 data were analyzed through STATA and the census data were analyzed in MS Excel. Again, GeoDa software was used for generating the cartographic maps.

2.4. Ethical Consideration

The study used the secondary data available in the public domain for larger use by researchers and policymakers and hence any ethical approval was not sought for this study.

3. Results

3.1. AQI in Selected Million-plus Cities, 2016

Table 3 shows the AQI and the particulate matter (PM) measurements for the selected million-plus cities of India. A lower AQI value means better air quality, whereas a higher AQI value means worse air quality. For the year

Table 3. Air quality index in selected million-plus cities of India, 2016.

Million plus cities	Population (2011)	Density (2011)	Air Quality Index (2016)*	$PM_{2.5}$**	PM_{10}**
Mumbai	12,442,373	20,634	100 (42-158)	64.0	104.0
Delhi	11,034,555	19,660	293 (186-372)	143.0	292.0
Bengaluru	8,495,492	11,470	145 (76-220)	46.0	96.0
Hyderabad	6,993,262	27,638	116 (61-295)	44.0	84.0
Chennai	4,646,732	26,553	147 (68-308)	49.0	80.0
Pune	3,124,458	40,093	173 (88-250)	50.0	89.0
Jaipur	3,046,163	62,85	221 (148-301)	105.0	193.0
Lucknow	2,817,105	8077	307 (192-393)	138.0	255.0
Kanpur	2,768,057	10,377	261 (165-378)	173.0	319.0
Patna	1,684,222	15,640	290 (178-426)	144.0	266.0
Agra	1,585,704	13,152	233 (76-309)	131.0	194.0
Varanasi	1,198,491	14,598	291 (186-375)	146.0	260.0
Jodhpur	1,056,191	13,438	186 (114-333)	98.0	180.0

Data source: *Central Pollution Control Board, 2016, **WHO Global Ambient Air Quality Database (update 2018).

2016, Lucknow showed the highest AQI of 307, followed by Delhi (293), Varanasi (291), and Patna (290). On the other hand, Mumbai showed the lowest AQI of 100, followed by Hyderabad (116), Bengaluru (145), and Chennai (147). According to the 2018 estimates for PM by the WHO Global Ambient Air Quality Database, the highest PM_{10} measurement (PM having an aerodynamic diameter ≤10 μm) was shown by Kanpur (319 μg/m^3) followed by Delhi (292 μg/m^3), and Patna (266 μg/m^3). These cities showed a similar pattern for $PM_{2.5}$ (PM having an aerodynamic diameter ≤2.5 μm).

3.2. Health Status of Under 5 Children in Selected Million-plus Cities of India, 2015-2016

The health status of the children under 5 years is associated with certain environmental indicators in selected million-plus cities of India (Table 4). As may be seen, a higher percentage (44%) of the under 5 children in the city of Kanpur, which was having a poor AQI (PM_{10}-319), found to be stunted. As against, in Hyderabad, with a better AQI (PM_{10}-84), only 16% of the under – 5 years children were found to be stunted. In addition, in Varanasi, which is having a relatively poor AQI (PM_{10}-260), 5% of the under – 5 years children suffer from ARI. However, there were inconsistencies in the perceived association between AQI and child nutrition, as there are many other significant factors that influence child health and nutrition.

3.3. Temperature and Rainfall in Selected Million Plus Cities 1901-2000

Temperature and rainfall are important environmental indicators having an influence on the health status of the population. Figure 1A-C presents the mean minimum temperature, the mean maximum temperature, and the mean rainfall for a 100-year period in selected cities of India (1901-2000). The figures clearly showed the monthly changes in these indicators between 1901 and 2000. The mean minimum temperature was observed to be higher in Chennai, Mumbai, and Hyderabad, whereas the mean maximum temperature was higher in Jodhpur, Jaipur, Agra, Lucknow, and Varanasi. On average, Mumbai and Chennai received higher rainfall in a year.

3.4. Urban City Scale Score in Million-plus Cities of India, 2011

Figure 2 is the cartographic presentation of urban city-scale scores in million-plus cities of India in 2011. There were a limited number of million-plus cities in eastern India and most of the cities from that region, except Kolkata, had low urbanicity scores. There was not a single million-plus city in the Northeastern region. Most of the million-plus cities of south India had relatively high urban city scores.

Table 5 reveals the urbanicity scores for all the 40 million-plus cities of India. Intercity score variations are crucial to capture the differences in each domain. For example, Mumbai had the highest score for the population (10.0) but the lowest score for health infrastructure (6.20). Delhi had a score of more than 9.0 for population, economic activity,

Table 4. Health status of children (under aged 5 years) in selected million-plus cities of India in 2015-2016.

Million plus cities[#]	Stunted	Wasted	Underweight	ARI*
Mumbai	25.5	25.8	22.7	1.8
New Delhi	28.5	20.3	32.0	2.3
Bengaluru	29.4	25.7	28.0	0.4
Hyderabad	16.4	15.0	17.2	2.3
Pune	22.3	26.7	23.6	4.1
Jaipur	35.8	13.5	25.2	4.0
Lucknow	32.0	32.0	41.5	1.9
Kanpur	43.5	22.7	38.6	2.5
Patna	34.7	29.9	36.7	0.9
Agra	39.8	14.8	30.0	3.2
Varanasi	38.6	24.8	43.8	5.0
Jodhpur	39.0	20.6	32.6	0.6

Data Source: National Family Health Survey – 4, India 2015-2016. # – Based on the district's urban population. *ARI – Acute Respiratory Infection in the past 2 weeks preceding the survey.

built environment, and educational infrastructure but low scores for diversity and health infrastructure. As compared to Mumbai and Delhi, Madurai had a relatively lower score for the population (4.50) but higher scores for education (9.5) and health infrastructure (8.8), which made it possible for it to have an overall higher urbanicity score. Similarly, many other cities such as Jodhpur, Vadodara, Aurangabad, and Kota had low population scores but higher scores for the built environment, health, and education. Population, health infrastructure, and diversity were the leading contributors to the variations in the urban city scale. There were only 10 cities (of 40) with scores of more than 5.0. With 10 points, Mumbai had the highest score followed by Delhi (9.0) and Hyderabad (8.0). By contrast, Aurangabad, Kota, and Vasai-Virar city had the lowest score (1.5). The domain of economic activity showed little variation, with the scores ranging from 9.3 to 9.9. On the other hand, the domain of health infrastructure had huge variations, with the scores ranging from 1.0 to 8.8.

4. Discussion

This study through the development and use of the urbanicity scale highlights the existing inequalities in infrastructure, services, and environment of the 40 million-plus cities in India. The present study has established the possibility of constructing a quantitative measure of the urban environment through the urbanicity scale, allowing for an examination of the urban infrastructure and available services. Previous urbanicity scales – drawn for the Philippines (Dahly and Adair, 2007), India and Sri Lanka (Allender, Lacey, Webster, *et al*., 2010; Allender, Wickramasinghe, Goldacre, *et al*., 2011), China (Mendez and Popkin, 2004), and Uganda (Riha, Karabarinde, Ssenyomo, *et al*., 2014) – were based on seven to 12 domains of urbanicity, depending on the availability of information and the source of data. Planning and existing infrastructure vary considerably within cities and are contingent on the choices government and planning bodies make over time (Sorensen, 2018). This study's findings are similar to those of previous studies which assessed sustainable development of urban India by assessing the infrastructural differences (Novak, Allender, Scarborough, *et al*., 2012; Cyril, Oldroyd and Renzaho, 2013; Riha, Karabarinde, Ssenyomo, *et al*., 2014; Sothmann, Krumkamp, Kreuels, *et al*., 2015; Panda, Chakraborty, Misra, *et al*., 2016). Although population density and population size varied across the cities, economic activity was similar in all the million-plus cities of India. Population density and size are a significant factor that may affect health, education, communication, economic status, and related environment (Jones-Smith and Popkin, 2010; Novak, Allender, Scarborough, *et al*., 2012).

The study found that many cities have relatively less population, but better health-care systems and educational facilities, which may motivate people from other urban as well as rural areas to move to these cities. The results imply that if certain places grow into urban areas but have inadequate infrastructural facilities and services, their residents may migrate to other cities that have better infrastructure and services. For example, the recently released Indian migration data show that nearly 800,000 people out-migrate from the city of Mumbai to nearby suburban towns/cities in search of a better environment and affordable homes (ORGI, 2011). Some of this migration may also be due to the shifting of

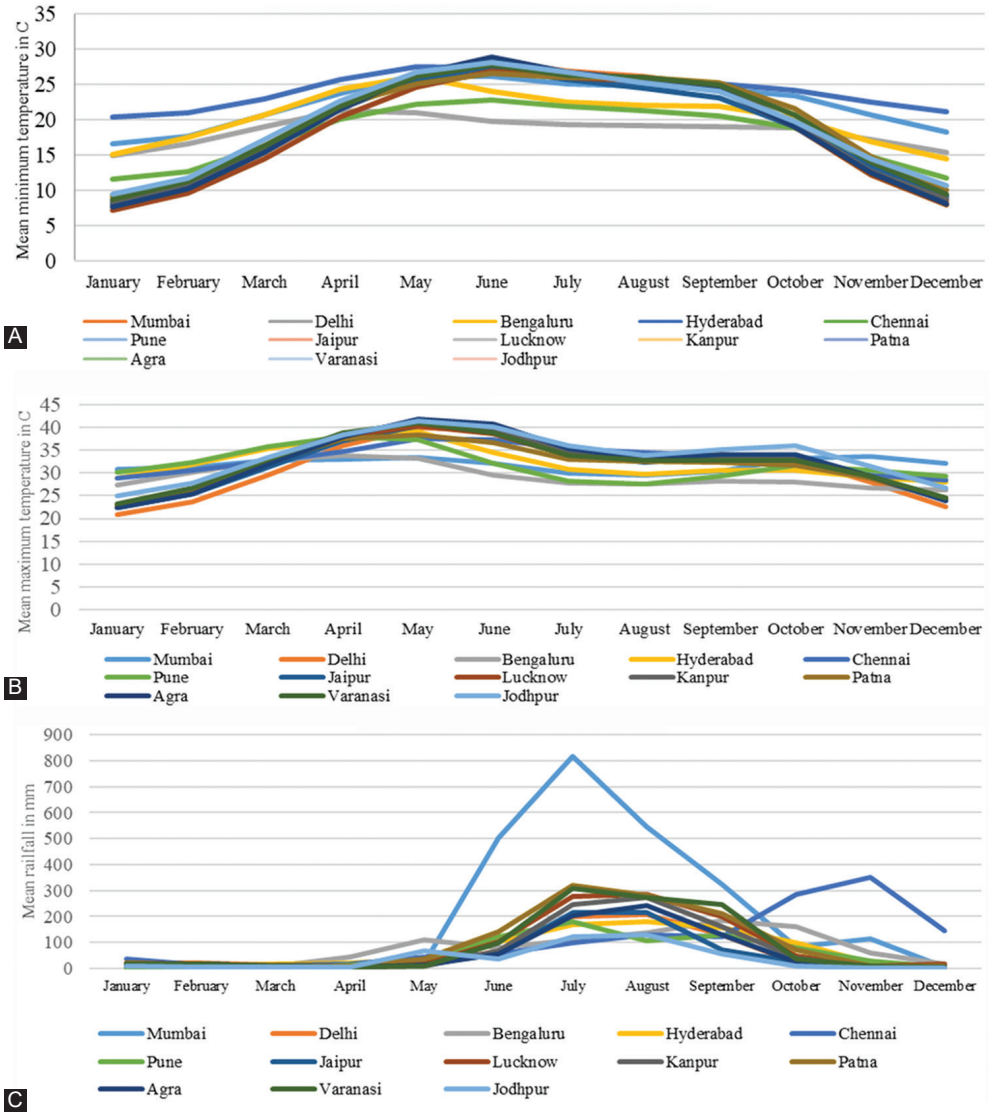

Figure 1. A: Mean minimum temperature in selected million-plus cities of India over a period of 1901-2000; B: Mean maximum temperature in selected million-plus cities of India over a period of 1901-2000; C: Mean rainfall received in selected million-plus cities of India over a period of 1901-2000. Climatology of important cities, Government of India. Available at: https://data.gov.in/catalog/climatology -data-important-cities-5?filters%5Bfield_catalog_reference%5D=394661&format=json&offset=0&limit=6&sort%5Bcreated% 5D=desc. Accessed on 15 August 2019.

industrial units from the core city to the agglomeration areas, thus changing the place with economic opportunities. Some of the most populous cities known for high immigration pose a risk – such as congested/no drainage, reclaiming river beds, and cutting mangroves, congested housing, and inadequate infrastructure to cater to the needs of the inhabitants. This is often cited as the reason behind calamities like floods in some cities. The waterlogging and flood in Mumbai in the years 2005, 2017, and 2019 and the flood in Chennai in 2015 are often credited to poor urban planning aggravated by huge in-migration.

The Government of India has many infrastructural development programs in place to provide a decent quality of life in terms of a clean and sustainable environment through the use of smart solutions in the domains of sanitation, waste management, public transport, and governance. The Atal Mission for Rejuvenation and Urban Transformation assures the availability of water supply, sewerage connections, green, and open spaces and reduced pollution from the transportation sector. The Swachh Bharat Mission - Urban (SBM-U) aims at making urban India free from open

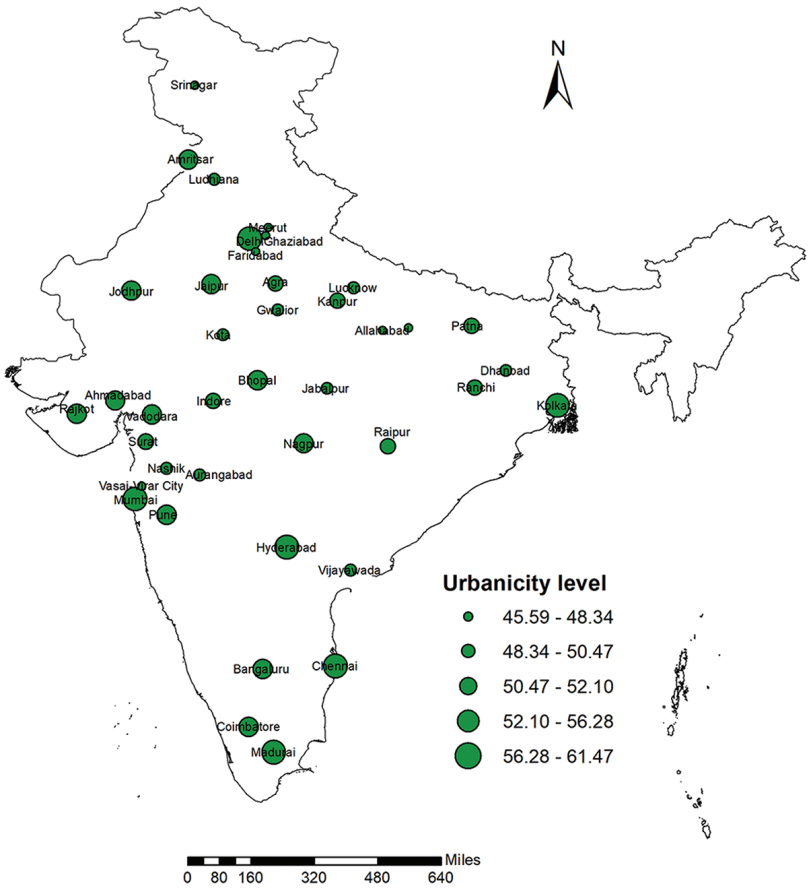

Figure 2. Spatial distribution of urbanity level for million-plus cities of India, 2011.

defecation and promoting scientific management of municipal solid waste in statutory towns (Ministry of Housing and Urban Affairs). The smart cities initiative aims to develop the necessary infrastructure and services based on a resilient sustainable model. However, the findings of the study reveal that these cities are far from achieving the strategic goals under SDG 13 (United Nations, 2017).

Environmental condition is directly associated with health. The study found that the temperature and rainfall of these cities are changing over time and vary across cities. Inconsistent rainfall and increasing temperature will work adversely for cities often known for high density and poor urban planning. Although this study found, the inconsistent association between selected child health indicators and air pollution in selected million-plus cities, there is enough evidence highlighting their significant inverse association (WHO, 2017; Christian, Zubrick, Foster, *et al*., 2015).

The strengths of this study are that it is the first attempt to estimate the urban exposure level in 40 million cities in India. The urbanicity scale highlights the differences and variations in the levels of urban exposure among the large million-plus cities. It is also helpful to understand; why and how urban settings are predisposed to health. The urban city scale can be useful for a better understanding of the process of urbanization and its relationship/association with health and development in urban areas. Results also highlight which indicators have a more significant impact on health and sheds light on the potential policy interventions to improve urban infrastructure and programs for combating health issues related to urbanization. The study findings may also help to develop resilient cities to mitigate or minimize the effects of climate change.

One of the limitations of this study is that the urbanicity scale gives information only for a particular point of time, whereas urbanization is a long-term process. Thus, the conclusions are based on the scale scores without a historical perspective on the resilient development of the cities and climate change. Another limitation is that the Census data do not provide information on health and climatic conditions, which would be useful to understand the association between urban exposure and diseases. Finally, the variables used for the development of the urbanicity scale may have an internal association.

Table 5. Urban exposure level through the urbanicity scale's components in million-plus cities of India.

Cities	Population	Economic activity	Built environment	Communication	Education infrastructure	Health infrastructure	Diversity	Total score
Delhi	9.00	9.94	9.40	8.86	9.38	7.20	7.69	61.47
Mumbai	10.00	9.90	8.03	7.96	9.49	6.20	8.31	59.89
Chennai	7.00	9.85	9.91	7.75	9.51	7.00	8.04	59.05
Hyderabad	8.00	9.60	10.00	7.48	9.15	5.80	8.74	58.99
Madurai	4.50	9.89	10.00	7.48	9.55	8.80	7.92	58.14
Kolkata	7.00	9.84	9.46	9.00	9.32	5.20	7.57	57.38
Bengaluru	7.00	9.78	9.66	7.68	9.43	5.20	7.52	56.28
Pune	6.50	9.88	8.70	8.45	9.48	4.40	8.68	56.09
Ahmadabad	5.50	9.86	9.24	7.32	9.41	6.60	7.71	55.65
Jodhpur	2.50	9.76	8.86	8.45	9.02	8.40	8.48	55.47
Vadodara	2.50	9.69	9.28	7.94	9.52	7.80	8.49	55.22
Amritsar	5.50	9.64	8.90	7.69	9.21	7.20	7.03	55.17
Jaipur	3.50	9.70	8.32	8.41	9.17	8.20	7.56	54.85
Nagpur	4.00	9.86	8.64	8.39	9.60	6.40	7.92	54.81
Rajkot	2.50	9.85	9.74	9.00	9.38	5.60	8.36	54.43
Coimbatore	2.50	9.87	9.36	7.42	9.56	6.60	8.31	53.63
Bhopal	2.50	9.67	8.95	8.57	9.17	8.00	6.65	53.51
Indore	3.50	9.77	9.27	7.36	9.28	6.40	6.51	52.10
Raipur	2.50	9.71	8.48	7.68	9.30	7.60	6.70	51.96
Surat	5.00	9.87	8.92	6.95	9.39	3.60	7.84	51.58
Agra	3.50	9.46	9.38	8.32	8.66	6.20	5.95	51.46
Kanpur	4.00	9.61	9.39	8.55	9.12	5.80	4.89	51.36
Ranchi	2.50	9.52	9.30	8.77	9.37	6.40	5.36	51.22
Patna	4.50	9.29	6.90	9.13	9.17	6.00	5.82	50.81
Aurangabad	1.50	9.60	9.47	7.92	9.37	4.60	8.00	50.47
Kota	1.50	9.56	7.74	8.48	9.14	6.40	7.44	50.25
Nashik	2.50	9.51	9.07	7.43	9.49	3.40	8.76	50.16
Lucknow	3.00	9.61	8.13	8.40	9.12	5.00	6.77	50.04
Gwalior	3.50	9.59	9.04	7.75	9.21	4.00	6.91	49.99
Jabalpur	2.50	9.69	7.40	8.36	9.36	6.00	6.56	49.87
Dhanbad	4.50	9.76	9.02	8.03	8.97	4.40	5.11	49.80
Vijayawada	2.50	9.61	10.00	7.08	9.07	2.80	8.43	49.71
Ludhiana	3.50	9.78	8.46	7.80	9.29	3.20	6.66	48.70
Faridabad	2.50	9.65	8.88	8.20	9.19	4.40	5.52	48.34
Srinagar	2.50	9.47	7.68	9.28	8.46	2.80	7.83	48.01
Allahabad	2.50	9.62	7.60	8.35	9.23	3.40	6.88	47.58
Ghaziabad	2.50	9.57	8.20	7.88	9.24	3.40	6.53	47.31
Varanasi	3.50	9.56	7.23	7.82	8.96	3.40	6.66	47.14
Vasai-Virar City	1.50	9.55	7.68	8.96	9.43	1.00	7.46	45.59
Meerut	2.50	9.40	7.67	7.52	8.78	3.40	6.32	45.59

5. Conclusions

Urban exposure provides a good reflection of inequality in infrastructure, services, and environment across the 40 million-plus cities in India. Population, health infrastructure, and diversity are the domains contributing the most to the inequality

among the million-plus cities. Results suggest the need for a customized domain-oriented policy for addressing city-wise concerns of urban exposure level. Unless addressed urgently, these inequalities in infrastructure and services will affect the sustainability of these million-plus cities and may hinder the country's achievement of SDG 13 on climate change.

Authors' Contributions

Conceived and designed: Surendra Kumar Patel and Manas Ranjan Pradhan. Review of literature: Surendra Kumar Patel. Data analysis: Surendra Kumar Patel. Drafted and wrote the manuscript: Surendra Kumar Patel and Manas Ranjan Pradhan.

Conflicts of Interest

There are no conflicts of interest.

Availability of Supporting Data

The Census of India 2011 data is available at https://censusindia.gov.in/. The NFHS-4 data are available at https://dhsprogram.com/Data/. The AQI data are available at https://www.cpcb.nic.in/and the temperature as well as rainfall data is available at https://data.gov.in/catalog/climatology-data-important-cities-5?filters%5Bfield _catalog_ reference%5D=394661&format =json&offset=0& limit=6&sort %5Bcreated %5D=desc.

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APPENDIX

Table 1A. Information used for the calculation of urbanicity scale and respective scoring of items.

Cities	Population	Density	Proportion of people involved in agriculture	Paved road	Sewerage System (Open-1/Closed-2/ Both-3)	Proportion of household with flush Latrine	Electricity services	Proportion of household with electricity	Proportion of household having TV	Proportion of household having mobile	Population per theatre	Public telephone	Public internet
Delhi	5.00	4.00	9.94	2.00	2.00	1.64	2.00	1.76	1.79	1.28	1.80	2.00	2.00
Mumbai	5.00	5.00	9.90	2.00	2.00	0.74	2.00	1.29	1.70	1.26	1.00	2.00	2.00
Chennai	2.00	5.00	9.85	2.00	2.00	1.91	2.00	2.00	1.91	1.25	0.60	2.00	2.00
Hyderabad	3.00	5.00	9.60	2.00	2.00	2.00	2.00	2.00	1.69	1.39	0.40	2.00	2.00
Madurai	0.50	4.00	9.89	2.00	2.00	2.00	2.00	2.00	1.83	1.46	0.20	2.00	2.00
Kolkata	2.00	5.00	9.84	2.00	2.00	1.46	2.00	2.00	1.69	1.31	2.00	2.00	2.00
Bengaluru	4.00	3.00	9.78	2.00	2.00	1.71	2.00	1.96	1.75	1.34	0.60	2.00	2.00
Pune	1.50	5.00	9.88	2.00	1.34	1.36	2.00	2.00	1.76	1.29	1.40	2.00	2.00
Ahmadabad	2.50	3.00	9.86	2.00	1.34	2.01	2.00	1.89	1.67	1.25	0.40	2.00	2.00
Jodhpur	0.50	2.00	9.76	2.00	2.00	1.31	2.00	1.55	1.63	1.23	1.60	2.00	2.00
Vadodara	0.50	2.00	9.69	2.00	1.34	2.00	2.00	1.95	1.69	1.24	1.00	2.00	2.00
Amritsar	0.50	5.00	9.64	2.00	2.00	0.95	2.00	1.94	1.82	1.28	0.60	2.00	2.00
Jaipur	1.50	2.00	9.70	2.00	2.00	0.94	2.00	1.38	1.68	1.32	1.40	2.00	2.00
Nagpur	1.00	3.00	9.86	2.00	1.34	1.72	2.00	1.58	1.74	1.25	1.40	2.00	2.00
Rajkot	0.50	2.00	9.85	2.00	2.00	1.74	2.00	2.00	1.74	1.46	1.80	2.00	2.00
Coimbatore	0.50	2.00	9.87	2.00	2.00	1.76	2.00	1.61	1.83	1.39	0.20	2.00	2.00
Bhopal	0.50	2.00	9.67	2.00	2.00	1.60	2.00	1.35	1.55	1.22	1.80	2.00	2.00
Indore	0.50	3.00	9.77	2.00	2.00	1.72	2.00	1.55	1.70	1.26	0.40	2.00	2.00
Raipur	0.50	2.00	9.71	2.00	2.00	1.00	2.00	1.48	1.53	1.14	1.00	2.00	2.00
Surat	2.00	3.00	9.87	2.00	1.34	2.02	2.00	1.56	1.32	1.43	0.20	2.00	2.00
Agra	0.50	3.00	9.46	2.00	2.00	1.73	2.00	1.65	1.77	1.34	1.20	2.00	2.00
Kanpur	1.00	3.00	9.61	2.00	2.00	1.69	2.00	1.70	1.57	1.38	1.60	2.00	2.00
Ranchi	0.50	2.00	9.52	2.00	2.00	1.54	2.00	1.76	1.56	1.41	1.80	2.00	2.00
Patna	0.50	4.00	9.29	2.00	2.00	0.14	2.00	0.77	1.65	1.48	2.00	2.00	2.00
Aurangabad	0.50	1.00	9.60	2.00	2.00	1.47	2.00	2.00	1.56	1.36	1.00	2.00	2.00
Kota	0.50	1.00	9.56	2.00	2.00	0.65	2.00	1.09	1.53	1.34	1.60	2.00	2.00
Nashik	0.50	2.00	9.51	2.00	2.00	1.19	2.00	1.88	1.66	1.36	0.40	2.00	2.00
Lucknow	1.00	2.00	9.61	2.00	1.34	1.12	2.00	1.67	1.62	1.38	1.40	2.00	2.00

(*Contd...*)

Table 1A. (*Continued*)

Cities	Population	Density	Proportion of people involved in agriculture	Paved road	Sewerage System (Open-1/Closed-2/Both-3)	Proportion of household with flush Latrine	Electricity services	Proportion of household with electricity	Proportion of household having TV	Proportion of household having mobile	Population per theatre	Public telephone	Public internet
Gwalior	0.50	3.00	9.59	2.00	2.00	1.68	2.00	1.36	1.71	1.25	0.80	2.00	2.00
Jabalpur	0.50	2.00	9.69	2.00	0.67	1.69	2.00	1.04	1.62	1.15	1.60	2.00	2.00
Dhanbad	0.50	4.00	9.76	2.00	2.00	1.16	2.00	1.86	1.44	1.40	1.20	2.00	2.00
Vijayawada	0.50	2.00	9.61	2.00	2.00	2.00	2.00	2.00	1.58	1.30	0.20	2.00	2.00
Ludhiana	0.50	3.00	9.78	2.00	2.00	0.46	2.00	2.00	1.70	1.31	0.80	2.00	2.00
Faridabad	0.50	2.00	9.65	2.00	2.00	0.99	2.00	1.89	1.64	1.36	1.20	2.00	2.00
Srinagar	0.50	2.00	9.47	2.00	1.34	0.61	2.00	1.73	1.83	1.45	2.00	2.00	2.00
Allahabad	0.50	2.00	9.62	2.00	2.00	0.05	2.00	1.55	1.72	1.42	1.20	2.00	2.00
Ghaziabad	0.50	2.00	9.57	2.00	2.00	0.39	2.00	1.81	1.71	1.37	0.80	2.00	2.00
Varanasi	0.50	3.00	9.56	2.00	1.34	0.00	2.00	1.89	1.62	1.40	0.80	2.00	2.00
Vasai-Virar City	0.50	1.00	9.55	2.00	2.00	0.82	2.00	0.86	1.59	1.37	2.00	2.00	2.00
Meerut	0.50	2.00	9.40	2.00	2.00	0.14	2.00	1.53	1.56	1.36	0.60	2.00	2.00

Table 2A. Information used for the urbanicity scale and respective scoring of items.

Literacy rate	Education facilities: Primary/Secondary/University	Allopathic hospital	Hospital alternative medicine	Beds per lakh population	Doctors per lakh population	Para-medical staffs per lakh population	Proportion of having good quality of houses	Proportion of household with tap drinking water	Urbanicity score	Cities
4.38	5.00	2.00	1.20	2.00	1.20	0.80	3.47	4.23	61.47	Delhi
4.49	5.00	2.00	1.00	1.20	1.20	0.80	3.59	4.72	59.89	Mumbai
4.51	5.00	1.60	1.40	1.20	1.40	1.40	4.08	3.95	59.05	Chennai
4.15	5.00	0.60	1.40	1.40	1.40	1.00	4.08	4.66	58.99	Hyderabad
4.55	5.00	2.00	2.00	1.80	1.40	1.60	3.58	4.34	58.14	Madurai
4.32	5.00	1.60	1.40	2.00	0.00	0.20	3.32	4.24	57.38	Kolkata
4.43	5.00	1.40	0.60	1.60	0.40	1.20	3.96	3.56	56.28	Bengaluru
4.48	5.00	2.00	0.80	0.80	0.20	0.60	3.80	4.89	56.09	Pune
4.41	5.00	1.80	1.60	2.00	0.60	0.60	3.80	3.91	55.65	Ahmadabad
4.02	5.00	1.40	1.80	1.60	1.80	1.80	3.77	4.71	55.47	Jodhpur
4.52	5.00	1.20	1.20	1.80	2.00	1.60	4.03	4.46	55.22	Vadodara
4.21	5.00	1.00	2.00	1.60	1.00	1.60	3.47	3.56	55.17	Amritsar

(*Contd...*)

Table 2A. (*Continued*)

Literacy rate	Education facilities: Primary/Secondary/ University	Allopathic hospital	Hospital alternative medicine	Beds per lakh population	Doctors per lakh population	Para-medical staffs per lakh population	Proportion of having good quality of houses	Proportion of household with tap drinking water	Urbanicity score	Cities
4.17	5.00	1.20	1.80	1.40	2.00	1.80	3.62	3.94	54.85	Jaipur
4.60	5.00	1.80	0.40	1.60	1.00	1.60	3.76	4.16	54.81	Nagpur
4.38	5.00	1.60	0.80	0.60	1.60	1.00	4.01	4.34	54.43	Rajkot
4.56	5.00	1.80	1.80	0.60	1.20	1.20	3.52	4.79	53.63	Coimbatore
4.17	5.00	1.00	1.60	1.80	1.60	2.00	3.35	3.30	53.51	Bhopal
4.28	5.00	1.40	1.20	0.80	1.20	1.80	3.76	2.76	52.10	Indore
4.30	5.00	1.20	2.00	0.60	1.80	2.00	4.00	2.70	51.96	Raipur
4.39	5.00	1.80	0.60	0.40	0.60	0.20	4.01	3.83	51.58	Surat
3.66	5.00	0.20	0.00	2.00	2.00	2.00	3.12	2.83	51.46	Agra
4.12	5.00	0.80	1.40	1.40	0.80	1.40	2.87	2.02	51.36	Kanpur
4.37	5.00	0.40	1.00	1.20	2.00	1.80	3.60	1.76	51.22	Ranchi
4.17	5.00	0.20	0.60	1.40	1.80	2.00	3.43	2.39	50.81	Patna
4.37	5.00	0.80	1.80	1.00	0.40	0.60	3.85	4.15	50.47	Aurangabad
4.14	5.00	0.40	2.00	1.00	1.60	1.40	3.47	3.97	50.25	Kota
4.49	5.00	0.40	0.00	0.80	0.80	1.40	3.98	4.78	50.16	Nashik
4.12	5.00	0.80	0.00	1.80	1.60	0.80	3.31	3.46	50.04	Lucknow
4.21	5.00	0.60	1.00	0.80	0.40	1.20	3.69	3.22	49.99	Gwalior
4.36	5.00	1.20	1.00	1.00	1.80	1.00	3.25	3.31	49.87	Jabalpur
3.97	5.00	1.40	0.00	1.20	1.40	0.40	2.67	2.44	49.80	Dhanbad
4.07	5.00	0.80	1.20	0.40	0.20	0.20	4.20	4.23	49.71	Vijayawada
4.29	5.00	1.60	0.60	0.20	0.40	0.40	2.67	3.99	48.70	Ludhiana
4.19	5.00	1.00	1.60	0.20	1.00	0.60	2.93	2.60	48.34	Faridabad
3.46	5.00	0.20	0.80	0.40	0.60	0.80	3.73	4.10	48.01	Srinagar
4.23	5.00	1.00	0.80	0.60	0.60	0.40	2.49	4.38	47.58	Allahabad
4.24	5.00	0.60	0.40	0.40	0.80	1.20	3.59	2.94	47.31	Ghaziabad
3.96	5.00	0.60	0.00	1.00	0.80	1.00	3.12	3.54	47.14	Varanasi
4.43	5.00	0.40	0.00	0.20	0.20	0.20	3.92	3.54	45.59	Vasai-Virar City
3.78	5.00	0.20	1.60	0.20	1.00	0.40	3.23	3.08	45.59	Meerut

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REVIEW ARTICLE

Managing natural disaster risk with earthquake damage scenarios and shakeout exercises: Lessons from M_w = 8 Mandi multi-stakeholders scenario in India

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Abstract: Scientifically simulated Earthquake Damage Scenario (EDS) and Shakeout exercises help the policymakers to set up emergency plans for the immediate consequences and medium-long-term mitigation and prevention for a seismic event. The purpose of this study is to draw important lessons and a deeper understanding of issues and challenges in planning and implementing such exercises in a highly populous developing country like India. The Government of India developed a first-ever multi-state and multi-stakeholders EDS naming M_w = 8 Mandi and conducted a Mega Multicity Shakeout Exercise in the Western Himalayan Region during 2014. A cross-sectional research design consisting of a mainly qualitative research approach using a multi-stakeholders perspective approach was used to factor key lessons. The scenario development and shakeout exercise faced several challenges such as lack of awareness among concerned stakeholders, lack of technical know-how at the grass-root level, lack of poor coordination among various stakeholders, and unavailability of data on important issues. Due to the lack of understanding of the sensitivity of the issue, the success of implementation largely depends on the involvement of the top leadership of state governments. Scientific EDS exercises followed by mega shakeout exercises helped not only the community up to some extent but also mainly helped administration, government agencies in generating awareness of the earthquake and possible risk attached to it.

Keywords: Disaster risk management; Earthquake damage scenarios; Shakeout exercises; Mock drills; Earthquake management India; Multi-stakeholders simulation exercises

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1. Introduction

Disasters are large intractable problems that test the ability of communities and governments to effectively protect their people and infrastructure by reducing both human and property loss, and speedy recovery (Altay and Green, 2006). Earthquakes are one of the worst natural disasters that cause huge loss to lives, property, and the economy. Recent earthquakes (e.g., Turkey in 1999, Taiwan in 2001, Gujarat, India in 2001, the Indian Ocean in 2004, Kashmir, India in 2005 Sikkim, India in 2011, Tohoku, Japan in 2011, and Nepal in 2015) showed that seismic areas with concentrated population,

buildings and infrastructures are highly exposed to human and economic losses environments (Jaiswal and Wald, 2008). The earthquakes can neither be predicted nor prevented. However, preparation for such disasters in a diligent manner can save lives and livelihoods. The reduction of seismic risk of these areas, therefore, is of primary concern policymakers, for earthquake risk mitigation.

The past two or three decades have witnessed a growing interest of multidisciplinary researchers around the world to assess the seismic vulnerability of major cities and analyzing the associated risk (Dolce, Kappos, Masi, *et al*., 2006; Altay and Green, 2006). For analyzing the risk associated with earthquake disasters, the researchers usually prepare an Earthquake Damage Scenario (EDS) which provides a complete picture of what will happen when such an earthquake occurs (Altay and Green, 2006). A typical EDS exercise involves analyzing risk by estimating the probability of damages and losses based on all the previous earthquakes, over given earthquake circumstances (i.e., tracing the possible complex series of social, economic, and technical events likely to be triggered by an earthquake), combined with GIS technology to check and visualize the effects of any risk mitigation strategy (Dolce, Kappos, Masi, *et al*., 2006; Arya, 1992). The preparation of an EDS is a multidisciplinary and multi-stakeholders task. It involves the unification of knowledge workers from diverse fields such as seismology, soil mechanics, geotechnical engineering, structural engineering, transport engineering, urban planning, social studies, preventive medicine, economics, and emergency response. The outcome of such EDS exercises has helped the policymakers to (1) set up emergency plans for the immediate consequences of a seismic event by local and national authorities; (2) plan prevention policies for medium long-term mitigation in those areas; and (3) set up tools to forecast losses in a multidisciplinary as well as practical way.

Nations across the world started to use these EDSs, not just for preparing post-earthquake response plans and training (capacity building) of the concerned personnel in various roles, but also for getting local communities involved in the process of disaster mitigation (Arya, 1992; Dolce, Kappos, Masi, *et al*., 2006; Porter, Jones, Cox, *et al*., 2011). These scientific EDSs also help in identifying necessary earthquake risk management programs and to develop specific shake out exercises for public awareness. The shakeout exercises based on these scientific EDS has a positive impact on community participation (Dolce, Kappos, Masi, *et al*., 2006; Bernknopf *et al*., 2008; Muto and Krishnan, 2011; Porter, Jones, Cox, *et al*., 2011; Wein and Rose, 2011; McBride, Becker, Johnston, *et al*., 2019).

The National Disaster Management Authority (NDMA) is a federal government agency, responsible for framing policies, laying down guidelines, and best-practices for coordinating with the State Disaster Management Authorities (SDMAs). It developed a first-ever multi-state (involving more than one state [province] government) EDS naming M_w = 8 Mandi for a hypothetical earthquake of moment magnitude 8.0 in India. The developed EDS was used for conducting a Mega Shakeout Exercise on in the four cities of northern India, i.e., tri-cities of Mohali (Punjab), Panchkula (Haryana) and Chandigarh (UT), and city of Shimla (Himachal Pradesh). The success of this scenario would depend largely upon the active participation of the SDMAs, District Disaster Management Authorities (DDMAs), various line departments and other stakeholders in coordination with the NDMA and other central ministries/agencies.

The main objective of this paper is to document and learn from the experiences for bringing about improvement in designing and implementing EDS and conduct similar mega mock exercises in other seismically prone regions. The next section of the paper briefly explains the background and details about developed EDS and Mega Shakeout exercise. The third section explains the Methodology used for the evaluation of this EDS and Mega Shakeout exercise. The fourth section discusses the findings of the evaluation and the fifth section puts forward the discussion in the form of the lesson learned and the last section concludes the paper.

2. The Intervention: M_W = 8 Mandi Earthquake Scenario in India

India lies at the north-western end of the Indo-Australian Plate, which encompasses India, Australia, a major portion of the Indian Ocean, and other smaller countries. This plate is colliding against the huge Eurasian Plate and going under the Eurasian Plate. Three chief tectonic sub-regions of India are the mighty Himalayas along the north, the plains of the Ganges and other rivers, and the peninsula. The Himalayas consist primarily of sediments accumulated over long geological time in the Tethys. The Indo-Gangetic basin with deep alluvium is a great depression caused by the load of the Himalayas on the continent. The peninsular part of the country consists of ancient rocks deformed in the past Himalayan-like collisions (Sinha, Goyal, Krishna, *et al*., 2012). The seismic zoning map of India shows that about 58% of India's landmass is vulnerable to moderate or severe seismic hazards, i.e., prone to shaking of Medvedev-Sponheuer-Karnik intensity VII and above (India Meteorological Department, 2002). During the period 1990-2014, India has experienced 10 major earthquakes that have resulted in over 30,000 deaths and caused enormous damage to property and infrastructure (Meena, Shinde, Sapre, *et al*., 2013). The vast extent of damage and the consequent losses of life associated with these events reflect the poor construction practice in India (Jaiswal and

Wald, 2008). Federal and State Governments have initiated several programs from time to time to manage disasters, as well as to mitigate their adverse impacts. However, assessment of the effectiveness of these programs to mitigate earthquake risk was never done due to the lack of scientifically valid EDS (Meena, Shinde, Sapre, *et al*., 2013; Sinha, Goyal, Murty, *et al*., 2014).

To understand the direct and indirect consequences of high magnitude earthquake and needed preparedness of administration for it, NDMA initiated a study to develop a multi-state earthquake disaster scenario for a hypothetical earthquake of moment magnitude 8.0. Indian Institute of Technology (IIT), Bombay, and Madras undertook this scientific exercise to develop earthquake scenarios for the Northwest Himalayan Region. The epicenter of the hypothetical earthquake was planned in a "seismic gap" in western Himalaya and several scientists expect this region to experience a large earthquake soon. The project was undertaken in the states of Punjab, Haryana, Himachal Pradesh, and Union Territory of Chandigarh, considering the high level of seismic vulnerability (seismic zone III to V) in the Himalayan belt (Sinha, Goyal, Murty, *et al*., 2014).

The earthquake scenario developed under the project involved as many as 32 stakeholders ranging from various government agencies at federal, state and local levels, defense organizations, and academic institutions, including schools, colleges, and non-government organizations with well-defined responsibilities. The EDS development team was led by the NDMA, consisted of scientific experts in the field of earthquake engineering (from IIT Bombay and IIT Madras). Representatives from Himachal Pradesh, Haryana, Punjab, state governments, and Union Territory of Chandigarh were also involved in the project. Inputs were also sought from organizations involved in earthquake monitoring, hazard assessment, and managing major infrastructure or facilities in the affected region such as IMD, Geological Survey of India, Border Roads Organisation, Central Water Commission, and Bhakra Beas Management Board. A part of seismotectonic information for the Western Himalayan was provided by the Wadia Institute of Himalayan Geology. The project team also includes a Coordination Agency (namely, Geo-Hazards Society India) to facilitate the coordination between the various stakeholders, particularly at the state level. Software RISK.iitb v3.1 developed by IIT, Bombay, for integrated seismic hazard, vulnerability, and risk assessment was used for simulations in Mandi EDS (Sinha, Aditya, Gupta, *et al*., 2008).

Table 1 shows the silent features of the developed EDS by considering the seism-tectonic profile of the region. It could be observed that the Main Boundary Thrust which runs along South-West districts has not been ruptured due to a great earthquake in the past 100 years. The Indian plate is moving toward the Asian Plate, but it is observed there are no many great earthquakes in this region which appears insufficient to compensate the 15-20 mm/year movement observed geodetically (Zhang, Santosh, Wang, *et al*., 2012). For the selected moment magnitude and location of the earthquake,

Table 1. Multi-state earthquake scenario.

Parameters	**Details**	
Earthquake	Multi-state earthquake scenario	
Region	Mandi district	
Mw	8	
Depth	15 km	
Epicenter	Sundernagar, Mandi District, Himachal Pradesh	
	Latitude	31033'00" N
	Longitude	76052'48" E
Parameters	**Details**	
Fault	Main boundary thrust (MBT)	
GMPE	Bore and Atkinson (AB08, NGA)	
Source	Line source	
Rupture model	WC84-all	
Rupture length	200 km	
Maximum MSK intensity	IX-X	
Grid size for analysis	0.5 × 0.5 km	

Source: Sinha *et al*. (2012, 2014). MSK: Medvedev-Sponheuer-Karnik.

the severity of ground shaking was estimated by using following Bore and Atkinsons' (2008) Ground Motions Prediction Equations (GMPE) (Figure 1).

$$\ln Y = F_M (M) + F_D (R_{JB},M) + F_S (V_{S30},R_{JB},M) \quad (1)$$

Here, F_M, F_D, and F_S were the magnitude scaling, distance function, and site amplification. M was the moment magnitude, R_{JB} was the Joyner Boore source to site distance, and V_{S30} was the inverse of average shear wave slowness from the surface to a depth of 30 km. The ground motion parameters were amplified towards the southwest which is due to the Indo-Gangetic plain region. The maximum Peak Ground Acceleration (PGA) was estimated to be 1.17 g. The damage intensities were obtained from the equations following proposed by Wald, Quitoriano, Heaton, *et al*. (1999) based on observations noted from the California Earthquake,

For $I < 5$

$$I_{mm} = 2.20 \log (PGA) + 1.00 \quad (2)$$

For $I \geq 5$

$$I_{mm} = 3.66 \log (PGA) - 1.66 \quad (3)$$

Information regarding the population, housing types, etc., was obtained from the Indian census 2011 data for the regions under study. The exposure was estimated for a night scenario. The resulted in injuries and deaths due to scenario

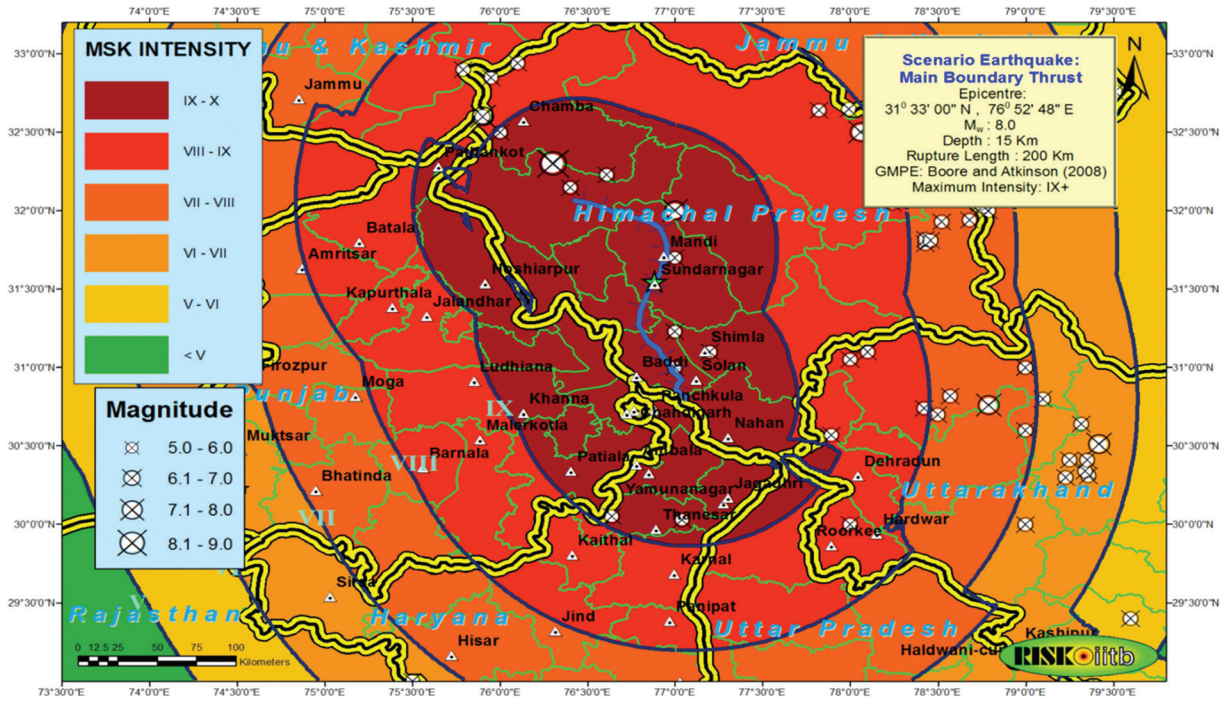

Figure 1. Population densities (persons per sq. km) over intensity contours (Source: Sinha 2014).

Table 2. Projected injuries and deaths in Mandi EDS.

State/UT	Injuries	Injuries (% population)	Deaths	Deaths (% population)
Himachal Pradesh	1,109,500	16.18	161,000	2.35
Haryana	1,596,100	7.66	345,800	1.36
Punjab	2,014,700	8.96	462,500	1.67
Chandigarh UT	102,400	12.00	24,200	2.33
Total	4,822,700		993,500	

Source: Sinha *et al*. (2012; 2014). EDS: Earthquake Damage Scenario.

earthquakes were estimated through the injury and death model RISK.iitb v3.0 (Sinha, Aditya, Gupta, *et al*., 2008). Table 2 highlights the total estimated social loss in the scenario.

Based on developed M_w = 8 Mandi EDS, rapid visual screening of water tanks, pipelines, and building training and capacity building program on Incident Response System (IRS) for various stakeholders were conducted. After necessary training and capacity building programs, a Mega Shakeout drill was planned and executed in all four states involved in the four main cities Shimla (Himachal Pradesh), Panchkula (Haryana), Mohali (Punjab), and Chandigarh (Union Territory). The Shakeout exercise was carried out in 15 locations in each city simultaneously with a sound of the siren as a symbolic occurrence of an earthquake. The shakeout exercise was followed by activation of response mechanism, including rescue and relief as per the directions from Emergency Operation Center (EOC) in district headquarters. The Shakeout exercises were coordinated by the DDMA team, National Disaster Response Force, local police administration, and the district administration in the presence of SDMA and NDMA members' experts.

3. Data and Methods

To evaluate the effectiveness of developed EDS and disseminate, the learning from these exercises (i.e., EDS team and Shakeout team) cross-sectional research design was used. Since this evaluation, as conducted after the intervention being carried out, therefore, a qualitative research approach was preferred as it gives deep insights into issues and challenges faced. The qualitative research approach also helped to trace and verify the effectiveness of various documents prepared during the EDS exercise. Both primary and secondary data sources were used in the study. The secondary data sources were used to analyze the facts and details about the developed EDS and Shakeout exercises. These resources include (a) detailed project report and its annexures submitted by IITs to NDMA on Multi-state Mega Mock Exercise under "Mw 8 Mandi Earthquake Scenario: Multi-state Exercise and Awareness Campaign," (b) developed district and state disaster management plan as the part of the exercise, and (c) unpublished documents/reports of the state governments and district administration related to disaster actions carried out by them.

The primary data were collected to get deep insights into the issues and challenges faced in the preparation and implementation of Mw = 8 Mandi EDS. For this purpose, first, a multi-stakeholder expert group consisting of 12 members was formulated. Other than the authors of the paper, the other members of the expert group were eminent national and international experts from both academic and practitioner working in the field of disaster risk management or civil society organizations. Each member of the expert group had an experience of more than 15 years in their respective area of work. A day-long round table discussion was organized in which the expert group, the members of the IITs team involved in preparing scenarios and NDMA observers involved in conducting the mega mock exercise participants. The expert group members discussed and evaluated the various technical, economic, social, and administrative aspects of the EDS and the mega shakeout exercise in the round table discussion.

In addition to round table discussion with NDMA observers and IIT team, authors conducted 45 in-depth discussions with multiple stakeholders working at the state, district, and local levels who have participated in either formulation of EDS or conducting Shakeout exercises. These stakeholders include policymakers, top officials from the state government responsible for disaster management, and head of the various emergency services such as public administration, water sanitation services, fire, medical services, and transport. An in-depth interview guide was prepared to interview these stakeholders. Since it was an official assignment, therefore, each official responded to the interview in its official capacity, hence did not require any informed consent. However, each stakeholder was assured by the study team that their personal detailed will not be shared at any forum.

4. Results

4.1. Data Availability for EDS Development

The success of an effective EDS development depends on the availability of data not just of seismic hazards such as fault locations, but also it requires data on various demographic, social, and economic issues such as population density, vulnerable age groups, occupation and level and type of industry existence, literacy rate, building typology, and the income level of the population. During the in-depth discussion with IIT Bombay and IIT Madras, it was found that the Central Government/State Governments need to adopt data policy that should articulate the nature and resolution of data that would be collected and compiled by the government as most of the available data are not follow same standards. IIT Bombay team commented following about data availability:

> *"….In the Mandi project, where only a macro-level scenario was planned, the absence of data did not pose a critical obstacle. However, when higher-resolution simulations are carried out, the availability of data would need to be*

*carefully factored into the program until such time that more detailed data becomes available……. we feel that the Central Government/State Governments may be encouraged to adopt data policy articulating the nature and resolution of data that would be collected and compiled by the government…." (*IIT Bombay Project Team, Round Table Discussion)

"….the engineers of the State did not have formal details and data of all buildings and structures in their jurisdiction. Hence, the analysis of the built environment was a tedious task. Moreover, only "seemingly" representative structures were taken, and departures from these in other structures could not be addressed……." (IIT Madras Project Team, IDI).

4.2. Awareness of Key Stakeholders about the Earthquake Disaster Risk

The success of an effective EDS development and Shakeout exercise was largely dependent on the active participation and coordination of all stakeholders, i.e., SDMAs, DDMAs, various line departments, NDMA, and other central ministries/ agencies with the technical team from the IITs.

In the initial phase, the project had a slow start which was mainly due to lack of awareness, understanding, and importance of the project among state governments' officials. With continuous and repeated efforts of NDMA, IITs team, coordination agency, and involvement of political leadership, the activities gathered momentum. The project activities were duly endorsed by the top leadership of states. IIT Bombay and Madras' study team found it very tough to convince state and district administration, especially in Punjab and Haryana, about the chance of occurring such a high magnitude earthquake in their states as there is no recent history of such a high magnitude earthquake in these states. Similar issues were faced by the NDMA capacity building team.

"In the 3 days capacity building programs ……. except for the nodal district, representatives from other districts were few or nominal in numbers…… the key functionaries at the cutting edge-level (district level), namely, Deputy Commissioners, Senior Superintendent of Police, and District Medical Officers mostly did not attend or were represented by junior level officers who could not apprehend the enormity of the disaster……"(Master Trainer, NDMA, New Delhi Round Table Discussion)

The Shakeout exercise designed based on scientific EDS was able to major contributors to convince district and state authorities to get sensitize about the problem. Shakeout exercises with the involvement of the technical team from IITs build not only the confidence of the state and district officials but also helped them to identify the gaps in their preparation for high magnitude earthquake disasters.

"The Chandigarh Administration's participation in the Mega Mock Exercise 'Mw=8 Mandi, Earthquake Scenario' conducted by NDMA indeed proved to be a milestone in the direction of disaster preparedness. The event helped the Administration to assess its disaster preparedness and response during an emergency, to mitigate threats and also help for the preparation of the Chandigarh Disaster Management Plan, SOPs of the line departments along with resource inventory. This exercise also gives an idea about the tools and equipment required during the rescue operation, areas of the capacity gap among staff and areas needing coordination with the line departments and improving the capability of rescue officials in enhancing their effectiveness and efficiency to respond in any disaster." (Chairman, District Disaster Management Authority, Chandigarh, IDI).

Due to the lack of understanding of the importance of issue, among district and local officers' mass advertisements for Shakeout exercises were very late as a result of which community participation in these exercises was less than expected. State and district governments where these activities were implemented had not taken any commendable action after almost 1 year of completion of the exercise on the gaps identified during Shakeout exercises. The main reasons for such inaction reported by state and district officials are lack of technical capacity, trained manpower, and no allocation of budget on these activities as these were not the priority of state and local governments.

4.3. Rapid Visual Survey (RVS) Training and Capacity Building Programs

The selection of representatives from various line departments for RVS training or IRS capacity building programs was not rational, which impinges on the sustainability of the Incident Response Team. Most of the participants, who have undergone training for IRS, have already been either transferred to other departments or retired from services.

"….we have not organized RVS training in the district, only one of our assistant town planner took part in such training before mega mock drill (13 Feb.). Our engineers are curious to take part in such types of training programs in the future to prepare a team but we don't have the capacity for the same. Similar is the situation for the capacity of district officials……. We like to organize departmental training programs for them to make them understand their duties before, during and after any disaster……" (Deputy Commissioner of Mohali District, IDI).

Expert Group pointed out Scenario Manual developed, did not have an instructor manual containing key discussion points, a checklist for action required for ideal disaster management and Trainer of the Trainer Module for effective current and future capacity building program.

> *"……Scenario building and conduct of shakeout exercises were two important parts of the project. There was no synergy between them……..while formulating the hypothetical scenario, the scenario building team of scientists from IITs Bombay and Madras, did not consult the mock exercise experts at the NDMA and the State/ UT, who was going to implement it. The scenario was also made with half-baked and incomplete data/information from the concerned Ministries/Departments/Organizations. This resulted in the credibility of the scenario becoming suspect, as several inputs, including the large fatalities and injuries to humans and animals could not be substantiated with scientific proof. It turned out to be a scientific/academic exercise with little practical inputs from States/ experts……." (Master Trainer, NDMA,* Round Table Discussion).

4.4. Technical Issues Relating to Mw = 8.0 Mandi Earthquake Scenario

The Expert Group pointed many weaknesses in Mw=8.0 EDS. Major weaknesses include: (i) The scenario has considered only immediately nearby epicenter severely affected areas. It did not consider other potentially affected areas near the fault line densely populated areas of Delhi and Western Uttar Pradesh and hilly regions of Uttarakhand and Jammu and Kashmir by the Mega Earthquake. (ii) The EDS also ignored the effects of earthquake-triggered landslides, sub-soil characteristics, depth of soil, soil stratification, and the cascading effect of buildings/infrastructures in hilly areas. (iii) The EDS has not considered the infrastructure, and economic losses due to mega-earthquake, which have major implications for post-earthquake relief planning operations. (iv) The factors like demographic distribution such as gender, age, occupancy classification, and socioeconomic status of the population in the affected area play a key role at the time of disasters. However, EDS did not consider these important factors in their calculations. (v) Similarly, the timing of earthquakes such as working hours or nighttime is a significant factor to determine the total number of injured and deaths. This factor is also missed in EDS development. (vi) The EDS has also not factored in the micro-zonation information and the community preparedness, i.e. level of awareness among the community about disaster management due to the unavailability of data.

5. Discussions

Based on the results mentioned above, we have developed a framework for effective planning and implementation of multi-stakeholder EDS and shakeout exercises (Figure 2). The main features of the framework are discussed in the following subsections.

Figure 2. Framework for effective multi-stakeholder earthquake damage scenarios planning and implementation.

5.1. Leadership

Strong effective leadership with a clear command system is a must during disaster events to improve both outcomes for casualties and the positive experience of the attenders (Filmer and Ranse, 2013). In EDS which involves multiple state governments, effective leadership by federal government agencies like NDMA becomes very important. The federal agencies need to not just ensure collaborative efforts of state government agencies (Waugh and Streib, 2006) but also bottom-up approach (Arai, 2006; Musacchio, Falsaperla, Bernhardsdóttir, *et al*., 2016) in the form of participation by district-level officials and community in the planning of such exercises.

5.2. Mass and Social Media

The growing adaption of Information and Communication Technologies and social networking platforms such as WhatsApp, Twitter, and Facebook has created numerous opportunities (Imran, Castillo, Diaz, *et al*., 2015) of information propagation that would not exist otherwise before, during, and after the disasters. However, harnessing credible information about disaster events from social media is a very challenging task (McBride, Llenos, Page, *et al*., 2020). If the right information is sifted through social media, it can facilitate the authorities to make better decisions for emergency response (Yin, Karimi, Lampert, *et al*., 2015). Therefore, effective preplanning and timely utilization of mass and social media are must for such mega Shakeout exercise to ensure community involvement. As a part of preparedness exercises, the mass sensitization and awareness must be generated in a manner that is impressionable and remains etched in the memories of the people at the time of disaster (McBride, Llenos, Page, *et al*., 2020).

5.3. Vulnerability Assessment

Vulnerability assessment surveys and mock drills should be a part of ongoing activities of national, regional, and local bodies for building sound programs to effectively mitigate the negative effects of natural disasters (Duzgun, Yucemen, Kalaycioglu, *et al*., 2011) These vulnerability assessments should also include a periodic survey on existing knowledge level, awareness and preventive practices of disaster management by the community (Dolce, Kappos, Masi, *et al*., 2006; Goltz, Park, Nakano, *et al.*, 2020). These assessments would help to design future media strategy, development of EDS, and device action plans as done by Himachal Pradesh State Government in India.

5.4. Capacity Building

Regular Training of the Trainers at the state and district levels should be undertaken to ensure the outreach of such programs (Kaur, 2006). To develop the capacity of the state, district, and local bodies' officer focused executive development programs (EDPs) for 2-4 days should be organized (Goltz, Park, Nakano, *et al.*, 2020). EDPs on disaster management should be made compulsory for all licensed and registered private practicing civil engineers, architects, and town planners (Shaw, Gupta and Sarma, 2003). Three-day EDPs focusing on the application of earthquake safety-related codes and standards should be organized for professionals working in the local bodies.

5.5. Training Material

For success and future utilization of tabletop exercises, conduct experts, simulation exercise building experts, and trainers from both federal and state should work in synergy. A detailed trainer's manual consisting of what is the scenario, learning outcomes of tabletop exercise, how to conduct the tabletop exercise, etc., should also be developed which can be used by the trainers during capacity building programs (Hosseini and Izadkhah, 2010). Further, Tabletop exercises need to be further tailor-made as per the local needs (McBride, Llenos, Page, *et al*., 2020). Similarly, training materials should be peer-reviewed and pretested before disseminating across the level.

5.6. Emergency Operating Centre

Competent agencies like Federal Government should help both technically and financially to build EOCs at each state and district (Engelmann and Fiedrich, 2007) as this is the bare minimum requirement for the functioning of the IRS.

5.7. Community Participation

Before organizing mega shakeout exercises, small scale shakeout exercises should be organized in decentralized locations to ensure effective community participation (Yin, Karimi, Lampert, *et al*., 2015). Single toll-free numbers for all types

of emergencies covering fire, accident, ambulance, police, and the emergency operating center should be designated and widely publicized (McBride, Llenos, Page, *et al*., 2020).

5.8. Practical EDS

The simulation exercise for earthquake magnitude 6.0 and 7.0 for seismically prone locations should be designed as they have more probability of occurrence (Larsson, Bynander, Ohlsson, *et al*., 2015). This will lead to better participation of stakeholders (Waugh and Streib, 2006). Parameters related to topography and all parameters mentioned above should be included for the future development of scenarios as lack of information on these parameters defeat the very purpose of scenario development (Brainard, Ladd, Tappen, *et al*., 2019). Further, it should also include cost and timeline for rescue and rehabilitation.

5.9. Data Availability

State government and related agencies (national and state level) should be directed by the federal government to make relevant data accessible to the teams engaged in developing such type hypothetical scenarios. This will help to integrate the outcome of the scenario by the inclusion of infrastructure and economic losses.

5.10. Financing

Considering the lack of awareness and sensitization about earthquake disasters in the high-risk zone among community and administration, appropriate funds and time should be allocated (Wein and Rose, 2011). Appropriate funding should be given for such exercises so that technical aspects pointed by the Expert Group should be incorporated in future projects.

6. Conclusion

The scientific EDS exercise followed by mega Shakeout exercises helped the administration, government agencies, and community in generating awareness of the earthquake and possible risks attached to the high magnitude earthquake. The exercises also helped the administration to know their level of preparedness and identified gaps that need immediate attention. The scenario developed exercise faced several challenges such as lack of awareness among concerned stakeholder, lack of technical know-how at the grass-root level, lack of poor coordination among various stakeholders, unavailability of data on important issues such as the effect of earthquake-triggered landslides, sub-soil characteristics, depth of soil, soil stratification and cascading effect of buildings/infrastructure, and socioeconomic status of people living affected areas. Indian experience has shown a threefold framework for effective EDS planning and implementation. This includes a strategic action map, i.e., pre-requisites for EDS and Shakeout exercise, action needs at the planning stage of EDS, and checklist for the implementation of EDS and Shakeout Exercises in other countries. These practical suggestions are a must for successful EDS and Shakeout exercises planned for other states.

Authors' Contributions

Authors have collected the data from all relevant sources and stakeholders after due informed consent obtained and carried out detailed analysis using qualitative data analysis methodology with a systematic literature review.

Ethics Statement

The ethical clearance was not required for this study, as this study mainly involved post-event study. The study involved in-depth discussions with the key stakeholders and officials involved in the process. The informed consent of the officers was taken in advance before inviting them for the workshop. All views expressed by the officials were in their official capacity.

Availability of Supporting Data

All important relevant data related to the study can be found at the NDMA website and the IIT Bombay website.

Acknowledgment and Conflict of Interest

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RESEARCH ARTICLE

District-level analysis of climate vulnerability and household nutrition status among rural communities in Odisha, India

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Abstract: Good nutrition is the foundation of human well-being that leads to better health, effective engagement of the workforce, and productive lifestyle, resulting in higher income and an integrated development trajectory. This paper attempts to comprehend the impact of climate vulnerability on household nutrition status through agriculture production systems in Odisha, India. This study using secondary data estimates a composite index of climate vulnerability on the agriculture ecosystem in Odisha at the district scale. Results suggest that among all the districts in Odisha, Bhadrak (0.193) is the most vulnerable district followed by Sonepur (0.191) and Baudh (0.190). On the other hand, Mayurbhanj (0.099) is the least vulnerable district followed by Ganjam (0.103) and Sundargarh (0.105). The findings also suggest that there is a wide variation in vulnerability indicators among the districts in Odisha (0.099 – the lowest district value vs. 0.193 – the highest). The results of multivariate analysis evince that in households (both women and children) nutritional status, the composite value of "climate vulnerability" has a greater role in predicting the predictors in Odisha through the agriculture production system. The climate vulnerability has a positive and significant relationship with forest area (r=0.403*), gross cropped area (r=0.489**), percent of scheduled caste population (r=0.510**), percent of urban area (r=0.427*), and per-capita income (r=0.712**). The findings also signify that district-wise gross cropped area (t=3.01), average annual rainfall (t=4.05), area under irrigation (t=3.36), cropping intensity (t=3.60), and forest areas (t=1.81) play a more predictive role to determine the household nutritional status along with socioeconomic and health factors such as per-capita income (t=1.8), urbanization (t=1.91), and women's anemic status (t=2.74). Drawing inferences from the empirical evidence, the study suggests that climate vulnerability has a much greater role in influencing household nutrition status, particularly with women and child nutrition through the agriculture production system. Appropriate policy level measures for climate-sensitive and adaptive action are the need of the hour to make agriculture production ecosystem contributes positively to nutrition status.

Keywords: Climate change, Climate vulnerability, Nutrition, India

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1. Introduction

Good nutrition is a foundation of human well-being that leads to good health, effective engagement in the workforce, and productive lifestyle, resulting in higher income and an integrated development trajectory. Over the years, the burden of undernutrition and micronutrient deficiencies remains staggering across the globe with the regional disparity at the center. Research findings on public health reveal that better-nourished mothers can give

birth to well-nourished children, and better-nourished children can keep themselves more engaged in productive work during their youth and adulthood (Global Nutrition Report, 2014). Proper nutrition averts death (particularly during childhood). It enables healthy growth of the body and the growth of cognitive skills to its full potential, without which life and livelihood become quicksand. Malnutrition is also responsible for ill-health than any other cause is (Global Nutrition Report, 2014). Malnutrition is a universal issue. Its burden remains unacceptably high, coupled with stunted progress all over the world. Children under age five face multiple burdens of malnutrition. Gender disaggregated data show that women have a higher propensity of a burden than men in certain forms of malnutrition, i.e., obesity and overweight. As per United Nations Children Fund (UNICEF) estimates, globally, 151 million children under age five are stunted, 50.5 million are wasted, 38.3 million are overweight, and a quintile million babies are born with the low birth weight each year. Nearly one of four adults (38.9%) are overweight or having obesity, one-third of women in reproductive age have anemia, and a million women are still underweight (UNICEF, 2006). Poor nutrition and deficiency of vitamins and minerals in food plates result in physical disorders and higher susceptibility to several diseases (Horton and Steckler, 2013). The latest analysis available suggests that undernutrition is associated with three million child-deaths annually, which is almost half of child mortality globally (Global Nutrition Report, 2018). Nearly one-third of global stunted children (about 57 million) are living in India and the majority of them live in rural areas which are a matter of great policy concern.

Across the world, it has been well recognized that linking policies and investments on agriculture with improved health and sanitation have a potential impact on improving the household nutrition outcomes. Unfortunately, in India, the agriculture production system is still reeling under traditional staple grain fundamentalism. This has a limited scope to address the issues of undernutrition through available food systems. Black, Victora, Walker, *et al*. (2013) have found that agriculture has strong potential to influence the underlying determinants of nutrition outcomes by improving global food availability and access through enhancing household food security, dietary quality, income, and women's empowerment (Black, Victora, Walker, *et al*., 2013). In this backdrop, nutrition-sensitive agriculture interventions can be a potential source for ensuring positive nutritional outcomes by increasing the quality and availability of agricultural commodities, as well as the quality of food in terms of diet diversity, nutrient content, and food safety. As defined by UNICEF (1990), four main factors play a crucial role in determining the household nutrition status: (i) Availability and access to quality food; (ii) quality of feeding and caregiving practices; (iii) health of the surrounding environment, and (iv) access to health care services (UNICEF, 1990). Each of these determinants is a necessary but not a sufficient condition for proper nutrition at the household level. This paper attempts to comprehend the factors that are influencing the availability of and accessibility of quality food at the household level in Odisha, particularly from a climate vulnerability perspective. The study conceptualizes that the availability of quality food at the household level is affected by climate vulnerability, contributing partly to poor household nutrition outcomes.

1.1. Relationship of Climate Vulnerability and Household Food and Nutrition Status

Climate-induced variability has a significant contribution to the vulnerability quantum of biophysical as well as socioeconomic ecosystems. The biophysical ecosystem consists of mountains, rivers, forests, wetlands, etc., whereas socioeconomic ecosystem comprises the hill communities, coastal communities, agriculture, and animal husbandry, etc. Intergovernmental Panel on Climate Change (IPCC) defines "vulnerability" as the "propensity or predisposition of a system to be adversely affected." It is an intrinsic property of a system which includes "sensitivity," i.e., susceptibility to harm, exposure to potential hazards, and "lack of adaptive capacity" (IPCC, 2014). As per IPCC report 2014, global climate change will reduce agricultural production by 2% every decade while the demand for food will increase by 14% every decade until 2050. Yields of primary crops will face an average decline of 8% for Africa and South Asia by 2050. The decrease in food production and a reduction in nutritional quality could increase child malnutrition up to 20 % by 2050 and additional 600 million people will suffer from hunger due to climate change (IPCC, 2014). The poorest countries and regions are generally most susceptible to damage caused by weather extremes and climate variability. Countries with a higher human development index (HDI) are less likely to be affected by the ill effects of floods, droughts, and cyclones (Malik, Awan and Khan, 2012; Patt, Tadross, Nussbaumer, *et al*., 2010). Among all the countries of the world, India is quite vulnerable because; more than three of ten poor people live in India, 70% of its inhabitants are engaged in agriculture, 40 million hectares of land susceptible to floods, 68% of its agricultural land vulnerable to drought, long coastline prone to cyclones, and rising annual mean temperature (GOI, 2004; GoO, 2017; Radhakrishnan, Sivaraman, Jena, *et al*., 2017). The State of Odisha has been experiencing distinct weather variability resulting in significant negative effects on agriculture production, thus elevating the prospect of hunger and malnutrition. Odisha features as one of the most vulnerable states in India to climate change regime and the occurrence of natural disasters, including floods, cyclones, drought, and heatwaves (Ray-Bennett, 2009; GOI, 2012; GoO, 2016; Patel, 2016). The geographic location and

climatic conditions of Odisha make it conducive for witnessing in multiple disasters due to this Sharma, Mohanty, and Islam, (2016) observes that the State Odisha is the disaster capital of India (Sharma, Mohanty, and Islam, 2016). Using 45 years of data for seven selected crops (panel data) of Odisha Das (2017) observed that changing climate, particularly at the rainfall and temperature level, has significant impacts on the crop production in Odisha (Das, 2017). Research studies using panel regression analysis found that climate change has a significant influence on the agriculture production system in Odisha (Mishra and Sahu, 2014; Mishra, Sahu and Sahu, 2015; Patel, Mathew, Nanda, *et al*., 2020).

IPCC (2007) working Group-II estimates that changing climate in India will lead to a drop in wheat production by 4-5 million tones, 4-35% reduction in rice yields, and negative impacts on livestock (WG-II, IPCC-2007). The panel also highlights a 10-30% decline in freshwater supply due to floods and droughts, which have significant negative impacts on livelihoods and biodiversity. Rising temperature due to climate change seems to increase the probability of higher morbidity and mortality from heat stress and vector or water-borne diseases. Rapid variation in rainfall intensity and occurrences resulting in more frequent floods and droughts will also contribute to higher morbidity and mortality. Weather variability and climate-induced stress result in low land utilization and productivity. In this way, it is marked with high unpredictable production rates from a unit of input invested. Increasing the probability of crop loss or production failure due to pest attack, pathogens, poor weed, and plant growth management is also marked with less availability of physical labor for agriculture. Besides these, the impact of crop production on the dynamic balance of biophysical resources (soil quality, water availability, sunlight, and temperature suitability) cannot be ignored. Samuel, Smith, and Guth (2017). observed that climate change has significant influence on each of those above discussed dimensions of agricultural production (Samuel, Smith and Guth, 2017).

1.2. Research Objectives

Climate change has a paramount role in changing household nutrition patterns by influencing agriculture production system and access to the availability of quality food at the household level, and this can be deduced by reviewing various research documents. Changing climate will lead to a change in temperature pattern. Thus, the agriculture ecosystem will face severe consequences of weather stress in the form of drought, erratic rainfall, low pressure, excess or scanty rain, flood, severe pest attack on plant, the incidence of pathogens, poor weed management, less growth of the plant, nutrient loss of the crop, inadequate availability of the agriculture labor and direct impact on the livestock reproduction system. Ultimately less agriculture production and productivity, inadequate availability of nutritious food and quality diet at household level will lead to poor household-level nutrition outcomes. Hence, climate change affects food production and consequently, the household food and nutrition status. In this backdrop, the following questions have emerged, is there any significant impact of climate vulnerability on household food and nutrition status in Odisha through agriculture production pathways system? Do higher climate-vulnerable districts have low household-level nutrition indicator performances, particularly on women and child nutrition? Is there any relationship that exists between climate vulnerability and household nutrition?

The study examines to understand the role of climate vulnerability on the agricultural ecosystem and its cascading impacts on household nutrition status in Odisha to address the questions raised in the above section. The specific objectives of the study are to (1) rank the districts of Odisha based on their climate vulnerability extent with reference to agriculture production system by developing a composite index and (2) comprehend the linkage of climate vulnerability with household nutrition status, particularly among children under age five and women in reproductive age group through an agriculture production system.

1.3. Nutrition Status of Odisha – A Brief Sketch

Odisha is in the eastern part of India with a long coastline bordering the Bay of Bengal. As per Census (2011), the state accounts for approximately 3.46% of the total population of the country. For administrative purposes, Odisha is divided into three revenue divisions and 30 districts with a population of about 42 million (2011 Census). It has a cultivated area of 6.180 million hectares with highly skewed operational landholdings. Of this, more than 91% of areas belong to small and marginal farmers and the average size of landholding is 1.04 hectares (GoO, 2017). In the recent past, Odisha has progressed considerably on nutrition indices being a signatory to the global commitments to end malnutrition. As per the latest round of National Family Health Survey (NFHS-4) (2015-2016), one-third (34.1%) of children under age five in Odisha are stunted, which has reduced from 45% in 2005-2006. More than three (34.4%) of ten children in the age as a mentioned earlier group are underweight, and one-fifth of the children are wasted. It is also found that one of each four (26.4%) women in the reproductive age group are reported having below-average body mass index and more than half (51%) is anemic. Approximately half (47.6%) of pregnant women aged 15-49 years are also anemic (NFHS-4,

2015-2016). Further, tracking the global nutritional targets, as mentioned in the World Health Assembly, it is estimated that the pace of improvement in nutrition indicators is languid in India. Odisha must travel miles to reach to the WHA global nutritional targets set so far for 2025. Considering NFHS-4, 2015-2016 has been considered the base year for the study. It is found that of six global nutrition targets, India and Odisha can manage to achieve only four in the prescribed timeline of 2025. These four indicators are stunting, wasting, and anemia among women in the reproductive age group and exclusive breastfeeding in the first 6 months.

2. Data and Methods

2.1. Data sources

In this study, data have been collected from various secondary sources such as the Census of India 2011, Annual Health Survey-III, 2012-2013, Economic Survey-2013-2014, Agriculture Statistics, India Meteorological Department Data, Annual Year Book of Odisha Ground Water, and other published sources. All the collected data have been used for assessing the district-wise climate vulnerability of Odisha. More importantly, the study makes use of these datasets to construct the district level climate vulnerability status based on three parameters (i) sensitivity, (ii) exposure, and (iii) adaptive capacity on vulnerability to affect the agriculture production. These indicators are broadly "biophysical" or "socioeconomic" in nature. In the present analysis, we have identified 13 indicators pertaining to biophysical, socioeconomic, and demographic factors. Five indicators were chosen under the biophysical category, whereas eight indicators were identified under the socioeconomic category for calculations to estimate the vulnerability. The rationality of selection of the indicators is drawn from their inter-relationship available sources in reference to the years and weights allotted, which is presented in Table 1.

2.2. Measurements and Methods

2.2.1. Household nutrition indicators

The fourth round of NFHS (2015-2016) published data is used for deriving the household nutrition status. Until date, the NFHS has been conducted four times in India. The first survey refers to the year 1992-1993 followed by a second in 1998-1999, third in 2005-2006, and the latest in the year 2015-2016. This survey is a storehouse of data for several health indicators, namely, fertility, infant and child mortality, the practice of family planning, maternal and child health, reproductive health, nutrition, anemia, utilization, and quality of health and family planning services on national and states level separately. The NFHS is a large-scale, multi-round survey conducted in a representative sample of households throughout India. The survey is modeled in the line of "Demographic and Health Survey" conducted in many countries around the world. For understanding the household nutrition status in the study, three nutrition indicators have been used, i.e., two from child nutrition and one from women nutrition category. Weight-for-height (Wasting) children (0-5 years) and anemia children (6-59 months) from child nutrition category and anemia – women (15-49 years) are from women nutrition category. For child nutrition, wasting or weight-for-height is defined as an index for the measurement of body mass in relation to body height that describes current nutrition status. It provides an estimate for acute undernutrition and represents the failure to receive adequate nutrition in the period immediately preceding the survey and maybe the result of inadequate food intake or a recent episode of illness-causing loss of weight and the onset of malnutrition. Anemia is a condition that is marked by low levels (<11.0 for children 6-59 months and pregnant women age 15-49 years and <12.0 for non-pregnant women age 15-49 years) of hemoglobin content in the blood. Iron is a crucial component of hemoglobin and iron deficiency is estimated to be responsible for half of all anemia globally. Anemia is a severe concern for children because it can impair cognitive development, resulting in stunted growth, and increase morbidity from infectious diseases.

2.2.2. Normalization of vulnerable indicators

To comprehend climate vulnerability and its impact on household nutrition status, it is essential to develop an indicator that is quantifiable, comprehensive, and can establish the relationship. Toward this attempt, the study estimates the climate vulnerability using "Composite Index" method, factoring in information from various secondary sources. The composite index is computed based on the dimensional relationship of the indicators with climate vulnerability and agriculture production system. Before estimating the composite index, we have normalized each indicator to reduce its variability as different indicators have different measurement units. For example, the per capita income is defined in terms

of rupees, whereas the area under forest cover is defined as the percentage of total geographical area. More importantly, the normalization process provides us with the opportunity to estimate the single value and to comprehend the relationship thereof. The selection of the indicators for preparing a composite index depends on the nature of the relationship of the respective indicator with the predictor.

Let $\mathbb{x}_{ij}$ represent the value of the i^{th} climate vulnerability indicator in the j^{th} district if $\mathbb{x}_{ij}$ is positively associated with the climate vulnerability (i = 1, 2, 3, ……., 10; j = 1, 2, ……, 10). Let us write the equation as:

$$Y_{ij} = \frac{X_{ij} - Min_j X_{ij}}{Max_j X_{ij} - Min_j X_{ij}} \quad (1)$$

Where $Min_j \mathbb{x}_i$ and $Max_j \mathbb{x}_j$ are the minimum and maximum of $\mathbb{x}_{ij}$, respectively.

However, if $\mathbb{x}_{ij}$ is negatively associated with climate vulnerability, equation (1) can be written as:

$$Y_{ij} = \frac{Max_j X_{ij} - X_{ij}}{Max_j X_{ij} - Min_j X_{ij}} \quad (2)$$

Scaling the dimension index values, $\mathbb{y}_{ij}$ vary from zero (0) to one (1), where 0 indicates the lowest vulnerability and 1 indicates the highest vulnerability. In all parameters, no normal or goalpost value has been defined. The observed maximum value of parameters has been taken as the goalpost value, and the observed minimum value is taken as a minimum from the matrix of scaled dimension values, $Y = \{(Y_{ij})\}$. In this process, we constructed the "Composite Index of Climate Vulnerability" for different districts of Odisha. The above-mentioned method is quite like the United Nations Development Programme's HDI. The Ministry of Science and Technology also uses the method – Government of India under the National Mission for Sustaining the Himalayan Ecosystem as part of National Action Plan on Climate Change to develop the Climate Vulnerability Assessment of Indian Himalayan Region (DST-GoI, 2018-2019). Further, we have assigned the weights of the indicators using principal component analysis. The weight is also generated in view of the importance of indicator on determining climate vulnerability and its effect on agriculture production. While assigning the weight, it was ensured that the weight or proportion assigned to all the indicators add up to "1;" where, the weight W, of the i^{th} indicator, varies inversely as the variation in the respective indicator of climate vulnerability status subject to the condition:

$$0 < W_i < 1 \quad and \quad W_1 + W_2 + W_3 + ...+ W_m = 1$$

Such that,

$$W_i = \frac{K}{\sqrt{Variance\, Y_i}} \quad (3)$$

Where,

$$K = \left[\sum_{i=1}^{m} \frac{1}{\sqrt{Variance\, Y_i}} \right]^{-1} \quad (4)$$

The choice of weights in this manner is taken up to ensure that large variations in any one of the indicators will not unduly dominate the contribution of the rest and distort the inter-group comparisons across the districts. To obtain a weighted average of a composite aggregated index value, we have added the total weighted value of each indicator of the same district and the sum is divided by the total number of indicators of the same district. The signs of the indicators (+ve or −ve) are assigned accordingly based on the fact whether each of them is contributing to an increase in or decrease in climate vulnerability.

2.2.3. Methods

To investigate the effects, we have used a correlation matrix and the techniques of multiple regression analysis. Under multiple regressions, six different models (four models for child nutrition and two for women nutrition) are used to find out the association. Following two types of regression models are worked out to identify the factors responsible for determining the household nutritional status in Odisha. We define the (HNS) Household Nutrition Status as listed below with three indicators, BPI as Biophysical Indicators (five indicators as mentioned in Table 1), SEI defined as

Table 1. The rationality of selection of the indicator and its relationship with vulnerability.

Sl. No.	Indicators and dimension ()	Relationship with vulnerability	Data sources	Weight
	Biophysical			
1	Percentage of the area under forest cover 2016-2017 (−)	Forests provide safeguard to ecological processes, provide biophysical stability and alternate livelihood options, and enhance the adaptive capacity.	Census of India 2011	0.28
2	Average Annual Rainfall in millimeter – 2007-2016 (−)	Increasing average rainfall increases agricultural production and raises the adaptive capacity	India Meteorological department	0.18
3	Gross cropped area in hectare 2013-2014 (−)	Gross cropped area depicts the available land for cultivation and sensitivity to climate vulnerability	Agriculture statistics	0.16
4	Cropping intensity in % 2013-2014 (−)	It represents the frequently available land for cultivation which has direct sensitivity with food production and vulnerability	Agriculture statistics	0.09
5	The area under irrigation in 000' hectare 2013-2014 (−)	Availability of irrigation facility has a direct link with food production and sensitivity to the climate vulnerability	Annual report groundwater	0.09
	Socioeconomic			
6	Population density in 2011 (+)	Pressure on available natural resources increases sensitivity.	Census	0.05
7	% of SC population in 2011 (+)	Their adaptive capacity toward vulnerability is low	Census	0.01
8	% of ST population in 2011 (+)	Their adaptive capacity toward vulnerability is still\low	Census	0.01
9	% of female literacy in 2011 (−)	Educated women household have better adaptive capacity	Census	0.04
10	% of urban area in 2011 (−)	Rapid urbanization and development quick depletion of natural resources increases the sensitivity of vulnerability	Census	0.01
11	Infant mortality rate 2012-2013 (+)	It is synonymous of overall development indicator. Higher the value implies a lack of adaptive capacity.	AHS	0.02
12	Per capita income in rupees (NDDP) 2013-2014 (−)	A direct indicator representing the inherent sensitivity of people in a region	Economic survey	0.00
13	Average man-days employment generated under MGNREGA 2013-14 (-)	Provides alternate sources of income and enhances the adaptive capacity.	MGNREGS	0.00

"()" Sign under parenthesis is the dimension of the indicator

socioeconomic indicators (eight indicators as listed in Table 1), and CVCV acronym as Composite Value of Climate Vulnerability. District wise detailed value of these indicators are provided in Table A1. As mentioned above, three independent models have been run separately using Statistical Package for the Social Science version-21 to examine the association of climate vulnerability with household nutrition status.

3. Results

The results of this study are presented in two parts. The extent and variation of climate vulnerability among districts in Odisha are interpreted by computing a composite index, ranking the individual index values and then through categorizing the ranks associated with the indexes. Association of climate vulnerability with household nutrition is comprehended through multivariate analysis in the second stage. The study computes the climate vulnerability index notably, the vulnerability about agriculture production using various secondary published data sources, as mentioned in Table 2, considering both biophysical as well as socioeconomic factors. While estimating the weighted scores of the climate vulnerability in Odisha, it is found that among the districts, Mayurbhanj (0.099) is the least vulnerable district followed by Ganjam (0.103) and Sundergarh (0.105). On the other hand, Bhadrak (0.193) is the most vulnerable district followed by Sonepur (0.191) and Baudh (0.190). The study also found that around 37% (11 of 30) of districts in Odisha are categorized under a high climate vulnerability segment, 53% are in medium bracket followed by 10% in low segment. The details of the results are presented in Table 2.

3.1. Impact of Climate Vulnerability on Household Nutrition Status

Before applying the multivariate regression analysis, it is crucial to comprehend the cause and effect relationship of climate vulnerability and household nutrition status. It is observed that direct relationships between household nutrition status and climate vulnerability in Odisha, although the latter has a significant role through the agriculture production

Table 2. District-wise climate vulnerability in Odisha, India.

Districts	Climate vulnerability index	Rank	Rank category 0-0.106= Low, 0.115-0.170 = Medium, 0. 171-0.193 = High
Mayurbhanj	0.099	1	Low
Ganjam	0.103	2	Low
Sundargarh	0.105	3	Low
Angul	0.106	4	Medium
Keonjhar	0.115	5	Medium
Kandhamal	0.115	6	Medium
Sambalpur	0.126	7	Medium
Khordha	0.131	8	Medium
Cuttack	0.136	9	Medium
Koraput	0.141	10	Medium
Kalahandi	0.144	11	Medium
Dhenkanal	0.147	12	Medium
Jharsuguda	0.158	13	Medium
Bolangir	0.159	14	Medium
Rayagada	0.159	15	Medium
Gajapati	0.160	16	Medium
Jajpur	0.169	17	Medium
Jagatsinghpur	0.169	18	Medium
Balasore	0.170	19	Medium
Nuapada	0.171	20	High
Nabarangpur	0.171	21	High
Nayagarh	0.172	22	High
Deogarh	0.173	23	High
Malkangiri	0.174	24	High
Baragarh	0.181	25	High
Kendrapara	0.181	26	High
Puri	0.185	27	High
Boudh	0.190	28	High
Sonepur	0.191	29	High
Bhadrak	0.193	30	High

Source: Computed by authors using secondary data sources

system. The high climate-vulnerable districts are found to have a greater number of wasted children aged 0-5 years, anemic among children aged 6-59 months, and anemic women aged 15-49 years. Findings also reveal that districts having a high climate vulnerability burden also reveal high household malnutrition burdens, particularly among women and children. The details of the analysis are presented in Table 3.

For better comprehending the relationship of climate vulnerability (through agriculture production system) concerning household nutrition status, the study uses a correlation matrix, where the degree of relationship of the variables has been observed. It is also found that climate vulnerability has a strong positive significant association with district-wise areas under forest coverages (r=0.403*), gross cropped area (0.489*), the area under irrigation facilities (0.466**), and social-economic factors such as percentage of scheduled caste population (0.510**), urbanization (0.427*), per-capita income (0.712**), and average numbers of men-for-days employment generated under MGNREGS (0.688**). The results of the correlation matrix portray that the climate vulnerability of Odisha has a close inter-association with the agriculture production system through the gross cropped areas and area under forest coverage. The detailed results of the correlation

Table 3. District-wise climate vulnerability and household nutrition status in Odisha, India.

Districts	Rank	Rank category 0-0.106 = Low, 0.115-0.170 = Medium, 0. 171-0.193 = High	Weight-for-height (wasting)	% of Children 6-59 months who are having anemic	% of women 15-49 years who are having anemic
Mayurbhanj	1	Low	17.2	34.5	42.4
Ganjam	2	Low	16.4	37.4	41.3
Sundargarh	3	Low	31.4	75.3	71.4
Angul	4	Medium	21.6	37.4	44.0
Keonjhar	5	Medium	19.0	32.7	40.5
Kandhamal	6	Medium	23.1	42.7	52.7
Sambalpur	7	Medium	22.3	75.0	69.2
Khordha	8	Medium	13.8	19.0	45.3
Cuttack	9	Medium	9.1	18.9	37.8
Koraput	10	Medium	28.5	71.4	63.3
Kalahandi	11	Medium	24.8	67.2	68.7
Dhenkanal	12	Medium	19.0	39.4	39.4
Jharsuguda	13	Medium	24.8	67.1	69.2
Bolangir	14	Medium	26.1	67.3	61.1
Rayagada	15	Medium	23.1	49.8	55.4
Gajapati	16	Medium	18.4	57.9	58.5
Jajpur	17	Medium	9.1	18.9	37.8
Jagatsinghpur	18	Medium	12.6	23.4	35.8
Balasore	19	Medium	18.0	28.6	41.1
Nuapada	20	High	26.4	63.9	64.0
Nabarangpur	21	High	36.0	71.9	71.5
Nayagarh	22	High	17.5	26.5	39.8
Deogarh	23	High	19.9	30.0	42.6
Malkangiri	24	High	32.5	72.2	71.3
Baragarh	25	High	24.2	68.8	68.8
Kendrapara	26	High	12.3	28.7	42.3
Puri	27	High	12.1	29.2	44.3
Boudh	28	High	22.5	44.1	49.9
Sonepur	29	High	22.3	75.0	69.2
Bhadrak	30	High	15.3	22.7	43.5

Source: Computed by authors using data from secondary sources

matrix have been presented in Table 4.

The results of multiple regression analysis have been documented in Table 5. As mentioned above for better comprehension, under each dependent variable, two separate models were created. First is one to one matching of the composite values with dependent variables, and the second one is the matching of independent variables with all associating factors except composite values. In this process, six models were made to run for three identified predictors which relate to household nutrition outcomes. The results of the multivariate analysis suggest that household nutrition status, particularly child nutrition indicators (wasting and childhood anemia), are associated significantly with mother's anemic status, literacy level, and household's economic and social caste composition. The child nutrition status relates not only to socioeconomic factors but also to biophysical factors such as district's predisposition to gross cropped area, percentage of the area having forest coverage, annual rainfall, and irrigation facility.

Similarly, the study also finds that household women nutrition status is also influenced by household's socioeconomic attributes such as women's social category, level of urbanization, and biophysical factors such as cropping intensity. Ironically,

Table 4. Correlation matrix.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	PC	1																
2	PC	−0.143	1															
3	PC	−0.045	−0.061	1														
4	PC	−0.087	0.357	−0.145	1													
5	PC	−0.416*	0.163	0.768**	0.051	1												
6	PC	0.725**	−0.374*	0.003	−0.390*	−0.421*	1											
7	PC	−0.484**	−0.104	−0.255	0.136	0.117	−0.630**	1										
8	PC	−0.051	0.037	−0.109	−0.323	0.067	−0.052	0.060	1									
9	PC	0.457*	−0.161	0.053	−0.301	−0.197	0.267	−0.282	0.196	1								
10	PC	−0.565**	0.043	0.031	0.470**	0.326	−0.633**	0.557**	−0.240	−0.640**	1							
11	PC	−0.078	0.116	−0.093	−0.199	−0.064	−0.288	0.271	0.201	0.281	0.029	1						
12	PC	0.140	−0.053	−0.018	−0.140	−0.129	−0.084	0.261	0.084	0.265	−0.054	0.711**	1					
13	PC	0.261	−0.246	0.677**	−0.331	0.390*	0.201	−0.327	0.018	0.490**	−0.389*	−0.055	0.037	1				
14	PC	0.403*	−0.080	0.489**	0.0.209	0.119	−0.116	0.047	0.510**	−0.314	0.427	0.540**	0.712**	0.688**	1			
15	PC	−0.495**	−0.039	−0.056	0.541**	0.331	−0.704**	0.529**	−0.155	−0.121	0.613**	0.012	0.031	−0.056	0.754**	1		
16	PC	−0.315	0.107	−0.118	0.438*	0.231	−0.651**	0.491**	−0.135	−0.032	0.497**	0.010	0.099	−0.013	0.273	0.882**	1	
17	PC	−0.259	0.045	−0.019	0.460*	0.268	−0.542**	0.407*	−0.168	−0.038	0.478**	−0.124	0.068	0.085	0.280	0.850**	0.957**	1

Source: Computed by authors; PC: Pearson correlation; *Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed). 1-FR-Forest area, 2-AARF-Average annual rainfall, 3-GCA-Gross cropped area, 4-CI-Cropping intensity, 5-AUI-Area under Irrigation, 6-PD-Population density, 7-FLR-Female literacy rate, 8-IMR-Infant mortality rate, 9-SCP-Scheduled caste population; 10-STP-Scheduled tribe population, 11-PU-Percent of Urban, 12-PCI-Per-capita income, 13-MGN-Average man-days generated through MGNRESG, 14-CVCV-Composite value of climate vulnerability, 15-Wasting, 16-Ch Anea.- Childhood anemia, 17-Wo Anea.- Women anemia

the study also finds that in household (both women and children) nutrition parameters, the composite value of the climate vulnerability index does not have much role in predicting the predictors. Of course, the individual covariates play a more predictive role to understand the role of climate vulnerability on household nutrition status. Similarly, the findings also reveal that gross cropped area, availability of forest areas, and average annual rainfall are negatively correlated with household child wasting and positively associated with area under irrigation and cropping intensity. Similarly, among biophysical factors, within the household, women's nutrition status is more governed by forest area and to some extent, with the cropping intensity. The estimates of these variables are statistically significant, with expected signs and the results that are presented in Table 5.

4. Discussions

This study highlights the role of climate vulnerability and its impact on household nutrition status through agriculture production systems in Odisha. The districts of Odisha have different agro-climatic zones and varied socioeconomic conditions. The composite index value shows that climate vulnerability has a significant impact on the agriculture production ecosystem in Odisha, considering both biophysical as well as socioeconomic factors. The study observed that around two-third number of districts in Odisha are effected by climate vulnerability either in terms of a high or medium category where 70% of the population depends on agriculture as their primary source of food and livelihood (GOI, 2012; GoO, 2016). Unfortunately, the agriculture production ecosystem is widely affected by various climate-induced vulnerabilities. Many past studies have documented the same (Mishra, 2007; Chhotray and Few, 2012; GoO, 2016; Duncan, Tompkins, Dash, *et al*., 2017; Patel, Mathew, and Nanda, 2019; Patel, Mathew, Nanda, *et al*. 2020). This vulnerability not only affects agriculture production systems but also impacts nutrition outcomes of the household in terms of creating a scarcity of food, particularly nutrient-rich quality food for the agriculturally dependent households.

Table 5. Results of ordinary least square regression.

Dependent variable: Household nutritional status												
Covariates	**Wasting**				**Childhood anemia (0-59 m)**				**Anemia among women in 15-19 years**			
	B	**t-test**	**B**	**t-test**	**B**	**t-test**	**B**	**t-test**	**B**	**t-test**	**B**	**t-test**
FA	-	-	−0.73	−1.8***	-	-	0.52	1.4	-	-	−0.67	−1.4
AARF	-	-	−1.5	−4.1*	-	-	−0.21	−0.62	-	-	−0.09	−0.16
GCA	-	-	−2.5	−3.1*	-	-	−0.58	−0.81	-	-	−0.76	−0.78
CI	-	-	0.98	3.6*	-	-	−0.29	−1.2	-	-	0.54	1.3
AUI	-	-	2.1	3.4*	-	-	0.38	0.69	-	-	0.52	0.6
PD	-	-	−0.8	−1.5	-	-	−1.1	−2.2**	-	-	0.76	1.3
FLR	-	-	−0.5	−1.4	-	-	−0.12	−0.37	-	-	−0.06	−0.17
IMR	-	-	−0.4	−1.6	-	-	−0.24	−1.1	-	-	0.6	0.27
SCP	-	-	0.8	1.7	-	-	0.6	0.14	-	-	0.39	0.84
STP	-	-	0.3	0.8	-	-	−0.14	−0.39	-	-	0.53	1.34
PU	-	-	−0.02	−0.3	-	-	0.3	0.66	-	-	−0.86	−1.9**
PCI	-	-	0.4	0.87	-	-	−0.23	−0.57	-	-	0.72	1.8***
MGN	-	-	0.6	0.91	-	-	−0.37	−0.67	-	-	1.04	1.8***
CVCV	0.036	0.29	-	-	0.007	0.104	-	-	0.049	0.69	-	-
Wasting	-	-	-	-	-	-	-	-	-	-	−0.24	−0.81
Ch Anea	-	-	-	-	-	-	-		0.912	7.6*	0.99	5.7*
Wo Anea	0.849	7.9*	0.36	2.7	0.95	16.4*	0.89	7.7*	-	-	-	-
Constant	−0.265		0.5	0.6	−0.046	-0.096	0.84	1.2	−0.35	−0.69	−1.1	−1.4
Adjusted R^2	0.71		0.91		0.91		0.93		0.91		0.92	

***0 < P < 0.10, **0 < P < 0.05, *0 < P < 0.001. Source: Author's Computed; FR: Forest area, AARF: Average annual rainfall, GCA: Gross cropped area, CI: Cropping intensity, AUI: Area under irrigation, PD: Population density, FLR: Female literacy rate, IMR: Infant mortality rate, SCP: Scheduled caste population, STP: Scheduled tribe population, PU: Percent of Urban, PCI: Per-capita income, MGN: Average man-days generated through MGNRESG, CVCV: Composite value of climate vulnerability, Ch Anea.: Childhood anemia, Wo Anea.: Women anemia

The results of the composite value computation validate that Mayurbhanj district is the least vulnerable, although the district has the highest percentage of tribal population. A high concentration of tribal population is often characterized as a low socioeconomic indicator but for better biophysical factors. Particularly the fact that the district is situated in the north-central region having excellent irrigation facilities, the majority of land resources covered under various crops (higher gross cropped areas). It signifies the district's low climatic vulnerability toward agriculture production. Similarly, Ganjam, although the district is in the coastline of the state and is possess vast stretches of flood-plain areas with ample irrigation facilities and less concentration of tribal population. The district is found to be faring better in terms of agriculture production ecosystem.

On the other hand, Bhadrak is the most vulnerable district having low social and economic attributes along with biophysical factors. This district, like Ganjam, is also located in the coastline of the State. However, frequent natural disasters such as flood and cyclone compel the district to face high climate-induced vulnerability in agriculture ecosystem management. Districts such as Sonepur and Boudh tell similar stories. Although these two districts' geolocational position is a central part of the State historically, these two districts have recorded low socioeconomic parameters with a few portions of land left out for cultivation and frequent occurrence of natural disasters, particularly drought. Often these districts encounter long drought spells. The analysis in the study has also resulted low scores in both biophysical as well as socio-economic attributes for these districts despite having significant forest coverage. These are the districts that are characterized with few areas available for cropping, few cultivable lands having irrigation facilities, and low cropping intensity, low percent of women literacy, high concentration of scheduled tribe, and scheduled caste population. These are probably the factors that contribute to higher climate sensitivity coupled with low resilience and adaptive capacity in result in high climate vulnerability. The frequent occurrence of natural disasters in terms of drought due to climate vulnerability resulting in an extreme shortage of food and food security becomes a chronic issue resulting in a high burden of child and women malnutrition. Past studies observed that natural disasters had impacted the food security of people disproportionately (Duncan, Tompkins, Dash, *et al*., 2017; Mishra, 2017).

Climate vulnerability of Odisha has a close inter-association with agriculture production system through the gross cropped area and forest area which the past studies have also recorded (Mishra, Sahu, and Sahu, *et al*., 2015; Das, 2017) so far (Mishra, Sahu, and Sahu, 2015; Das, 2017). The empirical pieces of evidence establish that in Odisha, climate vulnerability has a significant role among factors that influence the agriculture production system and its consequent impacts on household nutrition status, particularly with children and women nutrition. Further, our observations have come up in the light of findings from one literature that confirms women's socioeconomic and biomarker status has a significant impact on the household child nutrition (Rachel, Levin, Hale, *et al*., 2020; Hoddinott, Alderman, Behrman, *et al*., 2013; Popkin, Horton, Kim, *et al.*, 2001; Cook and Frank, 2008; Finucane, Stevens, Cowan, *et al*., 2011; Patnaik, Das and Bahinipati, 2016). Moreover, our findings also indicate that child nutrition status relates not only to socioeconomic factors but also to biophysical factors such as district's predisposition to gross cropped area, percentage of an area having forest coverage, annual rainfall, and irrigation facility along with the socioeconomic attributes such as women's social category and level of urbanization. Although the composite value of climate vulnerability does not have a greater role in predicting household nutrition directly, the individual level factors play a crucial role in determining household nutrition. Findings also reveal that gross cropped area, availability of forest areas, and average annual rainfall are negatively associated with household child wasting and are positively associated with area under irrigation and cropping intensity. Our study has found out that districts having good cropping pattern or cropping intensity generally have high agriculture production and better women's biomarker indicators such as anemia which is positively associated with the household child nutrition status.

The Odisha government has recently formulated Odisha State Agriculture Policy – "*SAMBRUDHI-2020*," where the emphasis has been laid on doubling of farmers' income by promoting farmer-friendly agriculture programs. The document also highlights the promotion of nutritional crops by changing cropping pattern from staple grain dominant system to non-staple diversified cropping system. The document also echoes the role of the climate-smart agriculture system. It also initiates action toward the promotion of climate-resilient crops and varieties along with pro-poor climate policies with adaptation strategies for agriculture.

This study has some limitations as it has drawn the inferences analyzing different secondary data sources. Hence, the exact prediction and interpretation need caution. The limitation of the accuracy and precision of the secondary data sources along with the availability in timeliness is another point of concern.

5. Conclusions

It has been observed that due to the diverse agro-climatic conditions of Odisha, there prevails a great extent of variations in the climate vulnerability among the districts in the result of a high impact on the production system. Bhadrak (0.193),

the most vulnerable district followed by Sonepur (0.191) and Baudh (0.190) in terms of climate vulnerability on agricultural production and ecosystem, which are characterized with low socioeconomic development induces with a high concentration of scheduled caste population. Around 37% (11 from 30) of districts of Odisha are categorized under high climate vulnerability range, 53% are in the medium range followed by 10% in the lower segment. These vulnerable high districts do score poorly both on biophysical as well as on socioeconomic aspects, i.e., few areas available with the districts for extensive cropping with less cultivable lands having irrigation facilities. Attributes such as low cropping intensity and a high concentration of scheduled caste population coupled are primary contributors to higher vulnerability. Similarly, less per-capita income and few person-days generated through assured employment generation schemes have also contributed to the higher vulnerability of districts. This creates more sensitivity to climate shocks and high reliance on fragile agriculture production ecosystem.

Empirical evidence also indicates that household nutrition status not only results from socioeconomic factors but also relates to biophysical factors of climate vulnerability attribute such as gross cropped area, percentage of area under forest coverage, cropping intensity, average annual rainfall, and irrigation facilities. The findings of the study are in congruence with past studies that agriculture as an intervention has a strong potential capacity to influence household nutrition outcomes by improving household food availability, to access and to improve dietary quality, income, and child-caring practice empowering the women (Black, Victora, Walker, *et al*., 2013; Paolisso, Hallman, Haddad, *et al*., 2002; Mishra, Sahu and Sahu, 2015; Das 2017; Lloyd, Kovats and Chalabi, 2011). The socioeconomic factors such as women's social and economic status quo, per-capita income, and level of urbanization also have significant roles to contribute as far as household nutrition outcomes are concerned. This has been established both in correlation and regression analyses. Of course, the study finds that in estimating (both woman and child) household nutrition status, the composite value of the climate vulnerability index does not influence much to predict the predictors. Still, individual covariates play a more predictive role in determining the household nutrition status such as gross cropped area, forest areas, and concentration of scheduled caste population.

Further, analyzing the evidence, the study suggests that climate vulnerability has a much more significant role in influencing the agriculture production system through gross cropped area and area under irrigation and district-wise forest coverage. These are the factors that have a much more significant role in influencing household nutrition through the agricultural production system by making the availability of quality food and diet. Availability and accessibility of quality food have a greater role in addressing the problem of malnutrition in India and particularly in Odisha. For solving this challenge, there is an emergent need for strong committed and concentrated effort, especially to link production of food with its nutritional quality, safety, delivery, and last-mile availability also affordability with other determinants of nutrition. Given this, in the year 2015, the Government of Odisha has prepared Odisha Nutrition Action Plan (ONAP) which is a multi-sector plan keeping in mind the Sustainable Development Goals and World Health Assembly targets for nutrition. The state has also set a target to achieve a 20%-point reduction in malnutrition by 2025 (GoO, 2015). Special efforts have also been emphasized to address this problem through multiple interventions with a multidisciplinary approach and inter-departmental convergence at the government level instead of focusing on compartmentalized operations. Convergence in policies and actions would be required to ameliorate the present situation of undernutrition in the state with much more targeted interventions and strategies for certain vulnerable pockets.

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Authors' Contributions

Arabinda Acharya, conceptualized, designed the research, and undertook the analysis and wrote the paper. Both the authors edited and approved the final paper.

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We are declaring that "No conflicts of interest."

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Appendix

Table A1. District-wise selected indicators of Odisha, India.

District	A	B	C	D	E	F	G	H	I	J	K	M	N
Angul	199	68.64	48	42.6	1262	301.46	168	40516	13.18	18.81	14.1	16.2	121.18
Balasore	609	72.28	45	8.7	1631	322.2	169	20032	16.87	20.62	21.1	12.0	282.88
Baragarh	253	65.38	60	20.9	1274	473.01	142	19404	10.38	20.17	11.9	10.9	278.84
Bhadrak	601	75.83	48	4.0	1348	235.92	139	18217	17.32	22.23	19.0	10.1	195.29
Bolangir	251	53.5	97	23.4	1262	489.43	168	20689	37.01	17.88	12.6	4.7	148.50
Boudh	142	59.79	57	41.3	1161	138.3	163	17941	9.03	23.79	2.0	12.3	88.53
Cuttack	666	79.55	56	20.1	1545	303.11	193	30898	11.6	19.0	3.6	27.9	282.89
Deogarh	106	83.05	60	53.1	1214	108.53	175	23310	6.8	16.67	35.3	7.2	47.02
Dhenkanal	268	71	67	39.1	1537	261.42	195	24920	11.69	19.62	13.6	9.8	203.48
Gajapati	133	43.18	56	57.0	1283	150.2	198	23234	17.59	19.14	54.3	12.3	43.50
Ganjam	429	61.13	56	38.4	1378	704.38	181	24287	69.62	19.5	3.4	21.8	382.82
Jagatsinghpur	681	80.63	48	7.8	1427	177.23	197	25851	7.63	21.83	0.7	10.2	134.03
Jajpur	630	73.29	48	24.8	1483	279.5	198	23056	8.01	23.72	8.3	7.4	207.46
Jharsuguda	274	70.73	42	9.6	1294	80.98	133	32899	7.06	18.05	30.5	39.9	30.57
Kalahandi	199	46.68	54	32.1	1401	616.86	184	19409	35.74	18.17	28.5	7.8	307.88
Kandhamal	91	51.94	82	71.2	1425	188.54	176	29972	37.37	15.76	53.6	9.9	52.88
Kendrapara	545	78.96	58	9.5	1495	262.55	194	17646	11.69	21.51	0.7	5.8	215.59
Keonjhar	217	58.28	53	37.3	1370	393.33	161	30419	52.78	11.62	45.5	14.0	156.51
Khordha	799	81.61	67	22.1	1664	207.36	192	36088	7.70	13.21	5.1	48.1	150.67
Koraput	156	38.55	48	21.3	1531	400.34	147	26235	33.38	14.25	50.6	16.4	199.84
Malkangiri	106	38.28	48	57.9	1696	230.8	170	16327	10.24	22.55	57.8	8.0	128.94
Mayurbhanj	241	52.71	47	42.1	1110	491.81	138	20860	116.71	7.33	58.7	7.7	272.37
Nuapada	230	44.76	50	46.5	1800	289.65	160	14438	26.38	13.46	55.8	7.2	86.53
Nabarangpur	247	35.8	60	53.5	1469	242.27	192	16532	15.26	14.53	6.1	8.3	96.60
Nayagarh	157	72.05	49	48.1	1046	290.75	156	20107	15.55	14.17	33.8	5.6	104.42
Puri	488	78.28	75	4.0	1366	256.04	191	20120	6.05	19.14	0.4	15.6	259.41
Rayagada	136	39.19	58	39.7	1261	268.86	168	22376	22.82	14.41	56.0	15.4	97.61
Sambalpur	158	67.93	47	54.5	1383	273.22	153	33662	18.14	18.43	34.1	29.8	130.11
Sonepur	279	64.04	49	17.5	1325	230.38	190	17446	10.16	25.6	9.4	7.7	148.43
Sundargarh	214	65.48	47	51.1	1314	385.64	136	31622	48.07	9.16	50.8	35.5	149.97

A-Population density, B-Female literacy rate, C-Infant mortality rate, D-Forest area, E-Average annual rainfall, F-Gross cropped area, G-Cropping intensity, H-Per-capita income, I-Average Man-days generated through MGNRESG, J-Scheduled caste population, K-Scheduled tribe population, L-Percent of Urban, M-Area under irrigation

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RESEARCH ARTICLE

Values, environmental vulnerabilities, and implications on adaptation: Evidence from an indigenous Raika community in Rajasthan, India

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Abstract: Global environmental change has exacerbated the vulnerabilities of pastoral communities in India, who have already been sidelined in the current development and modernization discourse. The Raikas are one of the largest groups of indigenous nomadic pastoralists residing in the semi-arid regions of Northwest India. They are facing the brunt of shrinking grazing areas, social marginalization, and economic pressures. The past two decades have witnessed additional challenges, such as water scarcity and rainfall variability, which have pushed them beyond their adaptive threshold. These churnings have led to a radical shift in their values and climate adaptation strategies. However, the role and importance of social values in shaping their response to environmental change are not well understood. This study conducted life history interviews and focus group discussions with community members to examine social values and their linkages with climate adaptation decision-making in Raikas. The findings demonstrate that the community's livelihood, health, and social cohesion are severely affected by environmental change, entwined with social, economic, and political stressors. There is a parallel change taking place in their social values. Their values related to esteem, self-actualization, safety, and belongingness have witnessed shifts, leading them away from pastoralism. This has ramifications on their adaptation decision-making. Their time-tested and preferred choice of adaptation in the face of drought and water scarcity – seasonal livestock migration – is no longer desirable. New adaptation options, such as urban migration, have emerged, while traditional measures have declined in popularity. There is an urgent need to understand and engage with a broader set of methodologies and literature to facilitate the integration of social values in vulnerability and adaptation assessments. The inclusion of social values presents an opportunity to understand the subjective limits of adaptation better as well as to expand adaptation pathways.

Keywords: Climate change, Environmental vulnerability, Indigenous community, India

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1. Introduction

Adaptation can be defined as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC TAR, 2001: 982). The need for adaptation has outpaced its implementation, leading to an adaptation deficit (Eisenack, Moser, Hoffmann, *et al*., 2014). Therefore, it has become imperative to identify the limits of adaptation and overcome them. Most discussions on the limits of adaptation focus on external factors such as technology, ecology, and economy. This approach to envisioning the limits to adaptation is appealing because it provides analytical functionality, which aligns well with the other important dimensions of climate change analysis, namely, modeling variations in the earth system and energy-economic modeling of mitigation policy (Adger, Dessai, Goulden, *et al*., 2009: 337). While useful, these methods exclude the

cultural embeddedness of risks and overlook the everyday experiences, interpretations, and negotiations with environmental change (O'Brien, 2009; Jones and Boyd, 2011; Adger, Barnett, Brown, *et al*., 2013; Dow, Berkhout, and Preston, 2013).

Values, in their most open and broadest form, refer to what is considered desirable within an individual or society (Adger, Dessai, Goulden, *et al*., 2009; O'Brien and Wolf, 2010). They are ubiquitous and serve as guidelines or standards for our action, judgment, attitudes, desires, evaluations, and arguments. Therefore, it is essential to understand the values that shape human behavior to environmental change (Rokeach, 2008). The values-based approach to adaptation addresses climate change from the lens of how a society is organized and how the relationship between individuals, institutions, and the state is structured (Ramm, Graham, White, *et al*., 2017). It makes explicit the non-material parts of what people deem important and cherish about their lives, how environmental change impacts them, and how policies are framed (O'Brien and Wolf, 2010; Graham, Barnett, Fincher, *et al*., 2013).

The Raika community is one of the largest groups of indigenous nomadic pastoralists located in Rajasthan (Geerlings, 2011) and has been connected to livestock through myths of origin (Sharma, Köhler-Rollefson, and Morton, 2003). However, the shrinking of grazing areas, indifferent policy, financial pressures, and environmental change have led them to a crisis of livelihood and identity (Sansthan, 2004; Sharma and Sharma, 2015). Raikas operate in an environment characterized by low and erratic rainfall, low humidity, and high wind velocity. Rajasthan experienced 48 droughts of varying intensities between 1901 and 2002, which means that the chance of occurrence of a drought in the state is 47% (Rathore, 2004). Analysis by Singh and Kumar (2015) reveals a 50 mm decrease in the average annual rainfall between 1973 and 2008. The past two decades have witnessed acute water scarcity and rainfall variability (The Energy and Resources Institute, 2010; Pareek and Trivedi, 2011; Down to Earth, 2018; Sharma, Sharma, Panda, *et al.*, 2018). Seasonal livestock migration has been their adaptation of choice for decades, but it is not adequate or even desired anymore. There have been many studies on Raikas, but only a handful of them focus on their biophysical vulnerabilities. This research seeks to examine the extent, to which their adaptation practices are contingent on sociocultural values, access to resources, information, and power. Its objectives include the analysis of where, when, and how limits on adaptation arise and the social justice concerns that come into play. This study will help evaluate the utility of a values-based approach to adaptation and help strengthen state programs and policies.

1.1. Conceptual Framework

This study uses Graham, Barnett, Fincher, *et al.*'s (2013) framework to define and operationalize values. Their study reviews five disciplines – social impact assessment, climate adaptation, decision analysis, psychology, and human geography – to define values. Lived values can be defined as the "valuations that individuals make, in isolation or as part of a group, about what is important in their lives and the places they live" (Graham, Barnett, Fincher, *et al*., 2013: 15). As illustrated in Figure 1, this definition of lived values is followed by a categorization using Maslow's hierarchy of needs. The primary groupings are: Self-actualization, safety, health, belongingness, and esteem.

2. Data and Method

2.1. Study Design

A qualitative research design, using the case study approach, was employed to understand the linkages between the values and adaptation decisions of the Raika community in Rajasthan. The case study approach is particularly useful and can be widely applied to "gather a coherent and complete theory of migration related to environmental change" (Piguet, 2010: 522). The qualitative approach is suitable because it makes explicit that there are subjective, qualitative dimensions to environmental change that is of importance to individuals and cultures (O'Brien, 2009).

2.2. Study Site

The Rajasthan state, located in Northwest India, has an area of 342,000 sq. km. and more than half of this area falls under the arid category (Roy, 2014). The three districts selected for data collection were Sirohi, Jalore, and Pali, which are located in Southwest Rajasthan and have sizeable Raika populations. The literature review had affirmed the Raikas presence in these districts as well as its importance as a migratory route for this community.

2.3. Ethical Statement

The research design, tools, and process were reviewed and approved by the International Development Ethics Committee at the University of East Anglia. The purpose of the research was explained to all participants and oral consent obtained from them. The data were anonymized at the transcription stage to prevent any breach of confidentiality.

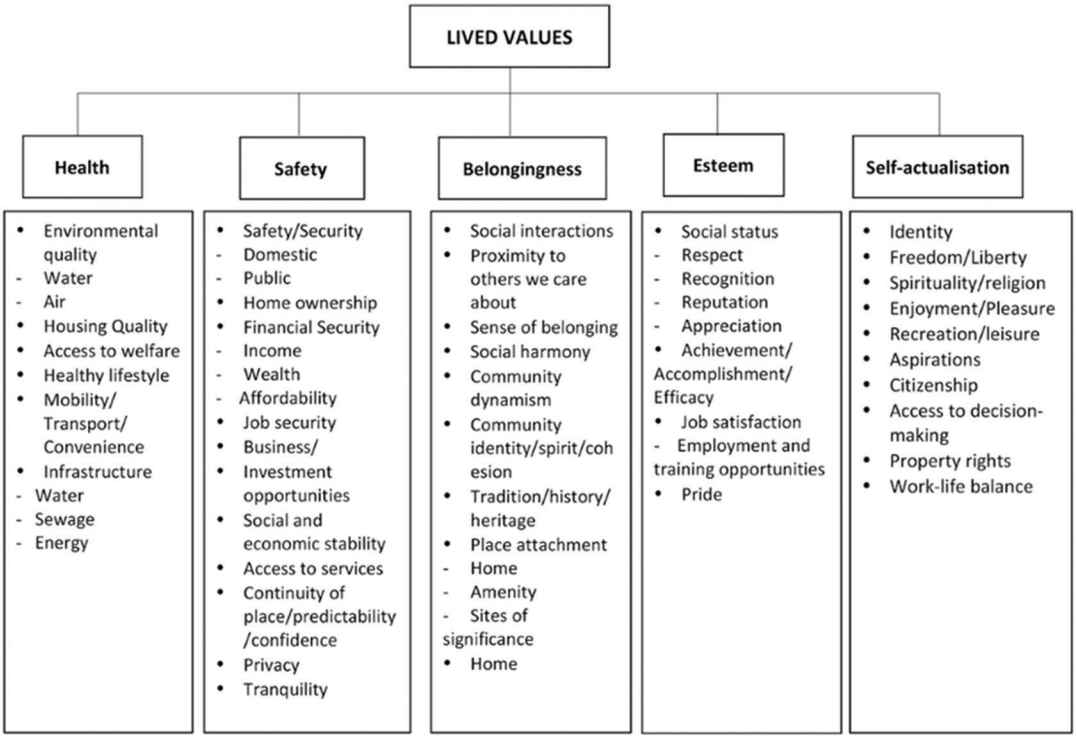

Figure 1. The categorization of lived values that may be affected by sea level rise.
Source: Graham, Barnett, Fincher, *et al.* (2013).

2.4. Data Collection

The study employs two different data collection tools, namely, life history interviews and focus group discussions. Nineteen life history interviews and two focus group discussions were conducted in the course of a month in Rajasthan. The mode of life history interviews allows respondents to talk freely and flexibly (Anderson and Jack, 2002). Interviews are a useful instrument to explore social values and are well-suited to research where the respondent's in-depth opinions are being sought (Bryman, 2016). Focus group discussions were initially not part of the research design. These were conducted during community celebrations held in Pali and Sirohi districts, to which the author was invited. The facilitation of Lokhit Pashu-Palak Sansthan (LPPS) a local Non-Governmental Organization, as well as the community's presence, made these possible. There were 15 male participants in each of these two discussions. Leveraging this opportunity, the researcher prepared a set of questions based on environmental risks, social values, and risk management strategies, and allowed the respondents to share their personal experiences, beliefs, and perceptions through a moderated discussion. This technique allowed for different perspectives to emerge, be contested, and be cross-checked.

2.5. Sampling

The snowball sampling method was employed for this study. The dearth of official records on the Raikas and accessibility challenges due to their migration cycle made snowballing necessary. First, contact was established with a local Raika, who agreed to facilitate introductions in Pali and Sirohi districts and translate from the local dialect to Hindi. A second data collection activity was conducted in Jalore district through LPPS, which works closely with the Raika community. This process led to the selection of 18 respondents and one key informant. The key informant was selected due to her deep knowledge and close association with the Raikas. The main characteristics of the respondents are presented in Table 1.

2.6. Data Analysis

The study identified and selected respondents' descriptions of values that matched the themes in Graham, Barnett, Fincher *et al.*'s lived values framework (2013). The five values are (i) esteem, (ii) self-actualization, (iii) safety, (iv) health, and (v) belongingness. Two separate sets of codes were created: One for past values and the other for new values. Through

Table 1. Characteristics of selected participants.

Identifier	Gender	District and village	Occupation	Age	Herd type	Herd size
P2	Male	Pali	Pastoralist	35	Sheep	30
P3	Male	Pali	Pastoralist	32	Sheep and goats	80
P4	Male	Sirohi	Pastoralist	35	Sheep and goats	60
P5	Male	Pali	Pastoralist	45	Sheep	100
P6	Male	Pali	Pastoralist	55	Camels	40
P7	Female	Pali	Entrepreneur and social worker (key informant)	N.D.	N.A.	N.A.
P9	Male	Pali	Pastoralist	60	Goats, sheep, and cow	40, 20, and 1
P10	Male	Pali	Pastoralist	60-70	Goats and sheep	30
P11	Male	Pali	Pastoralist	35	Goats, camels, and sheep	35, 15, and 150
P12	Male	Pali	Pastoralist	60-70	Sheep and goats	40
P13	Female	Pali	Pastoralist, laborer, and agriculture	N.D.	Goats and sheep	25 and 30
P14	Male	Pali	Entrepreneur	55	None	None
P15	Female	Pali	Pastoralist	65	Goats and sheep	45 and 35
P16	Male	Jalore	Laborer	20	None	None
P17	Male	Jalore	Pastoralist	60	Sheep	40
P18	Male	Pali	Pastoralist	35	Goats	200
P19	Female	Pali	Homemaker and laborer	40 and 42	N.A.	N.A.
P20	Male	Jalore	Pastoralist	60	Sheep	40
P21	Male	Pali	Pastoralist and entrepreneur	42	Cows and buffaloes	15

this process, a clear comparison between past and current values was made. The analysis used NVivo 12 software. Subsequently, the study identified the biophysical, political, and socioeconomic vulnerabilities of the Raikas and the resultant adaptation decisions. This exercise allowed the study to juxtapose the social values and vulnerabilities against the adaptation decisions. This process enables the discovery of similarities, differences, and linkages between and within these three elements (Seidel and Kelle, 1995: 55–56).

3. Results

3.1. Value shifts in Raikas

This study observed a definite shift in the lived values of Raikas across four of the five domains of Graham, Barnett, Fincher *et al*.'s framework (2013). Raikas experience a sense of inferiority and disillusionment about their current socioeconomic status. They feel left behind in the development and modernization discourse and are making efforts to move away from their traditional values, lifestyle, and livelihood practices. Traditionalism, in their context, refers to a firm adherence to Hinduism, patriarchy, and traditional practices and livelihoods; less emphasis on formal, western education; community living; and having large families (Inglehart and Baker, 2000). Westernization and modernization would imply the opposite traits and give precedence to western attire, education for women, freedom to choose a partner, etc. (Inglehart and Baker, 2000). The previous studies have found that the Raikas in the neighboring state of Gujarat also perceive themselves as a "backward group" that is excluded from the development around them (Dyer, 2012).

3.1.1. Esteem

In the past, Raikas associated esteem-related values (Table 2) such as social status, pride, and job satisfaction directly with their livestock quantity and nomadic pastoralism (LPPS, 2004). The larger a person's livestock, the more prestige and respect they enjoyed within the community.

"*For us, the real wealth was our number of cattle. If you had 200 goats, people would be happy to give you their daughter in marriage*." (55-year-old Raika)

Table 2. The change in the accomplishment value of a pastoralist.

Lived values	Past value quotes	Present value quotes
Esteem	*"There was a lot of prestige associated with migration and plenty of livestock."*	*"I left migration. If I migrate with livestock, my children's education will suffer. I was wild, and my children will also become wild like me."*

The practice of seasonal livestock migration also enhanced their social status, respect, and pride. They cherished the freedom, enterprise, and sense of adventure that is inherent in this practice.

"*I used to enjoy going to Madhya Pradesh with my livestock. Everyone used to treat us well. They would give us food to eat. We would smoke bidi*." (35-year-old Raika)

Chemical fertilizers have replaced cattle manure, which was provided by the Raikas in return for the farmers' hospitality. This respondent has stopped the practice of seasonal livestock migration. The same sense of esteem is now derived from education, government or private jobs, entrepreneurship, ability to speak English, and western clothes such as trousers and shirts.

3.1.2. Belongingness

Belongingness entails values such as social interactions, place attachment, and traditions. The Raikas' sense of belongingness was closely attached to many of the unique elements of their culture, such as the *dang* groups in which they migrated, their traditional attire, and their livestock. The Raikas are the only community to use camels on the occasion of *nikasi*, the departure of a groom's marriage party, and at the *toran*, the entrance of the bride's house (Tripathi and Rajput, 2005). These practices have dwindled in the past two decades. For example, the seasonal livestock migration in *dangs* has decreased.

"*This is our inter-generational work. My father kept livestock, and his father, before him. I used to accompany my father every day and learned how to tend to livestock. It is what we studied, but the new generation doesn't do that*." (55-year-old Raika)

3.1.3. Safety

The notion of safety was inextricably linked to their livestock until two decades ago. It provided Raikas a regular stream of income through the sale of animals, wool, dairy, and dung. Moreover, the milk and clarified butter derived from the livestock are essential ingredients of their daily diet. One Raika claimed that he would go hungry but not let the same happen to his camel. His resolve toward the well-being of his livestock demonstrates the importance of livestock in his life.

Things are changing fast in the safety domain as well. The past two decades have seen a breakdown of cooperation with farmers, scuffles, and thefts during migration cycles, low prices of wool, and overall financial hardship. Ninety percent of respondents stated that they are experiencing financial hardship and face personal safety risks in livestock migration. Thus, the sense of predictability, confidence, and safety that was derived from livestock ownership and seasonal livestock migration is no longer present.

3.1.4. Self-actualization

Earlier, the self-actualization values of the Raikas, such as identity, religion, freedom, ability to better themselves, work-life balance, and social mobility, were contingent on their livestock and social cohesion. The older generation advised the younger generation to focus on taking care of the cattle. The popular myths spoke of their sacred duty to protect and preserve camels. There was a sense of joy derived from a lifestyle closely attached to livestock.

"*My father and I used to go together for cattle grazing to the forest. I would follow him. This way, I learned how to drive cattle, how to herd them, where they can be fed water. We did that together. I used to enjoy it*." (60-year-old Raika)

This shows that livestock was inextricably attached to their sense of identity and freedom. The same respondent is now eager to sell his livestock.

"*I saw and heard from people that it is important to get the kids to study. So, we enrolled them in a primary school. The kids are now saying that father, you are right. If you had studied, we would have been even better*." (60-year-old pastoralist)

Thus, livestock management, which earlier offered them self-actualization traits like freedom and identity, is now perceived to be disadvantageous.

3.1.5. Health

In this study, "Health" is an outlier value since its parameters have not changed in the past two decades. The health value is concerned with the natural and social ecosystems in which Raikas operate, such as water, air, lifestyle, access to welfare, and infrastructure. Many respondents alluded to the fact that a rural lifestyle leads to better health outcomes. They pointed to the availability of better quality of air, food, housing, and overall lifestyle in villages. This indicates that the health value has remained aligned with their traditional lifestyle. Despite the admitted benefits, Raikas want their children to move to urban areas.

"*The air in rural areas is fresh. The city has stale air. I was in Mumbai for 18 years, and I had to switch the fan on during the day. When I go to the jungle, I don't need a fan*." (35-year-old pastoralist, who was keen to send his kids to the city despite health challenges there)

Thus, it can be surmised that the Raikas are willing to deprioritize the health value.

3.2. Multidimensional Vulnerabilities

This study contends that Raikas face multidimensional vulnerabilities that have their roots in the distribution and access to resources, information, and power. They reside in the outskirts of rural areas, away from the benefits of mainstream resources. Furthermore, their low-caste and ethnic status renders them unable to meaningfully participate in the governance processes. As a result, they are unable to put their interests and concerns in the public domain. Their financial capital has diminished with the marginalization of pastoralism and the breakdown of cooperative relationships with farmers. Environmental change is an additional strain on the already stressed sector. Rainfall variability and water scarcity cause a multiplier effect that pushes them beyond their adaptive capacity.

3.2.1. Government schemes, programs, and policies

Over the past two decades, the Raika community has faced a severe shortage of grazing land for their livestock (Geerlings, 2004). All the respondents that maintain livestock highlight this as the main threat to their livelihood. Conventionally, villages had common grazing land known as *gauchar*, and patches of jungle known as *oran*, reserved in the name of deities. These were open for cattle grazing. The Rajasthan Tenancy Act and the Allotment of Land for Agricultural Purposes Rules protected village lands from being turned into private agricultural land (Land Revenue Portal, n.d.). However, these commons have become increasingly diverted for other purposes (Geerlings, 2004; Sansthan, 2004). In the 1970s, the national government introduced a new forestry bill that allowed the local village council, called *panchayat*, to fence off common lands to improve vegetation cover. The resultant inability to find pasture directly affects the health of the livestock and has financial implications for the Raikas. During this study's fieldwork in June 2019, local newspapers reported a new bill by the State Government that would cordon off forest areas into the protected territory. It would make Kumbhalgarh Forest Area, a 562-sq. km. reserved forest, inaccessible for cattle grazing.

"*If they stop us from the jungles and make it a national park, that's the end of us. We will have to beg for our food*." (35-year-old pastoralist)

On June 30, 2014, the Government of Rajasthan designated camel as the state animal. The Rajasthan Bovine Animal (Prohibition of Slaughter and Regulation of Temporary Migration or Exports of the Camels) Bill 2014 was introduced to preserve the dwindling camel population, and to prevent the smuggling and migration of camels (Deccan Herald, 2014; Press Trust of India, 2014). With the Governor's assent, the act introduced severe punishment for selling camels for slaughter, for taking them outside the state, for castrating them, and even for using the nose peg (Köhler-Rollefson, 2015). The unintended consequence and faulty implementation of this legislation meant that it put a question mark on the citizen's right to rear and migrate camels – a routine activity of the Raikas. It impinged directly on their primary source of livelihood.

3.2.2. Biophysical factors

In the context of biophysical factors, the majority of the respondents pointed to the problem of low rainfall and water scarcity. Their perception was that the rainfall has decreased in the past two decades. They also point out that river Luni has dried up. The ramification of this situation is that the Raikas have had to search for other water sources for their livestock. This entails a variety of decisions, ranging from longer and farther migration to livestock reduction. Their observation is corroborated by Singh and Kumar's study (2015), which shows a 50 mm decrease in rainfall over the past 30 years in Western Rajasthan. The Raikas posit that low rainfall leads to low grass cover, which links directly to the unavailability of cattle fodder. This shortage of fodder would then decrease the productivity of livestock and impact them

financially. Thus, we can see that the vulnerability of the Raikas to environmental change is high as they rely heavily on natural resources for livestock management, whose availability is increasingly uncertain.

"*If there is less rain, there will be less agricultural production. If there is less agriculture, there will be less fodder for my livestock. It is all interdependent*." (60-year-old pastoralist)

The variability in rainfall directly impacts livestock management and agriculture. Heavy rainfall brings a different set of challenges. Sheep and goats refuse to walk in waterlogged areas, and thus, feeding them becomes a challenge. It also exposes livestock to physical injury as their hooves get puffed, insects take shelter in the grooves, and they are more prone to stepping on poisonous *angrezi babul* (*Prosopis juliflora*) thorns in these conditions. Finally, the risk of loss of agricultural produce due to heavy rains can lead to a shortage of fodder for cattle.

"*The rainfall has decreased significantly. Where is the rainfall now? Now, it comes for a few days and then goes. Earlier, it used to rain for all four months*." (55-year-old Raika)

3.2.3. Socioeconomic factors

The Raikas are also investing more financial resources in educating their children. This is an additional expenditure that needs to be borne from their meager pool of resources. It was not part of their financial expense earlier, as the children were expected to undertake livestock management.

"*My son is good in studies. So, I have put him in a private school. If we pay money, they will make him study… There is a village nearby that is good for education, but the expense is high*." (55-year-old Raika)

Furthermore, the shrinkage of pastures and inaccessibility of forests is forcing them to purchase fodder from farmers or pay grazing fees to the forest department (Sharma and Sharma, 2015). There has also been a decrease in the selling price of wool and dairy attributed to government import of second-hand wool from abroad. All of these factors are leading to a decrease in their financial capital.

There are considerable safety risks faced by the Raikas in their day-to-day lives. These range from the breakdown in their relationship with farmers to the threat of theft and physical violence during seasonal livestock migration. The literature indicates a harmonious and symbiotic relationship with farmers in the past (Agrawal, 1993; Geerlings, 2004). Raikas' cattle supplied manure to farmers, and the same fields could be used for fodder. The shift toward chemical fertilizers and round-the-year cultivation has led to a reduction of fallow periods, turning the Raikas into unwelcome guests. This has caused further marginalization and isolation of the community. A 45-year-old pastoralist reported this about the treatment meted out to them by farmers: The farmers tell them, "*Hey, this is my property. Take them [the cattle] out of here*." Their lived experience of conflict and theft during the migration cycle is corroborated by multiple studies (Agrawal, 1994; Geerlings, 2004; LPPS, 2004).

3.3. Adaptation Pathways

3.3.1. Seasonal livestock migration, reduction, and sale

Seasonal livestock migration is the Raikas' traditional adaptation pathway to environmental vulnerabilities. It entails migrating at the end of the monsoon season and continues for 6-9 months, contingent on fodder and water availability (Agrawal, 1993). When asked how they would respond to a drought tomorrow morning, all the livestock-rearing respondents spoke about the necessity of migration.

"*As long as we keep livestock, we will have to migrate during drought*." (35-year-old Raika)

Seasonal livestock migration remains a viable adaptation option in the face of severe environmental distress. However, as shown earlier, this strategy is declining in popularity in the past two decades and is practiced as a measure of the last resort. It meets their health values as it allows them to enjoy the pristine rural environment and lifestyle. However, it does not offer them safety, belongingness, accomplishment, or self-actualization.

Livestock reduction, on the other hand, entails periodic selling of cattle to meet household expenses. The past two decades have witnessed more and more households employing this strategy. A lesser number of livestock allows them to become sedentary as they can find sufficient fodder for them in the nearby areas. It also insulates them from heavy financial losses that may arise if their livestock's health deteriorates in harsh environmental conditions. Some Raikas choose to sell off their entire cattle and shift to other livelihood strategies. These alternative sources of livelihood better shield them from environmental stressors and offer them the opportunity to become sedentary, which has gained prestige and prominence. Thus, this strategy is more aligned with safety, belongingness, health, and self-actualization values.

"*I sell livestock for money. It is important for us. The whole family is dependent on it. We are also selling because if we keep less, we can manage with less fodder*." (35-year-old Raika)

3.3.2. Urban migration and informal sector employment

Urban migration is a relatively new adaptation option for the Raika community. It entails moving to cities such as Ahmedabad and Mumbai to work in the informal sector. More and more young men are exercising this option at the expense of livestock management, which is heavily impacted by environmental vagaries. They receive support from an increasing number of Raikas who have moved to these urban centers in the recent past. This option is congruent with all their values except health. These informal work and entrepreneurial opportunities are readily available in the city and provide financial safety. The Raikas now relate to the belongingness and esteem that comes with the western attire and lifestyle prevalent in the cities.

"*There is no place like Ahmedabad in all of India. No matter who goes there, he will return with 500 rupees in the evening*." (55-year-old Raika)

Many Raikas gain employment in garment and grocery stores or as watchmen in newly constructed buildings in and around rural areas. It is an adaptation strategy practiced by Raikas who shift their livelihood away from livestock management but continue to reside in rural areas.

"*The youth sets up business like a shop. Then we do not want to do livestock management. The income from livestock is not much. You have to follow them [the livestock] all day. For the previous generation, this was their work. The current generation does not want this*." (20-year-old Raika)

These jobs offer them greater financial safety through a guaranteed monthly income. It is also more in tune with the self-actualization, belongingness, health, and esteem values.

Selling milk is another livelihood-diversification strategy adopted by Raikas. It involves the sale of camel milk to consumers across Rajasthan through the storage and supply chain support provided by LPPS. It offers them a regular stream of income that can be utilized to meet household requirements in times of environmental stress. Two of the respondents of this study who practice camel-rearing are taking part in this livelihood activity. The study finds it to be congruent with their safety, self-actualization, and health values. First, this activity provides financial safety by assuring a constant stream of income. Second, it provides health benefits as Raikas can stay in their village. Third, it provides the freedom to move and work as they please, leading to self-actualization.

"*It is better to live here in our village. I can feed cattle here and go home when work is complete. I can live with my people, meet my people, and do my duty*." (55-year-old pastoralist)

3.3.3. Education

This adaptation pathway entails investment in children's primary education as a means to ultimately transition away from livestock management. All the respondents believe that the skills accrued by education can generate better livelihood opportunities and reduce dependence on natural resources.

"*There is no space for fodder anymore. My grandchildren will go to school*." (80-year-old Raika)

Education was deemed important, especially in the absence of livestock and increasing water scarcity. They expect better livelihood outcomes and higher social standing as a result of investing in their children's education. Many respondents mentioned education as the causal factor behind the improvement in the financial condition of some families, visible as concrete houses and western clothes. Thus, the study finds greater financial safety, esteem, belongingness, and self-actualization associated with education.

4. Discussion

This study finds linkages between social values and adaptation choices made by the Raika community in Rajasthan. Their social values, such as accomplishment, esteem, safety, and belongingness, have changed drastically in the past two decades. Previously, these values were aligned with traditional lifestyle and livelihood practices, but this is no longer the case. The Raikas have begun to favor modern and western values over traditional ones. Environmental change is a catalyst for these shifts. It acts as an amplifier of their structural vulnerabilities and diminishes their adaptive capacity. Social and spatial marginalization renders them unable to participate in the local governance process. As a result, policy measures have failed to accommodate their concerns and have had a detrimental effect on their livelihoods. Their adaptation strategies have witnessed a concomitant shift. These linkages between values and adaptation choices imply the need to include lived values as an integral element in the conceptualization and design of climate adaptation programs, policies, and processes. For the needs of research, the integration of social values into environmental vulnerabilities assessments will require engaging with a diverse set of literature on the linkages between climate change, on the one hand, and religion, culture, ethics, and psychology, on the other hand.

Seasonal livestock migration, which was the trusted adaptation strategy of the Raikas in the face of drought and water scarcity, has been sidelined by urban migration, education, and private jobs. In the past, entire villages would migrate with their livestock during the dry season. This adaptation strategy spoke of social cohesion and allowed them to achieve the belongingness value. A higher quantity of livestock was a source of esteem. It offered them financial safety and even determined marriage alliances. The same belongingness is now derived from wearing trousers and shirts like city dwellers. Marriage alliances are based on the level of education and ability to secure private jobs. This finding gives credence to the argument that social and individual characteristics limit adaptation (Adger, Dessai, Goulden, *et al*., 2009; O'Brien, 2009; O'Brien and Wolf, 2010; Grothmann and Patt, 2005; Neef, Benge, Boruff *et al.*, 2018). It implies that adaptation policy and practice must appropriate an understanding of the importance of social values to build sustainable adaptation pathways. Taking this argument further, this study highlights that the decline of seasonal livestock migration is matched by the rise in urban migration and education. The practice of these adaptation pathways is relatively new and driven by a change in social values. It must also be noted that power and preference foreground the expansion of adaptation pathways (Pelling, O'Brien, Matyas, *et al.*, 2015; Fook, 2017). This study advances this argument to posit that value preferences can not only limit adaptation but also offer a means to expand adaptation pathways.

This study also observes the dynamic and conflicting nature of values. Economic, demographic, and biophysical changes exert influence on Raikas' value systems and produce tensions. The youth have migrated to cities and are driven by ambitions of material wealth and consumption. They are often unwilling to partake in local customs and livelihood practices, while the older generation seeks to preserve some of these practices. This shift is consistent with the findings from other pastoralist communities such as Bhotiyas of Kumaon region in Central Himalayas in India, where young adults are discarding traditional practice in search of jobs in urban centers (Cultural Survival, 1998). The fact that there exist generational differences in values has been corroborated by Inglehart and Baker (2000) and O'Brien (2009). The insights on dynamism and conflicting nature of values build the evidence base for adaptation relative to place, time, and subjectivities.

The study raises questions on the social justice implications of adaptation, especially when it entails trade-offs in the allocation of resources. Masking these trade-offs marginalizes the less powerful groups and raises questions of social justice (Graham, Barnett, Fincher, *et al*., 2015). This dynamic is currently playing out in the rural areas of Rajasthan. The village commons have been fenced and closed for cattle grazing by powerful groups in the name of environmental protection. The inability to use these grazing areas has made it difficult for the Raikas to eke out a livelihood from livestock management. These conditions mean that adaptation policy needs to consider the interests and objectives of multiple stakeholders and identify the trade-offs that come with adaptation choices. Doing that would shed light on the winners and losers of adaptation as well as its acceptable and unacceptable losses (Nalau, Handmer, Dalesa, *et al*., 2016; Neef, Benge, Boruff, *et al*., 2018).

There has been little accommodation for sociological, legal, and philosophical perspectives on intergenerational rights and responsibilities (Rayner and Malone, 2001; Gibbons, 2014). Some of these tensions became visible in this study. For example, the Raikas invest time and financial resources on their children's education and encourage them to migrate to urban areas for work. These adaptation choices entail the compromise of their current adaptive capacity for future gains. Further, these choices trap older adults in villages, without adequate financial means and family support, to pursue livestock management. A similar development was recorded in Odisha, where the youth migrated to urban areas (after natural disasters), leaving the older adults to fend for themselves (Patel, Mathew, Nanda, *et al.*, 2020). Therefore, adaptation can involve intergenerational tensions as well as the sacrifice of short-term adaptive capacity to bolster long-term adaptive capacity. This study makes a case for closer scrutiny of these intergenerational dynamics.

It is not advisable to consider environmental vulnerabilities in isolation (Assessment A.C.I., 2004; O'Brien, 2008; McCubbin, Smit, and Pearce, 2015). Adaptation policies that do not respond to a suite of forces (socioeconomic, cultural, and political) run the risk of increasing vulnerabilities. This study reinforces the point that adaptation needs to be designed in response to multiple interacting forces. For instance, the study found that even when seasonal livestock migration was a viable option against environmental stressors, the sociopolitical context made the strategy unviable. The breakdown of the relationship between farmers and the Raikas meant that the farmers are unwilling to offer them shelter and food during their migration cycle. Furthermore, there is an increased occurrence of cattle theft by raiders, putting the Raikas in harm's way. This shows that their vulnerability is a result of a combination of factors. This study builds the argument that addressing these structural issues will allow adaptation policy to have a long-term impact.

Finally, the paper contributes to the literature on inclusive and participatory adaptation. It is imperative that there is meaningful participation of all stakeholders in governance mechanisms (Few, Brown, and Tompkins, 2007; Ayers, 2011). The study highlights that the Raikas find no space for participation in the local governance process. As a result, policy measures often have had a disastrous impact on their livelihood and adaptive capacities. For example, the closure of the Kumbhalgarh Forest Area to cattle grazing has been a death knell for the Raikas. A law designed to protect the dwindling camel population has had the unintended consequence of making it difficult for the Raikas to tend to their camel livestock. This study shows that adaptation needs to take an inclusive approach that puts local interests, knowledge, and aspirations at the front and center of the decision-making process.

The main limitation of this study is the lack of participation of young adult males as well as women. The study is skewed toward older male household heads as most of the young males had migrated out in search of jobs. Similarly, women are not adequately represented in this study because of cultural norms that made their participation difficult.

5. Conclusion

This study highlights that the Raikas are disproportionately affected by environmental stressors. Rainfall variability, water scarcity, and drought, in combination with structural vulnerabilities, are pushing them beyond their adaptive threshold. This paper has added to the understanding of the shift in their values and multidimensional vulnerabilities and how they relate to the Raikas' adaptation decision-making. It suggests that there has been a marked shift in esteem, safety, self-actualization, and belongingness values, which has driven the changes in their adaptation choices. New adaptation options, such as urban migration, have emerged, while traditional measures have declined in popularity.

This study recommends policymakers and researchers to engage with a wider set of methodologies and literature to facilitate the integration of social values in vulnerability and adaptation assessments. The integration of social values presents an opportunity to understand the subjective limits of adaptation better as well as to expand adaptation pathways. It is important to consider the intergenerational elements in adaptation decision-making and to undertake holistic studies to arrive at the multidimensional vulnerabilities and their linkages with adaptation decision-making. This will contribute toward adaptation policies that are people-centric, sustainable, and grounded in the local realities.

Author's Contribution

Anmol Arora conceived, designed, and implemented the study, including data analysis and presentation, interpretation, and discussion of the results.

Conflicts of Interest

The author declares that they have no conflicts of interest.

Consent

Informed verbal consent was obtained from each of the respondents who participated in the study.

Ethical Approval

The ethical approval for this research was granted by The International Development Ethics Committee at the University of East Anglia, the institution that oversaw the conduct of this research.

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Availability of Supporting Data

All data files used in this manuscript are available on the Harvard Dataverse at the link given here: https://doi.org/10.7910/DVN/KZS4BB.

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REVIEW ARTICLE

A review of disasters in Jammu and Kashmir, and Ladakh region in India

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Abstract: India has always been a disaster-prone country, with multiple states afflicted by different types of disasters. The impact of these disasters is exacerbated when an area is prone to multiple types of disasters. This study attempts to understand the impact of natural and man-made disasters on the people of Jammu and Kashmir (J&K) and Ladakh region in India as well as it also examines the resilience mechanisms adopted by the people, and identifies measures taken by the government in response to these disasters. To understand these disasters' dynamics, we conducted both offline and online desk reviews for this study. The review suggests that J&K and Ladakh region is afflicted not only by multiple natural disasters such as floods, earthquakes, avalanches, and landslides but also by the terrorism and violence, which has caused unparalleled death and destruction. These natural and man-made disasters have adversely affected most aspects of life and development in the region. To mitigate the risks, effective disaster risk reduction and management systems, early warning systems and infrastructure need to be strengthened. In addition, community engagement needs to be enhanced with the goal of addressing the grievances of the population and engaging them in the design and implementation of sustainable development programs.

Keywords: Natural disaster; Man-made disaster; Conflict; Terrorism; Violence; Jammu and Kashmir; Ladakh; India

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1. Background

Disasters are a global phenomenon. Natural and man-made disasters have had an impact on the development, economy, and health of both developing and developed nations and have put pressure on populations across the world. The United Nations International Strategy for Disaster Reduction (UNISDR) defines the term disaster as "a serious disruption of the functioning of a community or a society involving widespread human, material, economic, or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" (UNISDR, 2009). Disasters that are the result of natural hazards such as earthquakes, floods, cyclones, and droughts are called natural disasters. Those that are the result of anthropogenic activity such as industrialization, wars, global terrorism, political conflicts, and economic crises are defined as man-made disasters (Shaluf, 2007). A combination of natural and man-made disasters has affected most countries around the world and resulted in large-scale mortality and morbidity, destroyed livelihoods, creating millions of refugees, and migrants. Around 1.3 million people died due to natural disasters between 1996 and 2015, with low-income countries recording mortality rates that were 5 times higher than high-income countries (UNIDSR and CRED, 2016). On the other hand, in the year 2016, global terrorism – a man-made disaster – caused 25,673 deaths and losses of $84 billion to the global economy (Institute for Economics and Peace, 2017).

As a result of its geographical and climatic conditions, poor socio-economic profile, and numerous terrorisms-based violence, India is afflicted by multiple disasters. Over a period of 20 years, from 1996 to 2015, natural disasters killed 97,691 people in India. This represents the fifth highest mortality rate in the world (UNIDSR and CRED, 2016). India has also been affected by violent man-made disasters in the form of wars, insurgency, and terrorism. The Bhopal gas tragedy in 1984 remains the country's worst industrial disaster thus far. The recently bifurcated union territories (UTs) of Jammu and Kashmir (J&K) and Ladakh (hence forth has been used as J&K and Ladakh region) in the northernmost part of India, is one of the most severely affected regions by both natural (Table 1) and man-made disasters. It is a region prone to multiple hazards on account of its topography and varying, extreme climate. The region has suffered massive floods, devastating earthquakes, and recurrent avalanches and landslides (SDMP, 2017). The earthquake in 2005, flash floods and landslides in 2010, and the massive floods of 2014 are among the major natural disasters the state has faced over the past 15 years (Kumar, Martha, and Roy, 2006; Gupta, Khanna, and Majumdar, 2012; SDMP, 2017). The state has also borne the brunt of disputes between India and Pakistan, witnessing regular cross-border infiltrations, state-sponsored terrorism, and violent attacks. The displacement of communities from their homelands, long-drawn-out protests leading to curfews, and regular clashes between terrorists and armed forces, have been some of the manifestations of the violence (Shekhawat, 2009; Behera, 2016).

This combination of natural and man-made disasters has had adverse effects on key facets of J&K and Ladakh region's economy, including key sources of revenues such as agriculture, horticulture, handicrafts, and tourism (Sharma, Sharma, and Waris, 2012). These disasters have stretched the administrative machinery of the region and left its population vulnerable. However, there are lack of studies which have focused on the aftermath of specific natural disasters and incidents of terrorism and violence as a form of disaster. There have been lack of studies which have explored the impact of natural and man-made disasters on people's lives and development in a comprehensive way. This article attempts to review the impact of different natural and man-made disasters (e.g., terrorism and violence) on the people of J&K and Ladakh region. It reviews the impact of disasters and the mechanisms of resilience adopted by the people of the region, and identify measures taken by the government in response to these disasters.

1.1. Geography and Weather

As per the recently formed UTs of J&K (as of October 31, 2019), UTs of J&K has 20 districts and UTs of Ladakh has two districts, both combined covering the geographical area of 222,236 km^2 (Census of India, 2011). The climatic conditions vary from tropical heat in Jammu, to temperate conditions of the Kashmir valley, to the arctic cold of Ladakh. There is large variation in temperature from the average maximum of 33°C (Jammu) in summers to the average minimum

Table 1. Deaths due to natural disasters in India and J&K and Ladakh region, 2005-2018.

Year	Deaths due to natural disasters	
	J&K (including Ladakh)	India
2005	1157	22,415
2006	345	21,502
2007	278	25,153
2008	307	23,993
2009	226	22,255
2010	575	25,066
2011	314	23,690
2012	321	22,960
2013	308	22,759
2014	518	20,201
2015	387	10,510
2016	280	8,684
2017	127	7143
2018	131	6891

Source: National Crime Records Bureau, Ministry of Home Affairs, Government of India.

of −14.4°C (Ladakh) in winters. The average annual rainfall for the region is 1028 mm with the months of July and August experiencing the maximum rainfall (IMD, 2014). Agriculture is the direct and indirect source of livelihood for the majority (75%) of the population while paddy and wheat are the two major crops. Sharecropping along with goat and sheep rearing is the sources of livelihood for the nomadic communities. Rain is the major source of irrigation followed by spring irrigation and nallah irrigation (SDMP, 2017).

2. Key Findings

2.1. Impacts of Earthquakes

Situated next to the Himalayas, J&K and Ladakh region falls in a mountain building geological zone and thus experiences recurring seismic activity (Hassan, 2014). It is an earthquake-prone area that falls under the most active seismic zones in India (Zones IV and V). It has endured several earthquakes over the years. Between 1889 and 1990, 170 earthquakes were recorded in the region (Hassan, 2014). The year 1885 witnessed one of the deadliest earthquakes to strike the region, the effects of which were felt from Srinagar to Gilgit and to Shimla in the neighboring state of Himachal Pradesh (Anees and Bhat, 2016).

In 2005, a major earthquake – with a magnitude of 7.6 on the Richter scale – struck the border region between India and Pakistan. The fallout affected both countries. More than 80,000 people – majority of them in Pakistan – lost their lives, resulting in an enormous humanitarian crisis (SDMP, 2017). The earthquake also resulted in injuries to approximately 100,000 people in Pakistan and about 6300 people in India (Ali, Mir, Jabeen, *et al.,* 2010). It is considered the deadliest earthquake in the recorded history of the Himalayan region (Anees and Bhat, 2016). Around 1300 of those killed were from Uri in Baramulla district of J&K. The township saw severe damage to most of its buildings, with 121 of them collapsing completely and many villages in the vicinity were severely affected by the earthquake (Kumar, Martha, and Roy, 2006). Kumar *et al*. (2006) also highlighted using remote sensing satellite data that the earthquake and the subsequent landslides resulted in collapse of 25% of the buildings in Uri and Poonch townships, collapse of bridges, and road blockage.

In the regions of J&K and Ladakh, earthquakes not only cause immediate destruction but also long-term damage to the socio-economic condition of the people in the region (Shah, Khwaja, Shah, *et al.*, 2018; Yousuf, Bukhari, Bhat, *et al.*, 2020). The collapsed houses left entire families homeless and the impact on hospitals and government buildings interrupted health and other essential services when they were most needed (Hamilton and Halvorson, 2007). A study on the morbidity patterns of victims of the 2005 earthquake reveals that a majority of the 6270 injured suffered upper and lower limb injuries, followed by spinal injuries (Ali, Mir, Jabeen, *et al.,* 2010). A study based on the mental health services provided in the region revealed that within 6 weeks of the earthquake, majority of the respondents had severe psychological impacts, with adjustment disorders (39.6%), depressive episodes (21.8%), anxiety (4.6%), and post-traumatic stress disorder (PTSD) (3.3%) being the most common (Chadda, Malhotra, Kaw, *et al.,* 2007). This study noted that a major concern reported by people was the lack of basic mental health services outside the city of Srinagar, which can be a journey of up to 8 h for people from the remote areas of the region.

With existing inequalities interacting with a natural hazard, the earthquakes also had a devastating impact on the women of J&K. Women faced an environment of increased personal insecurity and psychological stress due to a lack of sanitation facilities and immediate food insecurity due to their social responsibility as caretakers of the family. The disruption in health and reproductive facilities also had severe impacts on pregnant women (Hamilton and Halvorson, 2007).

2.2. Impacts of Landslides

Landslides are another geological hazard common in J&K and Ladakh region. The region is home to young mountain ranges, which have a fragile rock base that can trigger a flow of debris, mud, and rocks when the stability of the slope gets disturbed. Heavy rainfall, cloudbursts, and earthquakes can trigger landslides. Anthropogenic activities such as deforestation, road construction, and other unsustainable development activities have further increased the vulnerability of the area (Singh, Bhat, Sharma, *et al.*, 2012). Most of the areas in J&K are prone to landslides, with the districts of Bandipora, Kargil, Anantnag, Kishtwar, Pulwama, and Shopian being highly susceptible (SDMP, 2017). The environmentally fragile region of Ladakh has also been adversely affected by human activities such as encroachment of hill slopes, forest fires, terrace farming, and vibrations through heavy vehicular transportation, making it a highly vulnerable zone for landslides and mudslides (Barnard, Owen, Sharma, *et al.,* 2001).

In 2010, the Ladakh region witnessed one of its most destructive landslides as a result of a cloudburst. The extreme rainfall triggered multiple landslides and flash floods, leading to the deaths of 234 people with foreigners accounting for

about 10% of the deaths (Gupta, Khanna, and Majumdar, 2012). The flow of debris from the hills wreaked havoc on its path, destroying hospitals, houses, roads, bridges, farmland, and other infrastructure. The traditionally built houses of Leh and Ladakh were severely damaged, with over 1000 houses completely washed away by the flow of debris (Gupta, Khanna, and Majumdar, 2012). Roads were damaged and freshwater supply was interrupted due to the destruction of many canals. The destruction of storage facilities and difficulties in transportation due to heavy rainfall resulted in a temporary shortage of food supply. The destruction of hospitals and lack of sanitation facilities meant that public health was also severely affected. The remoteness of certain areas also meant that the availability of health services was further delayed (SDMP, 2017; Gupta, Khanna, and Majumdar, 2012).

Singh *et al.* (2012) argue that unplanned development in the form of construction of roads and dams is the major cause of landslides in the region. The landslide on the Batote-Doda road along National Highway 1B in 2009 was a case of slope failure resulting from the construction of the Baglihar hydro-power project. It washed away 150 m of the highway, killed one person, and affected the daily lives, livelihoods, and food security of 600,000 people for over a month (Singh, Bhat, Sharma, *et al.*, 2012). Mining sites in the region are also located in highly landslide-prone areas. Laborers work under conditions of constant risk and the mining endangers the fragile environment, creating a vicious cycle. The influx of tourists and the simultaneous infrastructural development – while positively affecting the J&K and Ladakh region's economy – has also made its environment more fragile and prone to natural hazards such as landslides (SDMP, 2017; Verma and Mushtaq, 2013).

The blocking of highways and other roadways, which leads to a disruption of normal life, is a common occurrence across the region during landslides. The Jammu-Srinagar Highway, a lifeline of the Kashmir valley, gets blocked every year due to landslides and results in hundreds of vehicles being stranded (Indian Express, 2018). This also prevents essential commodities from reaching the valley, creating shortages, and increasing prices. Cultural and religious activities such as the Amarnath yatra have also been interrupted from time to time due to landslides. Landslides cover agricultural land with debris and mud, damaging crops and making the land uncultivable for a long period of time (SDMP, 2017). This has an enormous impact on the livelihoods of farmers and of nomadic communities that live in hilly regions. The annual migration of the nomadic communities gets affected by the blocked roads. Landslides also cover large areas, preventing them from grazing their animals (Anees and Bhat, 2016). Like most other disasters, landslides have a severe impact on women due to existing social inequalities. There have been few studies on the psychological impacts of landsides in J&K. However, studies conducted in other parts of the world show that survivors of landslides are more likely than others to experience PTSD (Catapano, Malafronte, Lepre, *et al.,* 2001).

2.3. Impacts of Floods and Avalanches

Flooding is one of the most common and also one of the most devastating natural disasters across the world (CRED and UNISDR, 2015). It is generally a result of overflow of water due to rainfall, melting of snow, or other natural causes, which ends up submerging an area of land. Besides these natural causes, there are human activities such as deforestation, rapid and unplanned urbanization, construction of dams and bridges without proper research, and changing patterns of vegetation that make an area more vulnerable to flooding. The region is prone to floods, with major rivers such as Jhelum, Chenab, and Indus flowing through its populated areas (SDMP, 2017). Kashmir valley's bowl shape, with its vast variation in altitudes, makes the low-lying areas of the region specifically prone to floods. In the two-major urban centers of the region – Jammu and Srinagar – the number of wetlands such as lakes and ponds, which act as natural sponges, have come down severely, resulting in frequent urban flooding (Gupta, 2014).

In September 2014, extremely heavy rainfall led to one of the most severe and widespread instances of flooding in the region. The Jhelum, Chenab, and Tawi basins were overflowing as the amount of rainfall received in just few days was 2-6 times (depending on location) the monthly normal for September (SDMP, 2017). The floods severely affected ten out of 22 districts in the region, with districts in southern part of Kashmir being severely affected. About 30% of the urban area in the region was submerged and 2600 villages were affected with 400 being completely submerged (Vithalani and Bansal, 2017). The floods were followed by landslides that damaged roads and bridges, including one that washed away 50 people in a bus in Rajouri district (Gupta, 2014). More than 300 people lost their lives during the floods and lakhs of people were displaced as more than 80,000 *pucca* houses and about 21,000 *kachha* houses were completely damaged (Vithalani and Bansal, 2017). Multiple roadways across the region were blocked for days, including the Jammu–Srinagar highway, which remained closed for over 3 days, disrupting relief measures (Gupta, 2014). Farmers suffered huge losses as crops were destroyed, agricultural land was inundated, and thousands of animals reared for animal husbandry perished (SDMP, 2017; Shah, Khwaja, Shah, *et al.*, 2018). In the immediate aftermath of the floods, food security was a serious concern. A study claimed that 86% of respondents in Kashmir and 36% in Jammu reported a decrease in food consumption (Sphere

India, 2014). There was also a substantial decrease in the usage of piped water in affected villages as water resources were severely damaged (Gupta, 2014). The region's healthcare services were completely overwhelmed, with four out of five hospitals in Kashmir unable to function due to the floods (Vithalani and Bansal, 2017). The shortage of medical supplies affected the most vulnerable members of the society, such as the old and physically challenged and those suffering from chronic diseases such as diabetes and cancer. Disruption of electricity and damaged equipment in GB Pant hospital in Srinagar resulted in the deaths of 20 neonates (Venugopal and Yasir, 2017). There was an increase in mental illness cases in the hospitals of Srinagar, with people showing early symptoms of PTSD (Tabish and Nabil, 2015).

The floods have had a long-term impact on the people of J&K as they had not only lost their homes but also their livelihoods, livestock, and important documents. The Federation of Chamber of Commerce in Kashmir estimated the economic loss to the region till 2017 at around $15 billion (Tabish and Nabil, 2015). The education of thousands of students across the region was affected as several government and private school buildings collapsed, leaving students without essential infrastructure (Venugopal and Yasir, 2017; Tabish and Nabil, 2015). As with all-natural disasters, women were affected even more than men because of existing gender inequalities and different social and cultural expectations. Their sanitation and reproductive health needs came under severe stress and their role as provider for the family led to considerable mental trauma. The lack of proper sanitation facilities in the relief camps and the lack of privacy for breastfeeding infants emerged as major issues for women in the aftermath of the floods (Gupta, 2014). Flooding of homes and the ensuing destruction caused severe psychological stress among people and aggravated existing mental health conditions. A study conducted 6 months after the year 2014 flood in Kashmir described that 60% of the population was suffering from severe PTSD (Fatima and Maqbool, 2017). The study also found that women and all elderly members of the society (above 60 years) were more affected by mental health issues such as depression and PTSD in the aftermath of floods.

Flash floods are extreme and sudden events that are usually triggered by a cloudburst or by the failure of dams. They trigger a high velocity current of water, submerging an area downstream within minutes or hours (SDMP, 2017). They usually occur in areas with steep slopes and, because of their sudden nature, can result in huge damage. Anthropogenic activities such as deforestation and unscientific road construction, which can trigger landslides, worsen the effects of flash floods. The cloudburst in the Ladakh region in 2010 resulted in the Indus river and its tributaries overflowing, triggering flash floods, and landslides. This led to the deaths of 234 people in the Ladakh region, left 800 injured, and caused many others to be washed away by the water and debris (Gupta, Khanna, and Majumdar, 2012). Transport was disrupted as many roads were washed away and the airport at Leh was flooded. Many buildings suffered severe damage with around 1000 houses completely collapsing. The damage was not limited to Ladakh region, with around 71 deaths being reported in 11 other districts (SDMP, 2017). Leh historically suffers a from lack of drinking water and sanitation facilities. These were further exaggerated by the flooding. Being a tourist destination, Ladakh was further hampered economically due to the destruction of tourist infrastructure. The district of Baramulla also suffered major losses of around $8.7 million in the agricultural sector and $8.3 million in the horticulture sector (SDMP, 2017).

Given the presence of the Himalayas in the region, J&K and Ladakh are also prone to avalanches. An avalanche is the flow of snow down a mountain slope and is very common in the high ranges of J&K (SDMP, 2017). Avalanches generally occur during episodes of heavy snowfall which can be attributed to the rising global temperature because of climate change (Rafiq and Mishra, 2018). Higher reaches of Kargil and Ladakh and the valleys of Kashmir and Gurez are the most avalanche-prone areas of the region (Hassan, 2014). Avalanches can also be highly difficult to predict and usually occur over a short period of time. The downward movement of snow can bring with it ice, soil, trees, and rocks, causing destruction to life and property (Ganju and Dimri, 2004). One of the most destructive avalanches stuck the region in 1995, resulting in the deaths of 150 people and the closing of the Jawahar tunnel on the Jammu-Srinagar highway (Hassan, 2014).

Avalanches have also proven deadly for the Indian armed forces as they are normally posted in inhospitable locations of the region. An avalanche in Gurez sector in 2017 killed 20 army men and four civilians and caused destruction to a tourist place (Rafiq and Mishra, 2018). Avalanches also lead to the blocking of roadways, creating shortage of essential commodities. They essentially paralyze the life of the communities living in the high mountainous areas of the region, while also resulting in economic losses due to the impact on tourism. Agriculture is impacted for a longer term as large-scale movement of snow causes soil erosion making the soil unproductive (Ganju and Dimri, 2004). Historically, J&K and Ladakh has been a region with abundant water, but with rapid urbanization and increase in global temperatures, occasional droughts have become a reality for the majority of the region (Hassan, 2014).

2.4. Impacts of Man-made Disasters

Almost all-natural disasters in J&K and Ladakh region are, to an extent, exacerbated by human activities and their destructive potential is linked to human actions. Man-made disasters, on the other hand, are completely dependent on

human actions. The political conflict stretching back to India's independence has contributed to the most lethal, destructive, and continuous man-made disaster in the region. The region went through multiple crises in terms of violent insurgency and terrorism from the neighbor country in the Kashmir valley after India's independence (Bose, 2003). There were repeated instances of violence against the region's minority Pandit community, leading to a mass exodus of the Pandit community from the valley in 1990 (Shekhawat, 2009). In recent times, the region has witnessed large-scale protests and stone pelting as a form of collective civilian resistance, along with a new wave of militancy (Behera, 2016).

According to the South Asia Terrorism Portal (SATP), the militancy or terrorism in J&K and Ladakh region over the past three decades has led to 47,689 deaths between 1988 and July 30, 2020; among the casualties were 15,138 civilians, 6979 security personnel and 25,572 terrorists (SATP, 2020). The terrorism-based violence has also displaced lakhs of people – the majority among them being Kashmiri pandits. The people of the region continue to live in a heavily militarized zone under the constant threat of violence and terrorism. Normal life gets disrupted on a regular basis and a small incident can result in large-scale protests and violence (Behera, 2016). Violence has not only led to physical injuries and deaths but also resulted in the disruption of daily life. The family structure comes under stress, traditional and cultural events loose significance or get banned for security reasons, and overall community life gets affected (Amin and Khan, 2009). The violence has impacted the growth of children as they have been born and raised in a militarized zone that regularly witnesses violence. Growing up in a society ravaged by violence has not only hampered their mental growth but also their cultural growth (EFSAS, 2017).

All these factors lead to high prevalence of stress, trauma, and deep and lasting psychological impacts on all sections of the population. A study conducted in Kashmir highlights that about 55% of the population suffers from some level of depression and that the condition is much more prevalent in rural areas compared to urban areas as socio-economic factors add to factors like violence (Amin and Khan, 2009). Disability and violation of modesty (Violation of modesty is the local equivalent for sexual violence and includes inappropriate touching, in accordance with the WHO's definition of sexual violence) are the most common factors that cause psychological stress among men, whereas for women, the most common factors are exposure to violence and a sense of powerlessness (De Jong, Ford, Van de Kam, *et al.,* 2008). In the 1990s, the threat of sexual violence was used to terrorize the Pandit community (Shekhawat, 2009). Over the years, the terrorism-based violence in J&K has resulted in the deaths of many more men than women, leaving behind thousands of widows (Qayoom, 2014). A number of men have disappeared during the violence with no proof of death and their wives are referred to as half-widows (Qutab, 2012). The widows and half-widows, who were mainly dependent on their husbands economically and socially, have to struggle for their daily survival. Widows from poor backgrounds with no education have found difficulty in getting jobs other than manual labor (Qayoom, 2014). Half-widows not only suffer from economic deprivation but also stigma and psychological problems as they are unable to get closure due to the uncertainty that persists about their partners and their possibility of returning (Qutab, 2012).

The terrorism in J&K has had a major impact on the economic condition of the region. Due to the terrorism, in 1989, private investment in the region came to a complete halt and the economy of the region grew at a much slower pace than the rest of the country, resulting in high unemployment rates – especially in the private sector (Mahapatra and Shekhawat, 2008). Given the security concerns, the limited resources of the region are often diverted toward internal security and policing. The periods of violence have affected sources of livelihood—especially tourism, horticulture, and handicraft industries. The horticulture industry considered the backbone of Kashmir's rural economy, with numerous orchards producing apples, strawberries, almonds, walnuts, and saffron, was severely affected during the 1990s (Sharma, Sharma, and Waris, 2012). Kashmir was once India's favorite tourist destination, but as the terrorism raged on, the industry declined, affecting the livelihoods of thousands of people.

The number of tourists visiting J&K and Ladakh declined from 557,974 in 1989–8026 in 1993 (Sharma, Sharma, and Waris, 2012). The progress on increasing the footfall of tourists back to the previous levels has been marginal. This is reflected by the fact that only 27,358 tourists visited the region in 2002. Thus, during the most violent years of the terrorism, from 1989 to 2002, the valley lost an estimated 27 million tourists leading to tourism revenue loss of approximately $3.6 billion (Sharma, Sharma, and Waris, 2012). Major tourist destinations and historical sites became militant hideouts. Terrorists attacked both Indian and foreign tourists, with tourist hotspots like Srinagar Airport being repeatedly attacked (EFSAS, 2017). It severely hampered the business of hotels and houseboats, while also crippling the handicraft industry that is dependent on purchases by tourists (EFSAS, 2017). In recent times, the number of tourists visiting the Jammu and Ladakh regions has grown faster compared to the Kashmir valley, which used to be the central attraction for tourists in the pre-insurgency days (Sharma, Sharma, and Waris, 2012). A study by Barbhuiya and Chatterjee (2020) also highlights that severe conflict or violence events affect domestic tourist arrival negatively, while natural disasters negatively impact international tourist arrival. Education also suffered during the conflict, with schools and colleges remaining shut during

militant attacks, protests, and indefinite strikes. Academic schedules have been disrupted and education has taken a back seat, with violence and anger taking their place, resulting in the loss of human talent and potential (EFSAS, 2017). The impact of violence on education and the economy has led to the reduction of job opportunities and this has created a generation of young people living in despair who can be potential recruits for militant activities.

2.5. Community Resilience and Government Measures on Disasters

In the aftermath of disasters, among the widespread death and destruction, individuals and communities have adopted various mechanisms to cope with the situation. This coping ability is directly linked to the vulnerability profile of the individual or the group. The vulnerability is determined by social and economic conditions such as age, gender, health, occupation, and other factors (SDMP, 2017). The ability of the population to cope with these natural disasters could also be linked to the socio-political history of the state, as noted in a study by Rakesh Chadda and others after the 2005 earthquake. The study argues that the years of violent conflict could have better equipped the people of the region to cope psychologically with natural disasters and to survive in tough conditions (Chadda, Malhotra, Kaw, *et al.,* 2007).

The social capital approach has been a key coping mechanism whereby people have gone out of their way to help each other, as was the case in the aftermath of the floods of 2014. Due to the lack of an early warning system, people were forced to evacuate in a hurry as the water level rose, which resulted in preventable losses. The Indian Army has been a key institution regarding the disaster relief in the regions of J&K and Ladakh. The army and the National Disaster Relief Force were brought into action and played a significant role in the rescue operations in 2014 (Venugopal and Yasir, 2017). The army also set up medical camps in flood-affected areas and a study shows that this played an important role in the aftermath of the disaster, but the low supply of certain drugs and the limited number of doctors available restricted the utility of these camps (Singh, Hasan, and Kasi, 2016). While the army and other administrative organizations did their best during the flood, it was the local youth networks that went out of their way to rescue people – including tourists – with the help of small boats and tyres (Venugopal and Yasir, 2017). There was also material help from other parts of the region in the form of food materials such as milk, vegetables, and rice, which helped people sustain themselves in the immediate aftermath of the floods (Bukhari, 2014). Organizations that are normally opposed to each other – such as the armed forces, non-government organizations (NGOs), separatists, and local youth – were all working toward the same goals during the natural disaster (Venugopal and Yasir, 2017). Women have played an important role in the event of disasters. In the aftermath of the earthquake in 2005, women organized relief efforts, helped in the building of temporary shelters, and prepared food in the aftermath of the earthquake (Hamilton and Halvorson, 2007).

The continuous presence of the armed forces in the rural and urban areas of J&K due to violence and terrorism has made the region a highly militarized zone. To avoid the constant patrolling by the armed forces, people have put up barriers made of rocks and pipes outside neighborhoods (Anjum and Varma, 2010). A study found that people living in J&K have reduced the number of times they leave their homes – especially during violent flare-ups (Khan, Ayoub, and Tahir*,* 2013). The age-old Kashmiri practice of storing dried foods and pickled vegetables due to the inaccessibility of the terrain during winters has re-emerged because of the conflict. People have been storing large quantities of food and grains at home as a way of coping with unforeseen circumstances such as prolonged protests and stringent curfews (Anjum and Varma, 2010). Displacement or migration is another coping mechanism. The biggest displacement from Kashmir was in the 1990s, when almost the entire Kashmiri Pandit community migrated to Jammu and other parts of India to escape the violence in the valley. Even after three decades, the community continues to live in exile (Shekhawat, 2009). There have also been other forms of displacement that is more cyclical in nature. People living in the border regions regularly migrate to more inner areas when increased tensions between India and Pakistan lead to cross-border shelling. In 2018, more than 1,000 people migrated from Uri district after heavy firing from across the border (SATP, 2020). A study conducted in the district of Srinagar found that people are open to migrating out of the conflict zone, but socio-economic conditions, and family and work commitments inhibit this migration (Khan, Ayoub, and Tahir*,* 2013).

During sudden and destructive disasters such as flash floods and landslides, it becomes imperative that the state machinery responds quickly and effectively to help people cope with the disaster. When flash floods and landslides wreaked havoc in Ladakh, the army, along with the civil administration and local people, launched massive search operations using army helicopters (Gupta, Khanna, and Majumdar*,* 2012). Due to concerns of contaminated water, purification units were installed to serve communities. Similarly, in the aftermath of the floods in 2014, Kashmiri student organizations from Delhi and other parts of India played an important role in helping people cope with the hazard (Venugopal and Yasir, 2017). The government has also followed a policy of providing compensation for the losses incurred by the people due to disasters. The central government provided $720 million in multiple packages to the government of J&K (then state of J&K) for relief and rehabilitation after the floods of 2014 (SDMP, 2017). After the avalanche in 2018, the erstwhile

state government provided relief of $5715 to the kin of those killed and $172 to the injured in accordance with the policy of State Disaster Relief Fund (SDRF) (New Indian Express, 2018; SDRF, 2015). The government has also attempted to integrate Disaster Risk Reduction with schemes such as Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and Indira Awas Yojana to enhance the capacities of the most vulnerable sections of the population (SDMP, 2017). MGNREGA is integrated with disaster management by focusing on generating work related to water harvesting, management of irrigation canals, flood control in water-logged areas, tree plantation, and renovation of traditional water bodies. The government has also promoted crop diversification and implemented crop insurance schemes to create a level of security against disasters for the rural population (SDRF, 2015). The J&K government had aimed at a growth rate of 4% in the agricultural sector by giving access to quality inputs such as seeds and fertilizers and by giving better inputs on soil and water management to the farmers (GOJ&K, 2013). Self-help groups (SHGs) have also been initiated by the government and the NGOs, with a special focus toward women. Women's SHGs have promoted micro-credit schemes, generated self-employment by promoting activities such as carpet weaving and goat and sheep rearing (Irshad and Bhat, 2015). This has helped in building capacity of women in rural areas and made them active participants in the development of the state and increased its resilience to disasters.

The victims of terrorist attacks in the region have also been provided compensation. In 2017, the government of the erstwhile state of J&K announced compensation of $8572 for the kin of the deceased after the attack on Amaranth pilgrims (Jameel, 2017). In 2015, the central government instituted measures to provide a monthly pension – apart from the one-time compensation – to widows of civilians killed in militant violence (GOI, 2008). A monthly cash relief of $36 (with a maximum of $145 per family) is also provided to Kashmiri migrants living in Jammu (GOI, 2015). The State Rehabilitation Council (SRC) has instituted schemes to rehabilitate thousands of women who have become widows over the many years of militancy. It also offers a one-time remittance of $290 for widow remarriage (GOI, 2008). Himayat, a scheme sponsored by the Government of India, was launched in 2011 as a skill development and placement program with the goal of providing jobs for the youth of the region (GOI, 2011). It aims to provide jobs for 100,000 youth with socially backward youth and school and college dropouts being the priority. There is also a youth exchange program under the project *Watan Ko Jano*, run by the SRC of J&K and Ladakh region, that aims to positively influence children between the age of 14 and 24 – especially orphans of militant violence (GOJ&K, 2015).

3. Discussion

The previous sections of this article have clearly outlined the devastating effects of disasters on the everyday lives of the people. These disasters have caused death, physical and mental trauma, destroyed livelihoods, and affected the economy of J&K and Ladakh region. Landslides and avalanches have been the most common natural disasters in the region, while floods and earthquakes, though less common, have caused more death and destruction. The 2014 flood was the most widespread natural disaster in the region in recent times while the 2005 earthquake proved most fatal. This study has also underscored the importance of human activity in disaster management – the frequency of disasters and their destructive potential increases due to unscientific and unsustainable development. The study also shows that while natural disasters have caused great death and destruction, terrorism, and violence have been even more destructive in the region, causing deaths of more than 20,000 civilians and security personnel, and displacing lakhs of people. Disasters have affected every aspect of life in the region – from industries such as agriculture, handicrafts, and tourism to the physical and mental health of people.

This study effectively synchronizes other studies (Sharma, Sharma, and Waris, 2012; Vithalani and Bansal, 2017) that have assessed the impact of disasters in the region in a comprehensive manner. The decline of the tourism industry, a lifeline of the region's economy, has led to increased levels of unemployment, which has created further disillusionment – especially among the youth of the region. This lack of jobs, when combined with the ongoing violence and widespread feeling of injustice, can lead to more and more youth getting attracted to the terrorism and armed struggle. In fact, conflict, terrorism, and disaster have created a vicious cycle, where development is hampered due to the ongoing violence and the lack of development creates unemployed youth, who then become potential recruits for terrorist organizations seeking to further the violence.

Mental or psychological health is an important aspect of human life that is impacted during both natural and man-made disasters. Conventionally, it has not got the importance it deserves. This study also contrasts the incessant and relentless nature of the violence with the more sporadic nature of natural disasters. The physical and mental trauma caused by disasters has been highlighted throughout this study. A natural disaster or a violent attack immediately results in major challenges for the underequipped and overcrowded health sector of the region, as was evident after the floods in 2014

(Vithalani and Bansal, 2017). The widespread violence, repeated disruptions to daily life, and the militarized nature of the region have had an adverse psychological impact on the people. Numerous studies have underlined that the prevalence of stress, trauma, and depression is quite common among the people and is directly linked to their exposure to the violence in the Kashmir valley (De Jong, Ford, Van de Kam, *et al.,* 2008; Amin and Khan, 2009; Housen, Lenglet, Shah, *et al.*, 2019; Wani, Suhaff, Khan, *et al.*, 2020). Another study after the earthquake in 2005 also highlighted the psychological impact of natural disasters, with depression, acute stress, and sleep disturbance being widely reported among the affected population (Chadda, Malhotra, Kaw, *et al.,* 2007). The conflict in Kashmir has also left thousands of women as widows and half-widows in a volatile and patriarchal society where sexual violence against women is widely prevalent (Qayoom, 2014; Qutab, 2012). Further, in the aftermath of a natural disaster, women are confronted with an atmosphere of increased insecurity and stress and a lack of privacy, sanitation, and reproductive facilities (Hamilton and Halvorson, 2007; Kelman, Field, Suri, *et al.*, 2018). In fact, natural disasters could potentially have a greater psychological impact on the people of the region than others due to the existing trauma arising from the violent conflict and due to the lack of resources to deal with mental health issues. The health facilities in the region require better infrastructure, more trained doctors, and mental health practitioners – especially in the rural and remote areas. Mental health needs to be a specific and ongoing focus. As the present study shows, psychological stress, trauma, and depression are widespread among the populace. The region also lags in health insurance coverage with only 4.2% of households having any insurance (GOI, 2017).

The study, while focusing on the impacts of natural and man-made disasters on the people of J&K and Ladakh region, also shows the linkages between the two types of disasters. First, the severity of natural disasters and their impact on people is largely determined by human activity. The impact of an earthquake is largely determined by the quality of the construction of buildings, whereas in the case of floods and landslides, human activities such as deforestation, urbanization, unscientific construction, and mining determine the extent of damage caused (Barnard, Owen, Sharma, *et al.,* 2001; SDMP, 2017). Second, the extent of damage can be minimized by immediate and effective responses taken in the wake of the disaster. The response by the government after the flash floods in Ladakh in 2010 was considered mildly effective, whereas there was a widespread perception of government failure, inadequate preparation, and poor relief measures in the aftermath of the 2014 floods (Venugopal and Yasir, 2017; Gupta, Khanna, and Majumdar, 2012). The floods laid bare the lack of warning systems, the poor levels of preparation of the authorities, and the inadequate relief and rehabilitation measures (Venugopal and Yasir, 2017). Third, conflicts, while being rooted in their specific histories and the prevalent political and social condition, are also impacted by natural disasters. The destruction caused by natural disasters creates conditions of resource scarcity, aggravates pre-existing inequalities in the society, and can lead to a general sense of grievance among people, thus further aggravating the conflict. A study using the data from the second half of the 20th century concludes that the risk of violent conflict increases in the short- and medium-term after a rapid-onset disaster like a flood or an earthquake (Nel and Righarts, 2008).

The government has taken steps to mitigate the effects of disasters by integrating livelihood schemes with disaster management, by promoting crop diversification, crop insurance, and by providing compensation to people affected by disasters. It has also made efforts to implement an extensive disaster management plan. While the plan highlights detailed and effective measures against disasters, it is imperative that the policymakers go beyond and take into account the diversity of the conditions in the region. There is an urgent need to improve the response and rehabilitation measures in rural areas after natural disasters, as was evident after the earthquake in 2005 when remote villages were ignored, and most relief measures remained focused on towns and cities (Zahir-ud-Din, 2005). Early warning systems, which were not effective during the 2014 floods, need to be made functional for different types of disasters. The structural integrity of the existing infrastructure in the state needs to be improved with safety audit of existing buildings and strict adherence to earthquake resilience for construction of future infrastructure (Yousuf, Bukhari, Bhat *et al.*, 2020). Social support among relatives, neighbors, and the community can also act as a source of resilience for people in the aftermath of disasters. A study done among adult survivors of 2014 floods in Kashmir region shows that high level of family and friends' support reduced the association between flood-exposure and symptoms of PTSD and depression to a great extent (Dar, Iqbal, Prakash, *et al*., 2018). There is also a need to engage with people and communities at the local level and formulate disaster management plans which makes use of the local and traditional knowledge systems. *Dhaji Diwari* is one such indigenous construction method which uses timber beams as means to reduce the impact of earthquakes on buildings. This method has been effective against earthquakes but is no longer widely practiced as people have moved toward more modern ways of construction using bricks and concrete which does not suit the unique landscape and climate of the region (Hassan, 2014; Yousuf, Bukhari, Bhat *et al.*, 2020). Traditional and indigenous industries like handicraft need to be supported and private investment should be encouraged in industries such as biotechnology, mineral extraction, and leather goods (Mahapatra and Shekhawat, 2008).

In a disaster-affected area, while focusing on economic growth, it becomes imperative that the government pursues sustainable development which does not negatively affect the fragile natural environment of the region. Economic measures are important, but all economic activity such as investment, trade, and tourism depends, to an extent, on the security of the area. Over the years, the security situation in the region has improved substantially but remains fragile and prone to outbursts in the form of violent protests and terrorist attacks (Khan, 2017). There exists a trust deficit between the local population and the administration and this need to be bridged by more inclusive community engagement approaches. There is an urgent need to increase the social capital of the people of the region by making local communities' stakeholders in the functioning of the government. It can be done through decentralization of power and authority and through the implementation of developmental programs focused on the needs of the community, with their active participation. In addition, the recent bifurcation of the UTs and administrative policy change in the region has given government enough space to work on the safety, security, and economic development agenda of the region.

4. Conclusions

While our study has managed to present a comprehensive overview of the impacts of disasters on the lives of people in the region of J&K and Ladakh, it does have some limitations. The study is based entirely on available literature and no primary data were collected for it. In a dynamic situation like the one in J&K and Ladakh region, the study, while being true to the intrinsic nature of disasters, terrorism and violence, may fail to present the current situation. The study also leaves scope for in-depth research into the different impacts of the disasters highlighted here. Based on the findings, the study recommends the strengthening of effective disaster risk reduction and management systems, early warning systems and infrastructure – especially health facilities, schools and roads – in J&K and Ladakh region. In addition, emphasis must be laid on reducing the underlying vulnerabilities of the population through better community engagement approaches for both development initiatives and conflict resolution, with a special focus on the youth. Interventions made by the government to improve the resilience of communities should be implemented in a sustainable way, taking into account the risks posed by both natural disasters and terrorism. This study strongly recommends in-depth research and advocacy to ensure that resilience measures with regard to both natural and man-made disasters in the region are appropriately addressed.

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Authors' Contributions

Conceived and designed: Sangram Kishor Patel. Review of literature: Sangram Kishor Patel, Ankit Nanda, Govind Singh and Sunita Patel. Contributed to tools/materials/data collection: Sangram Kishor Patel and Ankit Nanda. Drafted and wrote the manuscript: Sangram Kishor Patel, Ankit Nanda, Govind Singh and Sunita Patel.

Conflicts of Interest

No conflicts of interest were reported by the authors.

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REVIEW ARTICLE

Understanding the resilience and mental health impacts of natural disasters in India: A narrative review

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Abstract: The purpose of this study is to understand the linkages between natural disasters and their impact on the mental health of people as well as associated resilience mechanisms in India. Natural disasters affect not only the physical environment but also the economy, social life, and well-being of the population. In addition to the loss of precious lives and economic losses, disasters affect the natural growth and mental health of the affected populations to a great extent. It is extremely challenging to quantify the true scale of damage caused by a disaster because physical damage is visible, but hidden impacts could be much more severe and have catastrophic effects on the socioeconomic growth of the affected families and areas. Against this background and with the limited available evidence, this study has tried to understand how disasters lead to poor mental health among the affected populations around the globe and tried to conceptualize this in the Indian context. Our review documents the different pathways for disasters to adversely affect mental health, particularly among vulnerable populations. The review also highlights how an increased frequency of disasters with climate change can lead to a post-traumatic stress disorder, adjustment disorder, and depression. Changes in climate and global warming may require populations to migrate, which can lead to acculturation stress. It can also lead to increased rates of physical illnesses, which secondarily would be associated with psychological distress. This research is an initial step in bringing this important issue forward in the context of Sustainable Development Goals and outlining that better policies need to be designed for prevention, services, and psychological counseling of mental health problems due to disasters. This study also suggests for more longitudinal research to understand the development of disaster-related mental health problems and to develop adequate mitigation strategies.

Keywords: Climate change; Natural disasters; Resilience; Post-traumatic stress disorder; Psychological distress; Mental health; India

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1. Introduction

Disasters are the most prominent catastrophes which severely hinder the growth and pace of development of a country. In 2016, the world witnessed 191 natural catastrophes. Nearly 11,000 people died or went missing, and the profound economic loss from these disasters was estimated to be USD175 billion, the highest since 2012 (Swiss Re, 2016). Since 1970, the number of disasters worldwide has quadrupled to around 400 a year. Natural disasters increased by 13.9% in 2015 over the previous year (Guha-Sapir, Hoyois, and Below, 2016). Scientists believe that the increase in hydrometeorological disasters is due to a combination of natural and man-made factors. Global warming is continuously

increasing the temperature of the Earth's oceans and atmosphere, leading to more intense storms of all types, including hurricanes. However, natural disasters are deadlier and costlier than man-made disasters. In 2015, 6994 people were killed in man-made disasters, while 19,365 lives were lost to natural disasters. The economic losses incurred due to natural and man-made disasters in 2015 were USD80 billion and USD12 billion, respectively (Swiss Re, 2016).

Natural disasters have had multifarious ruinous impacts, invariably affecting the rich and the poor, the developed countries, and developing countries. However, natural disasters are more hazardous to low-income countries in particular, as they lead to long-term damages and resources are heavily diverted for reconstruction purposes (Johnson, 2006). Furthermore, low-income countries are more vulnerable as a higher proportion of people stay in areas that have poor infrastructure, and the lack of access to basic facilities heightens their exposure to disasters. Between 1994 and 2013, the Asian continent had the highest frequency of natural disasters and the greatest number of lives lost due to disasters. This is primarily due to the large and varied landmass in Asia – multiple river basins, flood plains, mountains, and active seismic and volcanic zones that are at high risk from natural hazards along with high population densities in disaster-prone areas. Nearly 48% of all disasters worldwide occurred in Asia in 2014 and 85% of lives lost were also in the same continent (CRED, 2015).

Natural disasters affect millions of people every year and leave residents and communities devastated and completely decimated. However, their impact is disproportionately more severe on the poor, farmers, and other marginalized groups of the population. Natural disasters brutally affect the agricultural sector, impacting livelihoods, and food production. With an approximate loss of USD80 billion owing to fall in crop production between 2003 and 2013, efforts toward hunger eradication have been hindered as a consequence of disasters that have impacted livelihoods and food security of over one-third of the developing countries (FAO, 2015). Statistics tend to count the lives lost and economic devastation of these events, but it is not easy to quantify the psychological impacts of a disaster.

The people left in the wake of these events have lost their homes, loved ones, and sometimes an entire way of life. For people already experiencing a mental illness, such a traumatic event makes symptoms even worse. For others, a natural disaster can lead to depression, extreme stress, generalized anxiety, eating and food issues, obsessive-compulsion, and a host of other problems. People are resilient – they begin to pick up the pieces of their lives and rebuild, but that does not mean the effects of a natural disaster do not linger. Studies have drawn out the mental health effects of natural disasters (McMichael, Woodruff, and Hales, 2006; Nahar, Blomstedt, Wu, *et al.,* 2014). Evidence suggests that the psychological impact of disasters is not restricted only to the people who have experienced it but also people involved in roles or occupations that require them to respond to disasters, for example, people involved in rescue operations and relief work; they are also susceptible to different psychological and mental stresses (Thormar, Gersons, Juen, *et al*., 2010; Brooks, Dunn, Amlôt, *et al*., 2016).

1.1. Rationale

Climate change is one of the greatest challenges of our time. The consequences of climate change on exposed biological subjects, as well as on vulnerable societies, are a concern for the entire scientific community. Rising temperatures, heat waves, floods, tornadoes, hurricanes, droughts, fires, loss of forests, and glaciers, along with the disappearance of rivers and desertification, can directly and indirectly cause human pathologies that are both physical and mental (Cianconi, Betrò, and Janiri, 2020). However, there is a clear lack in psychiatric studies on mental disorders linked to climate change. India has also been significantly affected by natural disasters over the years. Between 1994 and 2013, in terms of the cumulative number of people affected by natural disasters, India figured among the top countries (CRED, 2015). India also figured among the top five most disaster-hit countries in the past 10 years (Guha-Sapir, Hoyois, and Below, 2016). While a bound volume of evidence is documented on impacts of disasters on physical health, livelihood, food security, water and sanitation, and other socioeconomic dimensions in India, there is a dearth of studies on the impact of disasters on the mental health of the population in the country. With the above scenarios, this review article primarily aims to explore the pathways through which different natural disasters, which include heat waves, droughts, floods, cyclones, earthquakes, and landslides, impact the mental health of disaster affected-exposed people in India. We also aim to investigate the coping and adaptation mechanism of communities, as well as government strategies for tackling mental health impacts due to natural disasters, to suggest some future policy recommendations for better and effective disaster management in the country. To understand the pathways through which different natural disasters impact the mental health of people in India, we conducted a short review on theme.

2. Natural Disasters and Pathways to Mental Health

The expanding research literature on inter-linkages between climate change, natural disasters, and mental health includes increasing evidence that extreme weather events – which are more frequent, intense, and complex under a changing

climate – can trigger post-traumatic stress disorder (PTSD), major depressive disorder (MDD), anxiety, depression, complicated grief, survivor guilt, vicarious trauma, recovery fatigue, substance abuse, and suicidal ideation. Incremental climate change, such as rising temperatures, rising sea levels, and episodic drought, can change natural landscapes, disrupt food and water resources, change agricultural conditions, change land use and habitation, weaken infrastructure, and give rise to financial and relationship stress, increase risks of violence and aggression, and result in displacement of entire communities (Hayes, Blashki, Wiseman, *et al*., 2018; Solanki, 2016; Wind and Komproe, 2018).

Berry *et al*. (2010) described the putative direct and indirect relationships among factors which have both direct and indirect effects on mental health, as illustrated in Figure 1. This figure serves as a guide to bridge disciplines and to comprehend key concepts related to inter-linkages between climate change, natural disasters, and mental health of affected populations. The link between extreme anxiety reactions (such as PTSD) and acute weather disasters, such as floods (the most common disasters at the global level), forest fires, heat waves, and cyclones, can be direct and indirect. Climate change/natural disasters may affect mental health directly by exposing people to the psychological trauma associated with higher frequency, intensity, and duration of climate-related disasters, including extreme heat exposure, and also by destroying landscapes, which diminishes the sense of belonging and solace that people derive from their connectedness to the land. In addition, indirect effects to mental health may occur via two pathways. Climate change-induced disasters may affect (1) physical health, through increased heat stress, injury, disease, and disruption to food supply and (2) community well-being, through damage to the economic and, consequently, the social fabric of communities (Kjellstrom, Holmer, and Lemke, 2009; Berry, Bowen, and Kjellstrom, 2010).

3. Key Findings

3.1. Heat Waves and Mental Health

Heat waves pose a serious policy challenge as temperatures soar and heat wave mortality rates mount with every passing year. The year 2016 has been the warmest in the world till date – it was 1.1°C higher than pre-industrial levels (WMO, 2019). India has high exposure to heat waves, and with inadequate adaptive ability, the effect of heightened heat waves might turn acute. In terms of the number of deaths due to natural disasters in 2015, heat waves caused the third-highest number of deaths in India at 2248 (Murari, Daly, Patwardhan, *et al*., 2015). Heat waves not only account for mounting mortality rates but also have multiple life-altering impacts on populations and severely affect their employment, food availability, and basic life sources. Occupational health risks are likely to increase with a rise in heat exposure and thus

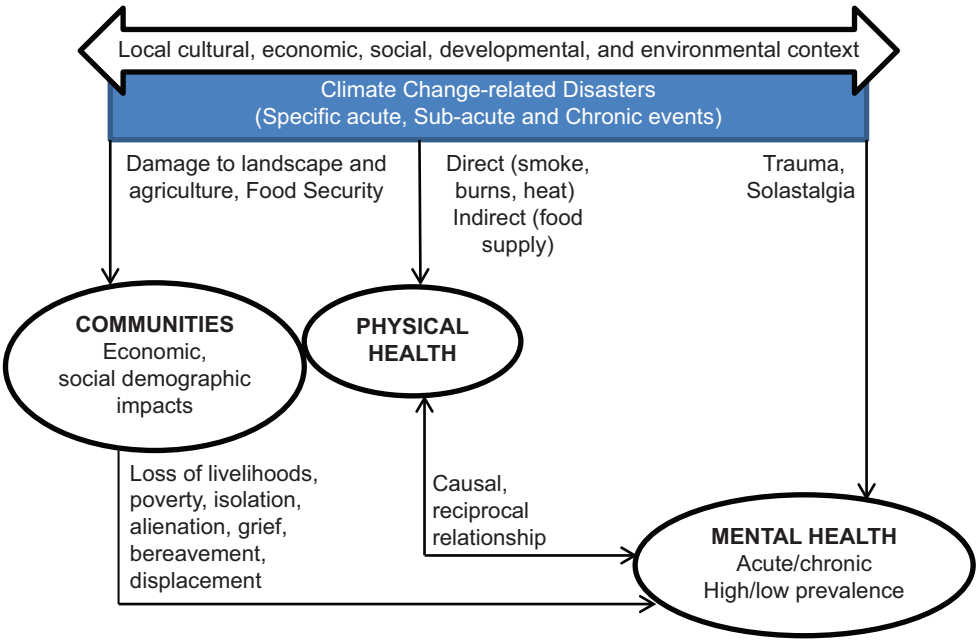

Figure 1. Natural disasters and pathways to mental health. Source: Referred from Berry *et al*. (2010).

adversely affect the productivity of workers (Kjellstrom, Holmer, and Lemke, 2009). Evidence shows that daily wage workers are not able to work continuously during heat waves, which affects their earning. People are forced to go out for work as they have no other choice. Vegetable vendors, construction workers, auto repair mechanics, rickshaw pullers, roadside kiosk operators, and other weaker sections in India have to work in the heat, thereby making them susceptible to the adverse impacts of heat waves such as dehydration, sun-strokes, and other health risks (NDMA, 2009b).

Exposure to heat waves also affects the mental health of populations. Evidence suggests that extreme heat exposure made people susceptible to symptomatic mental disorders, dementia, mood (affective) disorders, neurotic, stress-related, and somatoform disorders, disorders of psychological development, and other mental health consequences, for which admissions to hospitals rose during heat waves. At the same time, hospital admissions increased more among men, the elderly, and people in rural areas (Hansen, Nitschke, Ryan, *et al*., 2008; Trang, Rocklöv, Giang, *et al*., 2016). People also suffer psychologically and feel depressed when they are unemployed. People with low incomes have a higher likelihood to be afflicted by a chronic disease or other ailments such as mental illness or obesity due to heat waves (Kovats and Hajat, 2008).

In India, very limited evidence is available on how natural disasters affect the mental health of the affected populations. Heat waves are known to cause physiological and psychological stresses and even lead to death. It is known as a silent disaster as it develops gradually and harms both human beings and animals in the country. Global warming has resulted in increased heat wave conditions in India, consequently resulting in increased deaths due to heat waves in different parts of India, particularly in the north-western, southern, and south-eastern regions (Akhtar, 2007). Sudden increases are recorded in deaths arising due to mental and behavioral disorders during heat waves, especially among older persons (Solanki, 2016; Shukla, 2013). In Odisha, India, the increase in the frequency of extreme weather events has had an impact on the mental health of the people. The study conducted in Odisha showed that due to the extreme heat, water scarcity, and unavailability of labor force, majority of people suffered from a drought-like situation. They lost scope of agricultural productivity because of heat waves and scarcity of water. Many people migrated to other areas to work at low wages, which disturbed their financial condition. Loss of livelihood and income sources caused psychological stress. People became depressed as they had to struggle incessantly to meet their income needs, family commitments, and food requirements (Patel, 2018a).

3.2. Droughts and Mental Health

Drought has long been documented as one of the most insidious natural disasters and causes of human misery. Like other natural disasters, droughts often have significant health effects, typically mediated through complex environmental, economic, and social pathways. The catalog of harmful health effects associated with drought is still being assembled. Water scarcity also affects the functioning of public institutions such as schools and public health centers. Some of the health impacts owing to shortage of water include diarrhea, which occurs due to the consumption of contaminated water, while inadequate water intake can lead to dehydration. These factors are also a leading cause of infant mortality. Other health impacts of droughts include water-related diseases such as *Escherichia coli* and cholera, airborne, and dust-related diseases, vector-borne diseases such as malaria and West Nile virus, and mental health ailments (Stanke, Kerac, Prudhomme, *et al*., 2013). Women, children, and infants constitute the most vulnerable sections of the population in the event of a drought. Previous studies have shown that drought not only affects people physically but also psychologically. There was a high degree of concordance among the identified literature, leaving a strong impression of increased risk for adverse mental health impacts associated with drought. Studies have highlighted how droughts have affected the mental health of people in terms of emotional stress and anxiety (Dean and Stalin, 2010; Hart, Berry, and Tonna, 2011).

Along with the western US, China, eastern and southern Africa, and the Mediterranean region, India featured among the areas that were most drought-prone between 1984 and 2013 (FAO, 2015). In India, droughts are projected to exacerbate the levels of poverty and affect the means of livelihood sustainability. Most major droughts in India have been followed by a recession. It leads to a shortage of raw material supplies for agro-based industries and it also reduces the demand for industrial products owing to the low purchasing capacity of rural consumers. Losses in agriculture affect the livelihood of farmers as small- and medium-sized farmers turn into agricultural laborers (NDMA, 2009b; Singh, Bantilan, and Byjesh, 2014).

Defining health outcomes associated with drought is also challenging, particularly in the area of mental health. Interpretations of mental health outcomes vary across studies, and often outcomes are not explicitly defined. Although mental health concepts are complex and vary with social, cultural, and familial norms and values, categorization of adverse mental health outcomes is a prerequisite of further study. We considered mental health to be more than just the absence of a mental illness or disorder and determined by a host of socioeconomic, biological, and environmental

factors. Our review suggests a high degree of concordance among the identified literature, leaving a strong impression of increased risk for adverse mental health impacts associated with drought. Indian farmers continue to suffer regularly from drought, a frequent natural disaster that has profound effects both individually and collectively. Successive droughts and low agricultural productivity are a blow to the regular income sources of farmers. This has caused many farmers in recent decades to take the extreme step of ending their lives. Farmer suicides, due to droughts and related consequences, have emerged as an important area of concern in recent decades in India (Kalamkar and Shroff, 2011; Bharti, 2011).

Drought affects employment and income of farmers and leads to indebtedness, and is counted as one of the major reasons for suicides (Udmale, Ichikawa, Manandhar, *et al*., 2014; Patel, Mathew, Nanda, *et al*., 2019). In 2014, around 5650 farmers committed suicide in India, of which 20.6% was due to indebtedness and 16.8% due to the failure of crops. Crop loss, chit funds, debt burden, property disputes, daughter's marriage, and illness of family members are among the reasons for farmer suicides in Karnataka (Deshpande, 2002). One of the reasons for reduced yield/profitability among cotton farmers in Vidarbha that had increased suicides post-1995 was the shortage of water (Mishra, 2006). In Karnataka, farmers have to grapple with drought conditions and paucity of rain, and a high number of suicide victims had rain-fed lands (Deshpande, 2002). Here, it is important to understand the cycle which farmers affected by droughts go through and eventually decide to end their lives. Undoubtedly, they were depressed, psychotic, and impulsive, accompanied by a pervasive sense of suffering and hopelessness, as well as a desire to escape from the situation that has arisen due to successive droughts and indebtedness. The study conducted in Odisha showed that besides the impact of droughts on livelihoods, food security, and physical health, the mental health of people was also impacted in the process. People are under tremendous mental pressure to meet the basic requirements of the family (Patel, 2018b).

3.3. Floods and Mental Health

Floods are the most commonly occurring natural disasters globally. It is not unusual then that among all-natural disasters, floods have affected the largest number of countries. In the post-2005 period, 47% of weather-related disasters globally were caused by floods, thereby affecting 2.3 billion people. In Asia and the Pacific region, 3.35 billion people were affected by floods between 1970 and 2013, which is higher than other natural disasters in the region. The economic losses caused by floods amounted to USD 370 billion, which is the second highest in the region after a combined loss of USD 472 billion caused by earthquakes and tsunamis (UNESCAP, 2015). In addition to economic losses, detrimental short-, medium-, and long-term effects on well-being, relationships, and physical and mental health are common. While most people who are involved in disasters recover with the support of their families, friends, and colleagues, the effects on some people's health, relationships, and welfare can be extensive and sustained.

Flooding can lead to substantial social and mental health problems that may continue over extended periods of time. Flooding can challenge the psychosocial resilience of the hardiest of people who are affected. It is important to understand the effects of being separated from family and friends, disruption to family life and daily routine, the loss of pets and possessions, and moving to temporary accommodation, all of which can have an effect on the mental health of children. Symptoms can include separation anxiety; irregular sleeping patterns/nightmares; behavioral problems such as becoming withdrawn, increased aggression, bedwetting; and development of habit-forming behaviors such as routines/rituals about washing; and academic performance may suffer. Across the world, numerous studies have demonstrated that floods have impacted people psychologically. Floods have a range of impacts on physical and mental health. Women suffered from malnutrition due to food shortages after floods in Bangladesh. They were also subjected to mental torture, verbal abuse, domestic violence, and sexual harassment. Their vulnerability was increased due to the paucity of clothing and fuelwood (Azad, Hossain, and Nasreen, 2013). Flooding can lead to bereavement, behavioral issues in children, substance misuse, and even worsen mental health status (Stanke, Murray, Amlôt, *et al*., 2012; Lock, Rubin, Murray, *et al*., 2012). An epidemiological review by Health Protection Agency indicates that children and the elderly exhibit higher vulnerability to mental diseases as they depend on people of working age in terms of how they cope with floods. A study done in England indicates that people who were relocated due to floods and people with low earnings have a higher likelihood of severe mental health deterioration such as flashbacks, increased anger, and sleeplessness (Lamond, Joseph, and Proverbs, 2015 2015). Another study indicates that there is a higher likelihood of developing anxiety and PTSD among people who are displaced after flooding (odds ratio for depression 2.0 [95% confidence interval 1.3-2.9], for anxiety 1.7 [1.1-2.5], and for PTSD 1.7 [1.2-2.5]) than people who were not displaced (Munro, Kovats, Rubin, *et al*., 2017).

Floods in India ranked seventh in terms of the number of deaths and economic damage caused in 2015, and the second-highest number of victims at 13.71 million people (Guha-Sapir, Hoyois, and Below, 2016). More than 40 million hectares or nearly 12% of land in India is prone to floods and river erosion (NDMA, 2009b). Multiple factors that affect key aspects of the lives of people also cause mental stress. Several studies have highlighted the impact of floods on the

mental health of people in India. For example, studies in Kashmir have noted the mental health consequences of floods among people in terms of trauma, depression, stress, and anxiety (Fatima and Maqbool, 2017; Hassan, Singh, and Sekar, 2018; Dar, Iqbal, Prakash, *et al*., 2018). Some studies have documented the mental health impact of floods on people in Bihar. Livelihood concerns were among the main reasons for developing symptoms of depression. A study showed that the elderly are more susceptible to developing PTSD and depression following the floods in Bihar (scored high PTSD at $p<0.05$ compared to all other age-groups) (Telles, Singh, and Joshi, 2009; Telles, Singh, Joshi, *et al*., 2010). Another study showed the psychological impact in the form of sleep disturbance and flashbacks among the elderly survivors of the Uttarakhand floods. At least 16.1% of the sample experienced recurrent flashbacks following the disaster and mostly had difficulty in maintaining sleep (14.5%). At least 12.9% found themselves thinking about the disaster and its recurrence even when they did not want to, and experienced intrusive memories regarding the same. At least 6.5% experienced a loss of their sense of safety and security following the disaster, and many contemplated relocating to other relatively safer parts of the state. At least 21.0% experienced restlessness and increased physiological arousal, contingent with any stimuli associated with the disaster, while 1.6% experienced increased irritability and anger at minor instances. At least 3.2% of them experienced vague bodily complaints non-attributable to any specific reason, following the occurrence of the disaster and significant worry regarding the future. At least 19.4% attempt to avoid reminders of the disaster (Chandran, Roopesh, Raj, *et al*., 2015).

A study among high school students showed that, of all the adolescents aged 13-16 years, about one-third continued to suffer from trauma-related stress disorder even after 3 months of the flood in Uttarakhand in 2013 (Nisha, Kiran, and Joseph, 2014). The study shows that people struggle with psychosocial problems due to floods. They suffer psychologically because of the continuous loss of crops caused by floods. Farmers are always under immense mental pressure to sustain their families (Patel, 2018c). Due to erosion of the social, environmental, and material context, the recurrent floods have large negative impacts on the mental health outcomes and psychological and physical functioning of people in Northern India (Wind, Joshi, Kleber, *et al*., 2013).

The review indicates that flooding affects people of all ages, can exacerbate or provoke mental health problems, and highlights the importance of secondary stressors in prolonging the psychosocial impacts of flooding. The distressing events experienced by the majority of the people, transiently or for longer periods after disasters, may be difficult to distinguish from the symptoms of common mental disorders. However, there are a number of methodological challenges that arise when conducting research and analyzing and comparing data on the psychosocial and mental health impacts of floods. Most of the studies employed cross-sectional design without a control group. There is a lack of studies that report evidence from the monitoring of the mental health of the flood-affected populations. Studies were conducted during the 1st year, with no medium- to long-term follow-up. This is important because acute stress-related response, if not addressed properly, can evolve to more severe disorders such as depression.

3.4. Cyclones and Mental Health

Even as cyclones become a regular occurrence in the range of disasters worldwide, they continue to leave behind a trail of destruction. During 1980-2009, 412,644 people died worldwide from cyclones (Doocy, Daniels, Packer, *et al*., 2013). Several studies show that cyclones result in the destruction of property and infrastructure. They also indicate the damage wrought by cyclones on power supply and related infrastructure (Yuvaraj, Dharanirajan, Narshimulu, *et al*., 2015). In recent years, cyclones have resulted in the displacement of people in higher numbers compared to other disasters. In 2013, Typhoon "Haiyan" caused the maximum number of displacements of people in the Philippines at 4,095,000. Similarly, in 2014, Typhoon "Rammasun" in the Philippines caused the displacement of 2,994,100 people. In the last century, cyclones have affected populations worldwide. As for the biggest windstorm disasters between 1900 and 2005, Typhoon "Talim" was the third biggest disaster, affecting 19.6 million people in China (CRED, 2005). High levels of mental illness, PTSD, and suicidal attempts were reported among Hurricane Katrina affected people in New Orleans, USA (Sastry and VanLandingham, 2009).

This global trend of evidence-based research has also been seen in India. It has been acknowledged that India has traditionally been vulnerable to many natural disasters, including cyclones and tsunamis, on account of its unique geo-climatic conditions. Recent major cyclones in India include the Andhra Pradesh cyclone (1996), the super cyclone in Orissa (1999), and the tsunami in Tamil Nadu (2004). Cyclones have caused large-scale displacement and devastation in India. In terms of the biggest windstorm disasters between 1900 and 2005, India featured in the fifth position, while it had the second-highest number of major tropical cyclones. The super cyclone in Odisha in 1999 was the eighth biggest disaster in this period affecting 11 million people (CRED, 2005). In 2013, India ranked sixth in terms of the number of displacements, with Cyclone "Phailin" displacing 1,000,000 people. Cyclones also affect water and sanitation and impact health in the process.

While an event like a cyclone could serve as a catalyst for the occurrence of a disaster, the precise roots of mental health problems lie in the socially induced vulnerability associated with places and populations. In addition to the public health and medical consequences of these disasters, the social, cultural, and psychological impact of cyclones and tsunamis have an enormous and long-lasting impact throughout the world and a direct effect upon human development in general. The impact of gender, caste, socioeconomic status, and social network was apparent at virtually every stage of cyclone "Thane" in Puducherry, showing the salience of inequality and differential vulnerability in society (Parida, 2014). Cyclones have had a grave impact on water, sanitation, and health. Displaced people have a higher likelihood of suffering under outbreaks of waterborne and flood-borne diseases along with mental shocks (Chhotray and Few, 2012; Bhunia and Ghosh, 2011).

A growing body of research has pointed to linkages between mental health and environmental stressors exacerbated by climate change, including tropical cyclones. A study conducted 1 year after the super cyclone in India in 1999, found that a large number of children had post-traumatic symptoms. Another study showed that about 80.4% people had a probable psychiatric disorder, while 57.5% people had an anxiety disorder, and 52.7% had depression (Kar, Mohapatra, Nayak, *et al*., 2007). Cases of anxiety and abnormal behavior patterns were also reported (Patra, Tripathy, and Jena, 2013). After cyclone Thane, a number of people were uprooted from their homes and lost their livelihoods in Puducherry, India. They experienced trauma, acute anxiety, depression, and suicidal thoughts (Parida, 2014).

In fact, acceptance of the existence of psychological impacts of natural disasters and the need for focused services for the survivors became much clearer only after the cyclone. A study done more than 4 years after the tsunami struck India in 2004 showed the continued prevalence of psychiatric morbidity among a high percentage of survivors (Kar, Krishnaraaj, and Rameshraj, 2013). In the wake of the 2004 tsunami, some of the problems faced by children in India included sleep disorder and separation anxiety from parents, anxiety, and helplessness. Adults had to grapple with hypervigilance, hyperarousal, depersonalization, and panic attacks (Becker, 2007). The review of some of the qualitative studies reveals that the mental health of people is severely affected in the event of disasters alongside the destruction of livelihoods and agriculture. Many people were in mental trauma or grappled with post-traumatic disorders after the 1999 cyclone, some people were not even able to recognize their family members (Patel, 2018c).

3.5. Earthquakes and Mental Health

Earthquakes are the deadliest natural disasters worldwide. In the period between 1994 and 2013, earthquakes accounted for 55% of total deaths caused by natural disasters, more lives were lost in earthquakes than from any other natural hazard, and earthquakes were the third most frequently occurring disasters in this period. Studies have highlighted the economic damages (Cavallo, Powell, and Becerra, 2010) and infrastructural damages caused by earthquakes (Parker and Steenkamp, 2012; Kobayashi, 2014). Large-scale seismic damage was caused to engineering infrastructure, and structural damage was caused to non-engineered reinforced concrete buildings due to the earthquake in Sumatra in 2005; main arteries and small streets were destroyed, thereby affecting the transportation system and hindering relief efforts (Saatcioglu, Ghobarah, and Nistor, 2005).

Earthquakes, as a natural disaster, not only causes deaths, physical disease, damage to infrastructure, and economic loss, they also have long-lasting mental health effects on individuals involved. A study highlighted that older people had higher levels of post-traumatic stress symptoms after an earthquake (Ticehurst, Webster, Carr, *et al*., 1996). As per the Government of Nepal (2018), half of the people reported physiological stress on the day of the earthquake in Nepal, and far more women had psychosocial problems than men. About 40% of consultations in the aftermath of the 2005 earthquake in Pakistan were for trauma. PTSD, anxiety, and depression were prevalent among people 8 weeks after being affected by the earthquake in Thailand (Griensven, Chakkraband, Thienkrua, *et al*., 2006). About 58% people had severe mental health issues after the Bam earthquake in Iran in 2003, which was thrice the psychological distress in the general population (Montazeri, Baradaran, Omidvari, *et al*., 2005). A study showed that the middle-age group was more psychologically vulnerable and had a poorer capacity to cope with the earthquake in China due to their responsibility toward their family (Xu and He, 2012). A number of survivors of the earthquake in Wenchuan reported high levels of PTSD, anxiety, and depression. The prevalence rates of probable PTSD, anxiety, and depression were 26.3%, 49.8%, and 49.6%, respectively (Zhang, Shi, Wang, *et al*., 2011).

There are very few studies which capture the adverse effects of earthquakes on mental health in India. Mental health problems were seen among people in Andaman and Nicobar Islands following the earthquake and tsunami that struck the Indian subcontinent in 2004. The study also showed that people suffered from depression, adjustment disorders, anxiety disorder, panic disorder, and PTSD and that displaced survivors had higher levels of psychiatric morbidity than non-displaced people. Following the early phase of the disaster, 5-8% of the population were suffering from significant mental health problems which were expected to increase in the aftermath of the early relief phase. Psychiatric morbidity is expected be around 25-30% in the disillusionment phase (Math, Girimaji, Benegal, *et al*., 2006).

A study done on children and adolescents in displaced populations showed the prevalence of adjustment disorder, schizophrenia, PTSD, and other disorders, in Andaman and Nicobar Islands. The most common psychiatric morbidities observed among the primary and secondary survivors were adjustment disorder (13.5%), depression (13.5%), panic disorder (10.8%), post-traumatic stress disorder (10.8%), schizophrenia (2.7), and other disorders (43.2%). Subclinical syndrome was present in the majority of the primary and secondary survivors. Few tertiary survivors had subsyndromal symptoms (Math, Girimaji, Benegal, *et al*., 2008). Studies have observed the increase in mental health problems among survivors after the Gujarat earthquake in 2001 (Sharma, 2002). After the earthquake, psychosocial problems were reported, and some of the women who had suffered psychosocial shock even experienced premature delivery. A study showed that some of the people whose houses were ravaged during the earthquake in Kashmir in 2005, experienced adjustment disorders, depression, other stress reactions, and PTSD or PTSD-like symptoms. Some people lost their family members and/or injured physically (Chadda, Malhotra, Kaw, *et al*., 2007). A study showed that children had psychological stress following an earthquake in Sikkim in 2011. Sleeplessness, night-awakenings, and excessive crying were observed among these children (Mondal, Sarkar, Banerjee, *et al*., 2013).

The Marathwada earthquake in 1993 in India was one of the worst human tragedies of modern times, which captured global attention because of the massive impact it had in terms of loss of life and property. Moderate increase in psychiatric morbidity was observed in the medium term among the disaster-affected group, which for the most part, had subsided by the follow-up stage 5 years post-disaster. Differential distribution of cases was noticed in the affected villages paralleling the gradient of disaster losses. There was a clustering of cases within families (Shah, Parhee, Kumar, *et al*., 2005; Kar, 2010). The above review has summarized the current status of information on mental disorders caused by experiencing or witnessing a severe, life-threatening earthquake. Each earthquake phase has different mental health problems. The review suggests that common mental disorders due to earthquakes include depression, cognitive function disorders, PTSD, and schizotypal personality.

3.6. Landslides and Mental Health

Landslides are among the most significant disasters across the globe, primarily affecting hilly regions. Landslides adversely affect the economy and cause damage to property (NIUA, 2016). Roads, bridges, schools, irrigation canals, temples, and cremation sites are damaged as a consequence of landslides (Van der Geest and Schindler, 2016). The impact on lifeline systems (water systems, hospitals, health centers, energy, and lines of communication) present in the path of the landslide is massive. They can be severely damaged or destroyed. Indirect effects can include loss of property value, livestock and crops, and increasing the vulnerability of the population, reducing their coping and caring capacities. The psychosocial well-being and mental health of rescue workers and their families are also at risk during and after landslides.

In a case report on providing support after landslides, Clifford (1999) described the psychological support services provided after the Thredbo landslide in New South Wales, Australia, which resulted in 18 fatalities (including a member of the New South Wales Fire Brigade). The labor-intensive and hazardous emergency response was complicated by a number of stressors, including fatigue, frustration, fear for personal safety, personal knowledge of the victims, and media exposure. Catapano *et al*. (2001) reported a controlled prevalence study among the survivors of the landslide in Sarno, Italy, in 1998. Survivors were more than 20 times more likely than members of a control group to suffer from PTSD, with 27.6% of survivors meeting the diagnostic criteria for PTSD compared to 1.4% in the control group. Typhoon "Morakot" in 2009 was one of the most severe typhoons to hit Taiwan. Nearly all inhabitants of the steep mountainside communities in southern Taiwan were at risk of landslides. Female gender, being injured during the landslide, and bereavement as a result of the disaster were all associated with increased risk of PTSD (Yang, Yen, Tang, *et al*., 2011). People suffered mental stress and emotional trauma after the landslide in Nepal (Van der Geest and Schindler, 2016). Psychological well-being of children stood threatened as a consequence of floods and landslides in Myanmar (Government of Myanmar, 2015).

In India, the Himalayas are prone to landslides, particularly during the monsoon season from June to October. Various types of landslides occur in the Himalayas, including block slumping, debris flow, debris slide, rock falls, rotational slip, and translational slides. Studies show that more than 12% of the land area in the country is susceptible to landslides. The major landslide-prone areas in India include the Western Ghats and Konkan Hills (Tamil Nadu, Kerala, Karnataka, Goa, and Maharashtra), Eastern Ghats (Araku region in Andhra Pradesh), North-East Himalayas (Darjeeling and Sikkim), and North-West Himalayas (Uttarakhand, Himachal Pradesh, and Jammu and Kashmir). Landslides cause damage to private and government property, infrastructure, and heritage (NDMA, 2009a). Landslides in Darjeeling in 2015 led to several deaths and people were rendered homeless. Piles of debris were strewn across Darjeeling leading to disruption of communication, as roads were disconnected, and it took over a month to clear the debris (Sumantra and Raghunath

2016). Each year landslides lead to road blockages in Ladakh (Hodgkins). Landslides affect socioeconomically vulnerable people, severely affecting their livelihood and food security in India (NDMA, 2009a), and making daily life a struggle as key aspects of life get affected. This has potential mental health consequences for disaster-affected people.

While there is a large body of literature on the engineering and geological aspects of landslides, the mortality and morbidity caused by landslides are not as well documented. We could find a small number of relevant studies, as the documentation of the health impacts of landslides has been very limited. Mental health impacts were better documented, though some of the studies are now quite old. According to a study, the Himalayan landslides resulted in the loss of shelter and playing space and were associated with psychological distress, insecurity, grief, helplessness, and uncertainty in children (Aneelraj, Kumar, Somanathan, *et al*., 2016). Studies showed that psychological morbidity was higher among people in the immediate phase following floods and landslides, as compared to other disasters in Uttarakhand (Nisha, Kiran, and Joseph, 2014; Srivastava, Goel, Semwal, *et al*., 2015). People suffered from post-traumatic stress disorder, severe levels of depression, stress, and anxiety, and it was higher for those with lower levels of education (Sharma, 2016). A large number of people with severe mental disorders were seen wandering in the villages and near-religious places. Some of the shortcomings in disaster management with respect to mental health treatment included the absence and lack of availability of anti-psychotics, anti-depressants, anti-epileptics, and mood stabilizers in the district hospitals (Channaveerachari, Raj, Joshi, *et al*., 2015). Landslides in Udhampur, Jammu and Kashmir, India, led to deaths and loss of livelihood and mental illness (Sharma, 2016).

4. Mental Health Resilience to Natural Disaster

4.1. Coping and Adaptation

Risk management includes both coping and adapting, and the two concepts are central for adaptation to climate change in both research and practice. Understanding local strategies used in preparing for, responding to, and recovering from climate-related disasters will help to define the capacity to adapt to disasters and climate-related events. This approach has been widely recognized and adopted within the field of climate change adaptation across developing countries as a part of their response. This section describes a number of mechanisms that are adopted by people to cope with different types of disasters and, at the same time, to reduce their mental health problems due to natural disasters.

In Banda Aceh, Indonesia, after the December 2004 tsunami, victims were eager to return to normalcy, while external medical relief workers were still arriving in large numbers. A study showed that while youth feel stressed due to drought in Botswana, some of the coping mechanisms they adopt include taking up work in the capital city, engaging in sexual activities, and accepting that drought is an important characteristic of the climate in the country and the best method to cope is to train themselves to live with it (Babugura, 2008). Highly exposed survivors resorted to problem-avoidance, fantasy, self-blame, and sought assistance to cope with the Sichuan earthquake in 2008 (Xu and He, 2012). During power failures in Australia, elderly clients had often coped better with heat waves than younger people with neurological conditions, probably because of heat preservation techniques learned during the pre-air conditioning period. Some of the elderly people pretended to be ill, so they could seek refuge in air-conditioned hospitals (Hansen, Nitschke, Pisaniello, *et al*., 2011).

Numerous studies indicate the relevance of community support in helping people cope with disasters. A primary coping mechanism undertaken by people following the 2005 earthquake was to take up refuge with relatives in areas that either suffered less damage or those that were quickly stabilized (Hamilton and Halvorson, 2007). A factor that played a major role in avoiding negative mental health outcomes following floods was a rise in social cohesion such that people shared food with each other as there was a breakdown of caste barriers. While <1% people visited the traditional quack for mental health issues, drinking and dancing were taken up to deal with stress (Crabtree, 2013).

A study in Odisha, India, showed that people who were emotionally attached to the place, that is, genealogical rootedness, had strong emotional bonds and respect for ancestors, were alert to disasters that could potentially wreak havoc on their ancestral houses. People also helped their poor neighbors in reconstructing their houses after the cyclone. After cyclone "Phailin," people gave support and priority to the elderly, people with disabilities, and pregnant women in cyclone shelters (UNDP, 2015). Several factors helped people cope with the tsunami in 2004 in the Andaman and Nicobar Islands, including cohesive community, social support, altruistic behavior of the community leaders, and religious faith and spirituality. This was helpful in mobilizing people to help one another. In contrast to many disaster situations in South Asia, that show how women find it difficult to cope after natural disasters, this study showed that women were given priority with respect to social status, their safety, and security among the Nicobarese tribals (Math, Tandon, Girimaji, *et al*., 2008).

Some studies have observed the significance of mind-body practices in reducing the effect of mental stress. A study showed that mind-body practices (which include Tai Chi and Qigong, meditation-relaxation, mindfulness-based stress

reduction, and deep breathing) had positive effects on PTSD and depression (Kim, Schneider, Kravitz, *et al*., 2013). Another study showed that yoga proved useful in reducing sadness for victims of the Bihar floods (Telles, Singh, Joshi, *et al*., 2010). A study conducted on the survivors of the 2010 floods in Ladakh showed that only a handful had PTSD or MDD, and this was largely attributed to the social background and temperamental characteristics of the Tibetan culture (Ishikawa, Yamamoto, Yamanaka, *et al*., 2013).

4.2. Governmental Measures

Disaster preparedness prevents a surge in the local problems that health services normally handle. The immediate emergency response is provided under a highly political and emotional climate, and the responsibilities of the national or local health authorities are significant. The governments of various countries have introduced policies and programs for disaster management. The federal government in Brazil arranged for psychological assistance after a landslide in Rio-de-Janeiro (Pereira, Morales, Cardoso, *et al*., 2013). The Mental Health Support for Drought-Affected Communities initiative in Australia aims to provide crisis counseling to distressed individuals in rural areas that are drought-declared, in addition to training for clinicians and community leaders. It also aims to improve the capacity of communities to respond to psychological trauma resulting from droughts (Government of Australia, 2007). The Humanitarian Country Team assisted the Sri Lankan government in the provision of psychosocial support to children and teachers in schools, and women, to restore normalcy after floods. Other measures to restore normalcy besides mental health care support include improving access to food, water, and sanitation for victims (UNRCO, 2017).

Initiatives as part of the recovery and reconstruction plan after landslides included rebuilding of damaged health facilities and provision of psychosocial support. Priority activities encompassed early recovery psychosocial services (Government of Myanmar, 2015). In 2006, Substance Abuse and Mental Health Services Administration of the Health and Human Services department of the US government conducted 91,000 counseling sessions for victims of Hurricane Katrina. Catholic Charities USA, a charity which received over USD 146 million in donations, provided hurricane victims with food, housing, and mental health counseling (Wang, Gruber, Powers, *et al*., 2007).

The National Disaster Management Authority (NDMA) guidelines in India provide for emergency psychosocial first aid and evacuation of acute mentally ill persons that could be followed by activation of the Psychosocial Support and Mental Health Services response plan (NDMA, 2009b). Mental health experts were roped in by the administration to conduct counseling for survivors and relatives of victims affected by the landslide in Adivare, Maharashtra (Isalkar and Dastanel, 2014). Some studies have shown the usefulness of interventions providing mental health care support to survivors of natural disasters in India. A study done after the 2004 tsunami showed that people in Chennai, India, who received mental health support from trained volunteers, showed lower levels of depressive symptoms and psychological distress in contrast to people who did not get similar support (Vijayakumar and Kumar, 2008). An intervention that was initiated by NIMHANS in the wake of the 2004 tsunami was the stationing of teams of psychiatrists, social workers, and nurses, to provide support to survivors in Nagappattinam and Cuddalore in Tamil Nadu. This was done by providing training to local health-care providers and teachers who, in turn, trained 1200 community level workers who provided mental health care support to people. The study further advocated improvement in infrastructure and training with regard to the provision of psychosocial care (Becker, 2007).

5. Discussion

The widespread effects of natural disasters are well known. They affect not only the physical aspects of the environment but also the economy, social life, and well-being of populations (Gu, 2020). In addition to the loss of precious lives and economic losses, disasters affect the natural growth and mental health of the inhabitants to a great extent. It is often difficult to estimate the true scale of a disaster because physical damage is visible, but hidden damages could be much higher and affect the socioeconomic growth of the affected families and areas badly. There are some definite patterns that emerge in the aftermath of every disaster, which, if studied and understood well, can serve as an important pointer for the future. There is a growing need for public health practitioners and researchers to understand the health impacts of natural disasters. Our review critically documents several pathways for disasters to adversely affect mental health, particularly among vulnerable populations. As there is limited evidence available, we reviewed the literature on how disasters lead to poor mental health among the affected populations around the globe and try to conceptualize this in the Indian context. The review documents how increased frequency of disasters with climate change can lead to PTSD, adjustment disorder, and depression. Changes in climate and global warming may require populations to migrate, which can lead to acculturation stress. It can also lead to increased rates of physical illnesses, which secondarily would be

associated with psychological distress (Padhy, Sarkar, Panigrahi, *et al*., 2015). There is some evidence that individuals may suffer from post-traumatic stress through the impact of the disaster on their community, even if not individually impacted (Wind and Komproe, 2018).

Disasters affect the economy of countries as substantial damage is caused to infrastructure and the cost of recovery is high, given the increasing frequency of some natural hazards. People are uprooted from their homes and lose their livelihoods, and end up grappling with trauma, acute anxiety, depression, and suicidal thoughts (Parida, 2014). The review shows that with the wrecking of livelihoods, people find it difficult to secure alternate employment and the inability to cope with disasters and adapt, adversely affects their mental health. Natural disasters, especially heat waves, lead to an increase in morbidity, exacerbate physical illnesses, and cause heatstroke, making it difficult for informal sector workers to work during extreme heat wave conditions. Livelihood concerns were among the main reasons for developing symptoms of depression (Crabtree, 2013). Farmer suicides in recent decades are an important area of concern in the mental health arena. Given the increasing unviability of agriculture as an occupation and psychological problems that have emerged in recent years due to the livelihood impact of floods/cyclones, it is imperative to assess and further study the mental health impact of natural disasters on agriculture and other climate-sensitive livelihoods. It is also essential to improve infrastructure and facilities for mental health care besides strengthening programs for livelihood regeneration to avert suicides arising from indebtedness and loss of income sources.

The study clearly shows the psychosocial impacts of natural disasters, including sleep disturbances, flashbacks, helplessness insecurity, grief, uncertainty, depression, stress, PTSD, psychiatric disorders, trauma-related stress disorders, adjustment disorders, anxiety disorders, panic disorders, and abnormal behavioral patterns. Mental disorders that result from disasters are major challenges for public health and development (Stanke, Murray, Amlôt, *et al*., 2012). The fact that disasters have continued to affect countries severely shows that even though policies on climate change and disaster management have been introduced, they have not been entirely successful in curbing the severe effects of disasters. Some studies have observed the significance of mind-body practices in reducing the effect of mental stress (Kim, Schneider, Kravitz, *et al*., 2013; Telles, Singh, Joshi, *et al*., 2010). There is evidence which highlights inadequate facilities for mental health care (Channaveerachari, Raj, Joshi, *et al*., 2015), and the significance of interventions made to provide mental health care support in the aftermath of disasters (Vijayakumar and Kumar, 2008; Becker, 2007). Community mental health preparedness is important to find the most appropriate tool which will enable a suitable response when facing disasters. However, there is a lack of mental health preparedness in a majority of the countries; valid and reliable tools and context-bound programs should be developed based on the experiences and perceptions of the community (Roudini, Khankeh, and Witruk, 2017). There is a great need for long-term prospective studies on the effects of disasters and more interventional studies to find out the effectiveness of supportive measures provided to the victims. It is imperative to inculcate a mental health support system in the disaster response strategies in India (Kar, 2010).

The review shows that despite measures introduced by the government, mental health continues to be affected by disasters, and stronger measures need to be taken up. Boosting public education with regard to effects and aftereffects of disasters, mentally preparing people for natural outcomes, and improving public health surveillance to detect diseases and complications will add value to existing efforts. Giving special attention to mental health and post-disaster psychosocial rehabilitation will be an investment worth making. While rescue efforts are worthy of praise, recurrent disasters will warrant attention and care for all survivors well into the future. Psychological counseling needs to be facilitated in shelters/camps. Psychological and psychiatric care needs to be provided both in the immediate aftermath of disasters as well as for the long-term. Psychological first aid can be provided by field workers, including health workers, teachers, or trained volunteers, and does not always need mental health professionals. However, psychosocial teams (psychiatrist, psychologists, and psychosocial worker) may be needed for rapid psychosocial assessments and community-based psychosocial care and referral services in affected communities.

Post-disaster, rebuilding of an area, especially in relation to mental health, requires building emotional health of survivors through self-care; strengthening of families; supporting anganwadis, schools, colleges, and workplaces, to become places to promote mental health; creating caring communities from the Panchayat level; building resilience at the community level for long-term preparedness; and most importantly, to sensitize the administrative mechanisms toward the importance of mental health aspects, and coordination with the local authorities and policymakers (Chadda, 2018; Murthy, 2018). It is also important to understand that the psychological and mental health services and interventions are very much country- and culture-specific; therefore, any tailor-made intervention in one country may not be applicable in a similar disaster in other countries. For example, similar magnitudes of earthquakes in India and Iran would be two different contexts altogether; therefore, mental health and psychosocial services would certainly vary, although the core recovery

objectives and principles may remain similar and constant in both the countries. However, good intervention practices in one country may be adapted for the specific needs of another country's disaster-affected populations (Satapathy, 2012).

6. Conclusions

Given the current situation affecting most of the countries across the globe, and increasing concerns over the association between climate change and natural disasters, the linkages between natural disasters and mental health also becomes increasingly important. Globally, the prevalence of mental health issues is extremely high even without considering the added mental health consequences of a changing climate. While public awareness of the health implications of climate change and natural disasters continues to grow, the topic of mental health is frequently absent from this discourse. In some ways, this reflects the global discourse, where, in comparison to physical health, mental health, in general, has been neglected. There is a substantial body of literature on the topic that allows for the identification of several distinct and interrelated pathways by which disasters can adversely impact mental health, as well as several coping and adaptation strategies. Most of these relationships are mediated through environmental or socioeconomic pathways, and the outcomes most closely studied are PTSDs and, to a lesser degree, intimate partner violence and suicide. The associations between disaster exposure and adverse mental health outcomes have had large socioeconomic impacts. The mental health effects of climate change can be multifarious, direct or indirect, and short-term or long-term. Acute disaster events can act through mechanisms similar to that of traumatic stress, leading to well-understood psychopathological patterns.

This research is an initial step in bringing this important issue forward in the context of Sustainable Development Goals and outlining that better programs/guidelines need to be designed for prevention, services, and psychological counseling of mental health problems due to disasters. Longitudinal research will further help us understand the development of disaster-related mental health problems and develop adequate mitigation strategies to confront the increasing numbers of disaster-affected individuals with mental health problems. Moreover, an important step can also be to focus on social capital mechanisms, which can intentionally be promoted with beneficial effects on disaster mental health outcomes. Psychosocial interventions should be culturally applied to local survivors. In addition, the national mental health program should be integrated or linked to other government programs and departments, such as health programs, disaster mitigation programs, revenue department, and other allied programs so that the affected people can benefit and receive the services immediately without delay and live a dignified life free of mental health issues.

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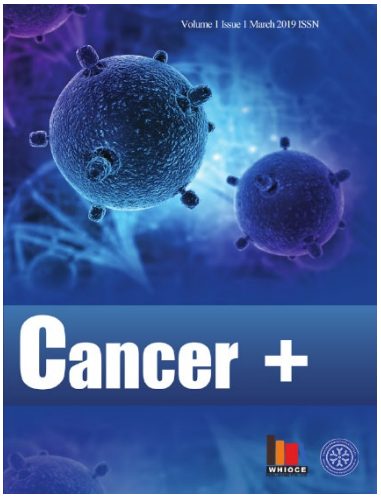

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