

Escalating Global Threat of Heatwaves and Policy Options for Adaptation and Mitigation

Muhammad Rafique Khan¹, Muhammad Abubakar², Ayesha Tahir³, Muhammad Waqas Dilawar⁴, Hafiz Muhammad Ali Hassan⁵, Sajid Rashid Ahmad⁶, Faseeha Saif⁷ and Muhammad Umair Chand⁸

<https://doi.org/10.62345/jads.2024.13.3.80>

Abstract

This study evaluates the effects of intense and frequent heatwaves on human health, food security and infrastructure all having a direct bearing on sustainable development. It emphasizes that health issues such as cardiac and respiratory disorders, strokes, and mental health diseases are aggravated in harsh climates. This study focuses on the adverse implications of hot weather and the impact of said phenomenon on various fields of life. The aftermath of the excessive burning of fossil fuels and the emission of greenhouse gases have severely impacted the world by disrupting the economic stability of many countries around the globe. The heat waves are also responsible for low crop yield, fertilizer shortage and adverse impact on livestock. The intense and hot weather has not only caused power outages but also challenged infrastructure sustainability. The continuous usage of cooling systems is leading to urban heat islands adding more heat in the environment. This study highlights the challenges of climate change and brings attention to the need for sustainable development and practices to ensure proper heat management. After a deep insight into information and responses collected for the research, the study suggests some recommendations requiring all stakeholders including policymakers, implementing agencies, organizations and civil society to play their crucial role in devising and implementing suitable policy options and practices for adaptation and mitigation of climate change factors.

Keywords: Heat Waves, Emissions, Health Issue, Global Warming, Urban Heat Islands.

Introduction

Climate change impacts have become so pronounced that climate change has attained a definitive place in the global agenda and has emerged a new discipline in natural sciences. The effects and risks of global warming have become apparent during the last two decades

¹PhD Scholar in Environmental Sciences, College of Environmental Science, University of the Punjab, Lahore.

²PhD Scholar, College of Earth and Environmental Science, University of the Punjab, Lahore.

Corresponding Author Email: muhammadabubakar704@gmail.com

³MPhil Scholar, Department of Sociology and Criminology, University of Sargodha, Sargodha.

⁴Institute of Metallurgy and Materials Engineering.

⁵University of Engineering and Technology, Lahore.

⁶Professor, College of Earth and Environmental Science, University of the Punjab, Lahore.

⁷Lecturer, Lahore College for Women University, Lahore.

⁸IAS, University of the Punjab, Lahore.



[Intergovernmental Panel on Climate Change (IPCC), 2024]. The severity of greenhouse emissions and burning of fossil fuels are having a terrible impact on the planet's atmosphere. The greenhouse gases get trapped into the atmosphere causing global warming, which in turn increases the heat leading to extremely high temperatures, triggering the glaciers and ice caps to melt and raising the global water levels. The average global temperature has already increased by 1°C (USGCRP, 2018).

The urbanized areas absorb more heat as compared to natural landscapes because of the infrastructure such as roads, buildings and residential areas that absorb more sun's heat. It creates an "island" effect, consequently raising the temperature. In the daytime, the temperature rises to 1-7°F as compared to outlying areas, while during the night, the temperature is 2-5°F higher than outlying areas (US-EPA, 2024). Moreover, El Niño and La Niña are climate patterns in the Pacific Ocean that are responsible for affecting weather worldwide. The El Niño and La Niña can both have global impacts on weather, wildfires, ecosystems and economies. The extreme and intense heat has resulted in various changes in the global weather patterns, causing unprecedented floods, droughts and heat waves. A significant decrease is witnessed in mountain glaciers, causing irreversible damage. If the average temperature of earth continues to increase, it will have devastating effects globally. Further, combined with heavy rainfall, the glaciers will be lost resulting in severe floods (Huber et al., 2024).

The 2022 flood in Pakistan and the 2023 heat wave in south Asia are evident of how climate change is affecting the human population, agriculture and infrastructure on a large scale. The 2022 heatwave is estimated to have caused approximately 90 deaths across India and Pakistan and have triggered an extreme outburst flood in northern Pakistan which resulted in economic losses of billions of dollars, and displaced millions of people from their homes. In Southeast Asia, the heat wave is hardest for daily wagers, as it limits their working capacity because of heat stress (World weather attribution, 2024).

Additionally, the 2022 heat wave in Pakistan also affected the agricultural sector, where a significant loss in the production of wheat was found as compared to previous years. Besides this, there was a global shortage of fertilizers (United States institute of peace, 2023). Studies suggest that heat stress is one of the main factors of long-term migration of men, predominantly having negative effect on their income (United States institute of peace, 2023).

Furthermore, extreme heat waves are responsible for aggravating violence, because high temperature have a negative impact on human body, emotional intelligence, comfort and ability to decide leading to "fight or flight" position, (United States Institute of Peace, 2023).

The south Asian region is the most susceptible to climate change but ironically, India, the most populous country in the world and geographically the largest country in the region, is itself third largest emitter of planet warming gases (Arasu, 2023). It is widely assumed that the human body can adapt to temperature, but studies show that after a certain level is reached, the human body is unable to perspire. When the heat is trapped in the body, it ends up heating the body causing health problems (Climate energy solution center, 2023). It is generally said that an increase in temperature over 6°C would have disastrous and uncomprehensible consequences for humankind and economy (Sherwood & Huber, 2010).

Heat stress is one of the leading causes of deaths. A hot day might alter the lifestyle and work progress of a person, thus hindering productivity. These impacts are likely to worsen in warmer climate (Sherwood & Huber, 2010). The average global temperature is expected to rise by the end of 21st century. Several findings and reports suggest that a 4°C rise in temperature would result in the elimination of nearly all the world's glaciers (Perkins, 2013). The circumstances,

thus warrant to do a comprehensive analysis of the factors and impacts of heatwaves and suggest appropriate measures for adaptation and mitigation of climate change challenges in the subject area.

Heatwaves Impacts

In most parts of the earth, the temperature is rising, and the southern part of Asia is no exception (IPCC 2013). More than 2000 people died within a week in Spain and Portugal because of the deadly heat waves in Europe (Saric et al., 2022). Further, according to the World Meteorological Organization (WMO), the heat waves will become more frequent in the mid-21st century (Europe WMO-WHO, 2022). A minimum of 22 countries have recorded maximum temperature of 50°C (122F) or above over a span of two years (AJLabs, 2023). As the temperature of earth increases with the passage of time, increase in frequency and intensity of extreme weather events is expected.

The Earth's temperature has risen by about an average of 1.1°C since the 1880s. The 2015 Paris agreement sheds light on how a 0.5°C rise in temperature can have devastating impacts on earth. Various global studies and findings have suggested that the south Asian region is most susceptible to climate change as compared to other regions of the world.

Extreme Temperature and Health Risks

Heatwaves are a phenomenon related to exceptionally high temperatures which can cause severe illness and can result in mortality. On the other hand, when the relative humidity is combined with air temperature, then the temperature felt by a human body is considered as heat index (HI). It is very crucial for the human body as when the temperature is relatively high, it becomes difficult for the body to cool down. Relative humidity is inversely proportional to the rate of evaporation. That is why when humidity increases, the body becomes warm because it is unable to cool itself down as the rate of evaporation decreases (NOAA's, 2024).

Thousands of deaths are caused due to extreme weather. Hot weather makes it difficult for the human body to keep its temperature at normal level and consequently, puts extra strain on lungs and kidneys. In case of cardiac problems, risk of suffering from heatstroke increases in extreme weather (Kovats & Hajat, 2008; Borden & Cutter, 2008). Analysis shows that more than 600,00 people died due to climate related conditions in developing countries since 1991. Developing countries are more susceptible to facing the effects of extreme weather whereas the developed countries' emissions are the main causes of climate change (Baker, 2023). The summer 2003 European and France heatwaves are a case in point wherein more than 70,000 people died in Europe and 15,000 deaths in France due to heat waves (Depietri et al., 2011). The International Federation of Red Cross and Red Crescent Societies (IFRC) said that the Heatwaves are "*an invisible killer*".

The global impact of heatwaves has been explained in **Figure 1** and **Figure 2** that shows 476,975 people were affected and 157,320 died in 143 events with average of 3335 and 1100.13 people affected and died per event respectively due to heat waves during 2000-2020 (Donatti et al., 2024).

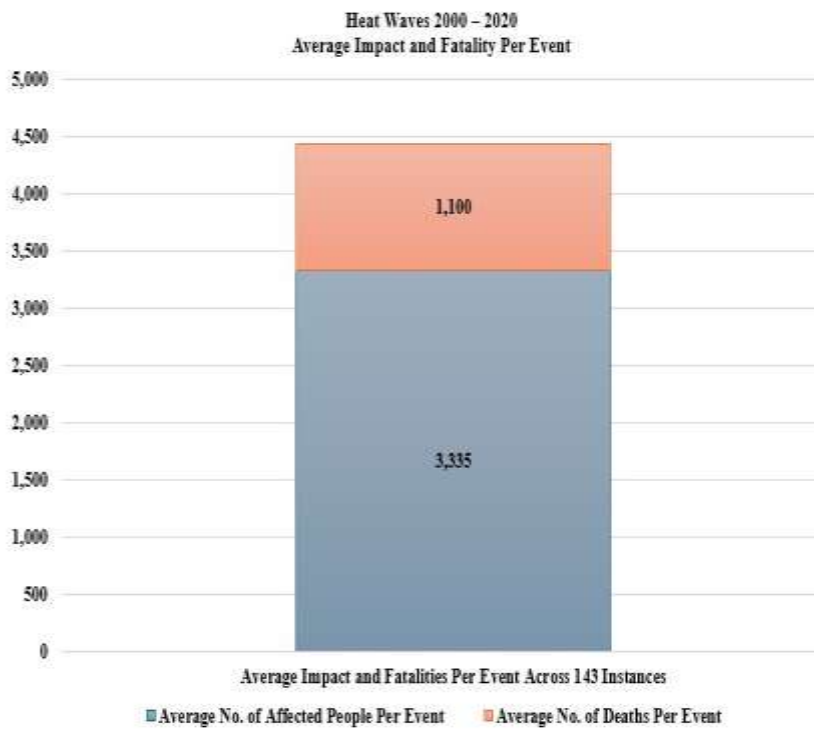


Figure 1 Average Impact per Event of Heatwaves

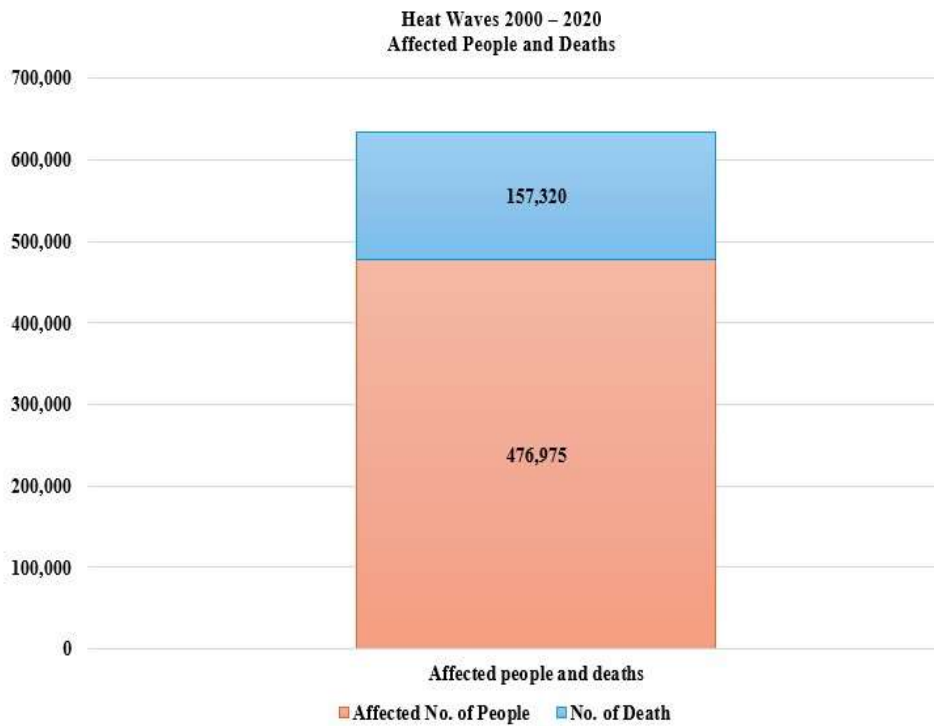


Figure 2 Global Impact of Heatwaves

Figure 3 depicts estimates of annual deaths due to extreme temperatures among different age groups as below:

- Heat related deaths (hot or cold exposure) under age 5: 1,802
- Heat related deaths (hot or cold exposure) from age 5-14: 1,402
- Heat related deaths (hot or cold exposure) from age 15-49: 13,570
- Heat related deaths (hot or cold exposure) from age 50-69: 16,677
- Heat related deaths (hot or cold exposure) above age 70: 14,620 (Ritchie et al., 2024).

Annual Deaths Among Different Age Groups Due to Extreme Temperature

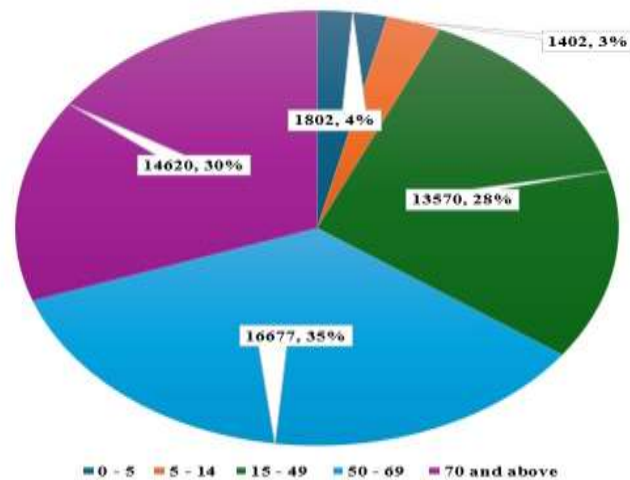


Figure 2 Estimates of Annual Deaths due to Extreme Temperature

Heatwaves Impact on Economy

The European Environment Agency estimates that heatwaves cost \$71 billion in 32 European countries between 1980 and 2000. The International Labor Organization (ILO) estimates that heat waves cost between 5% and 15% of GDP growth worldwide. It estimates it could reduce working hours by more than 2% by 2023. That is the equivalent of 80 million full-time jobs at a cost of \$2.4 trillion, almost ten times the figure in 1995 (Zachariah et al., 2022).

Economic losses due to climate change in 2023 are 800 million US dollars. Financial loss from heat waves is \$5.6 billion in 2021. The average loss between 2001-2020 is \$3.1 billion (Cred, 2023). while previously, it was considered that an increase in average temperature is affecting the global economy (Dell et al., 2012; Burke et al., 2015). However, recent findings suggest that rain and drought are also crucial factors in determining the overall economic condition of a geographical area (Waidelich et al., 2024).

Agriculture

High temperatures do affect agriculture leading to food insecurity. Extreme temperatures can negatively impact the growth of plants (Climate Energy Solution Center, 2023). Heat waves also impact the livestock. Cows suffering from heat stroke may face issues of retarded growth and decreased milk production (Das et al., 2016). Additionally, the high evaporation rate because of extreme heat makes it difficult for the farmers to irrigate crops, and it may end up resulting in a decrease in crop production (Global Water Forum, 2018).

Energy

High temperatures can affect energy sector in many ways, including production, transmission, and supply. In summer season, there is an increase in electricity demand for cooling purposes, but since the ability to transmit electricity is reduced in high temperatures, it results in frequent power outages and blackouts (Climate Energy Solution Center, 2023).

Climate Related Disasters in Pakistan

Climate change is one of the major challenges for Pakistan. Despite Pakistan's minimal contribution to global greenhouse gas emissions, it remains highly vulnerable to extreme climatic conditions. Changes in weather patterns over the past two decades in Pakistan, have severely impacted the lives of people and environment, as Pakistan is the 5th most vulnerable country.

The magnitude of the floods 2022 in Pakistan surpassed the infamous floods of 2010, when approximately one-third of the country was submerged, the lives of 33 million people were directly impacted, nearly 8 million were forced to flee their homes in search of safety, and left a trail of destruction (NDMA Annual Report, 2022)

The 2022 Pakistan heatwave was an extreme weather event which resulted in the hottest March. The unusual extreme weather occurred in the beginning of year and lasted till April of said year, affecting vast areas of Pakistan. Several cities recorded temperature as high as 47°C and 49.5°C. On May 14, the temperature of Jacobabad reached 51°C which set a global heat record for 2022 (Harvey, 2024).

There were 74 extreme weather events reported in Pakistan during the period 2000 – 2020 wherein 50,888,559 people were affected with an average of 687,683 people impacted per event (Yadav et al., 2023).

Climate change has also impacted Pakistan's economy. According to the report of Pakistan's Finance Ministry, severe floods in 2022 caused damage worth US\$ 30 billion. However, the United Nations' claim for humanitarian compensation is only \$472.3 million, accounting for only 1% of the actual damage, and only 19% is funded. Approximately 33 million people were also displaced. However, this number is not enough to help them (Baker, 2023). In addition, climate change also affects agriculture and construction businesses. According to the International Labor Organization (ILO), heatwaves will reduce the world's working hours by 2% in 2030, equivalent to 80 million full-time jobs, with losses reaching US\$2.4 trillion (ILO, 2024).

Pakistan has a robust legal and regulatory framework to combat climate change challenges and to ensure safe and sustainable environment. Pakistan has taken several significant steps to address climate issues. Foremost among them is Climate Change policy 2012, which was updated in 2021 accompanied by framework for implementation of climate change policy (2014-2030). National Clean Air policy was developed in 2023 for improvement in air quality, in addition to National Electric Vehicle (EV) Policy 2019 and Alternative and Renewable Energy policy, 2019. Moreover, provinces have also adopted legal and regulatory framework in line with the framework adopted by the Federal Government.

Current and Future Trends of Extreme Temperatures

According to the World Meteorological Organization (WMO), heat waves will be experienced more frequently in the 2060s (WMO, 2022). This is because the earth's temperature is increasing rapidly. By the end of the century, the temperature will increase by 0.5°C, from 1.5°C to 2.0°C and due to this increase, the period of heat waves will increase by 1/3 times. The oceanic storms will increase by one-third as well. Sea levels will rise at an alarming rate, and coral reefs will be at risk of severe degradation. The rise of 1°C is unavoidable because of a lack of proper action plans over the past ten years. Last year, the Northern Hemisphere's

summer was the hottest since 2000 (Esper et al., 2024) and January 2024 was the hottest in Earth's history (Copernicus, 2024).

Additionally, February 2024 is considered the warmest February in the ERA Five record, which dates to 1940. The same goes for March and April (Copernicus, 2024). A large warming zone is almost through at the end of the 21st century (Roxy et al., 2024).

A change in annual mean global temperature was detected two decades ago and a decade ago, trends in regional seasonal mean temperature similarly started to appear. Presently, we're also seeing trends in weather extremes (World Weather Attribution, 2024). According to the Intergovernmental Panel on Climate Change (IPCC), the global temperature is expected to increase by 1.5°C by 2052. This increase in temperature will result in more severe and frequent weather changes, which will have catastrophic effects (Arctic ice project, 2023). Since 1850, the year 2023 was the hottest. High temperatures recorded in recent years have resulted in extreme events such as heatwaves in South America, drought in South Africa, and flooding in Dubai in the year 2024 (Japan International Research Center for Agricultural Sciences, JIRCAS, 2024). In both the southern and northern hemispheres, large geographical areas were hit by hot extremes earlier than usual in 2023. Such extreme temperatures resulted in the reduction of the spring season. Because of changes in weather conditions, the Northern Hemisphere is hit with highly harsh winters (Zhang et al., 2024). A region across the Sahel and West Africa experienced severe heat, with temperatures in the Sahel reaching more than 45°C at the end of March and at the beginning of April 2024 (World Weather Attribution, 2024). By the 22nd century, the average global temperature is expected to rise within a range of 0.5°F to 8.6°F, which will result in the warming of Earth at least twice as much in the next 100 years as it has during the last 100 years (US EPA, 2024).

The objective of this research is to examine the impact of heatwaves on human health, agriculture and economy and to determine the role of climate change in driving the increasing frequency, severity, and duration of heat waves. This endeavour will also suggest some policy options for adaptation and mitigation to deal with the factors and impacts of climate change including heatwaves.

Methodology

To have a fair analysis of heatwaves impact both quantitative and qualitative approaches were adopted. For this purpose, primary as well as secondary data was used.

Quantitative Data

Quantitative data was collected through a survey consisting of 18 multiple-choice questions encompassing different aspects of climate change and heatwaves including main factors causing heatwaves in Pakistan; their effects on human health, agriculture and economy; government responses to combat heatwaves and long-term policy options to adapt and mitigate impacts of heatwaves. A survey on Google form was created and circulated via a shareable link. A total of 155 responses were collected. To ensure representation of different regions of the country responses were collected from different segments of population living in different cities of Pakistan. In order to gauge fair impact of heatwaves well-informed youth and farmers were also included in the data sample. This survey was conducted over a period from May 2 to May 31, 2024.

Qualitative Data

To explore multifarious dimensions of heatwaves and its impact on society and economy qualitative data was collected through in person interviews with different segments of society including farmers and construction workers to gain deeper insights into personal experiences and heatwave-related issues. They were asked, inter alia, to share their experience and views regarding extreme weather events, their impacts on human health, livestock, crops, power outages, adequacy of government responses and harsh weather's impact on their daily life and working. Interviews were conducted over a period from May 26 to May 31, 2024.

Table 1: Demographic Profile of Respondents

S. No	Demographic Characteristics	Frequency
1.	<u>Age</u>	
	15-20	65
	20-25	63
	25-30	7
	30-35	7
	35-40	5
	40 & above	10
2.	<u>Gender</u>	70
	Male	86
	Female	
3.	<u>Provinces</u>	
	Punjab	131
	Sindh	5
	KPK	20
	Balochistan	0
4.	<u>Living Area</u>	
	Urban	126
	Rural	30
5.	<u>City</u>	
	Gujranwala	37
	Bahawalpur	55
6.	<u>Study Program</u>	
	BS	30
	MS/M.Phil.	5
	PHD.	10

Results and Discussion

The results of in-person interviews with farmers and construction workers are discussed in the following paragraphs.

Unpredictable Weather

When asked about the unpredictable weather conditions, R1 said that he had witnessed unexpected and untimely rains in recent years which affected agricultural crops adversely and reduced his crop produce.

Health Issues

Heat waves are also responsible for various health-related issues. Working in scorching heat affects the well-being of farmers. R2 said "compared to previous years, this year's heat is more intense, and our work also involves exposure to sunlight, which sometimes leads us to face various health issues." Another respondent responded by saying, "once, I became unconscious while irrigating my fields due to the heat."

Effect on Livestock

The heat has an effect not only on farmers but also on livestock. They face several issues because of extreme temperatures. R3 responded that he had eight animals and last year, one of his buffaloes died during the summer due to scorching heat. Furthermore, R4 responded, "I am involved in the dairy business. Due to the heat, animals produce less milk."

They also mentioned that during the hot season, animals have stopped eating fodder or eat very little of it. In hot season, farmers have to give their animals buttermilk, mustard husk, and chickpea flour to prevent them from falling ill. Another respondent showed concern over the government response regarding the safety of livestock. He said, "a few years ago, the government initiated a program to vaccinate animals against various diseases, however, this year, it was discontinued. The government should establish hospitals for animals."

Electricity Concerns

There is an apparent connection between heat waves and power outages, as extreme heat results in overconsumption of electricity, and consequently, power outages and electricity shortages occur, which also affect the farmers and construction workers. Moreover, this might also increase the risk of deaths during blackouts (Stone et al., 2023). R5 said, regarding to power supply, "we use motor pumps to irrigate our crops. However, if there's a power outage, it results in untimely irrigation, leading to crop damage." Another respondent said, "due to the extreme heat, crops require more frequent irrigation, increasing water usage and energy costs for farmers."

Effect on Crops

Although hot weather is required for some crops to grow optimally, like okra, eggplants, and melons, however, extreme heat is damaging for several crops, and it results in the loss of gross crop production (Lu & Kueppers, 2015). This can lead to food shortage. R6 said that, "last year, by this time, we had irrigated our crops twice, and the quality was excellent. However, this year, we have irrigated five times, and the crops have still not grown properly."

Impact on Construction Workers

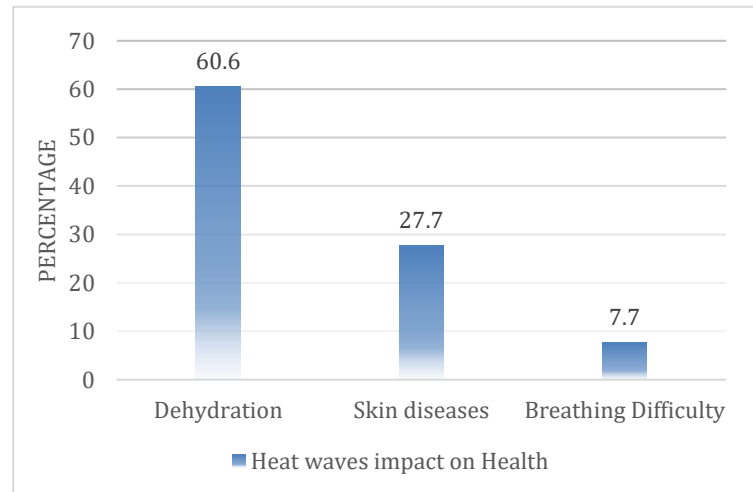
While talking to the construction workers about the heat waves and extreme weather, several workers responded that it was tough for them to work. During the scorching heat of June and July, the construction workers work less as compared to in winter. In order to tackle the heat, they use lemonade and cold water to keep themselves cool. A respondent said that many workers who work in the hot season become victims of multiple diseases because of scorching heat.

Table 2: Results of responses received from 155 respondents regarding the growing threat of heatwaves.

SR#	Growing Threat of Heat Waves	Percentages
1. Main factors causing severe Heatwaves in Pakistan		
	Climate change	37.4%
	Urbanization	16.1%
	Deforestation	45.8%
2. Heatwaves effects our health		
	Causing dehydration	60.6%
	Skin diseases	27.7%
	Difficulty in breathing	7.7%
3. Heatwaves increasing throughout years		
	Yes	91%
	No	5.8%
4. Government response to Heatwaves threats		
	Public awareness	68.4%
	Improve healthcare	16.1%
	Early warnings	12.3%
5. Long-term solutions to mitigating impacts of Heatwaves		
	Adopting renewable resources	27.7%
	Improving urban planning and infrastructure	37.4%
	Raising public awareness	30.3%

Table 2: Summary of Survey Responses

According to data collected from various areas of Pakistan, it is evident that heat waves have impacted people very badly in recent years resulting in many problems like skin diseases, dehydration, and respiratory disorders. 60.6% of the respondents replied that severe dehydration occurs during the period of intense heatwaves in June to August.

**Figure 3 Heatwaves Impact on Health**

According to the survey, most people consider heatwaves are increasing because of climate change, urbanization, and deforestation. 37.4 % of respondents think that heatwaves are

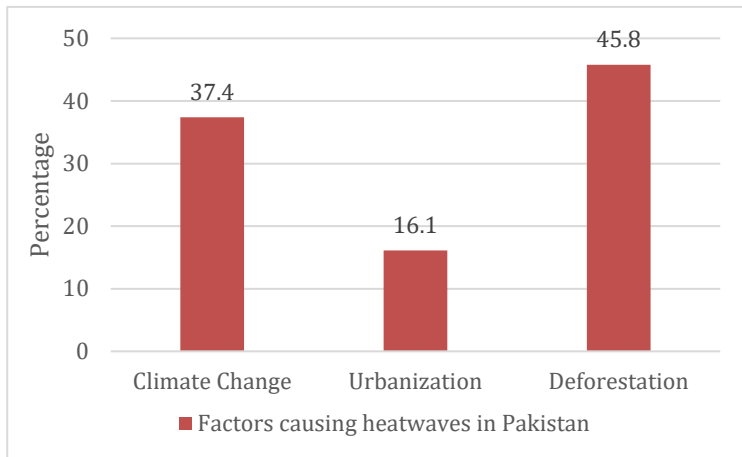


Figure 4 Factors causing Heatwaves in Pakistan

awareness is a long-term solution to mitigate impact of heat waves.

because of climate change whereas 16.1 % and 45.8 % respondents are of the view that main cause of heatwaves is urbanization and deforestation respectively.

Further, 27.7 % respondents think that adopting renewable resources are a long-term solution to mitigate impacts of heatwaves whereas 37.4 % are in favour of improving urban planning and infrastructure and 30.3 % think that raising public

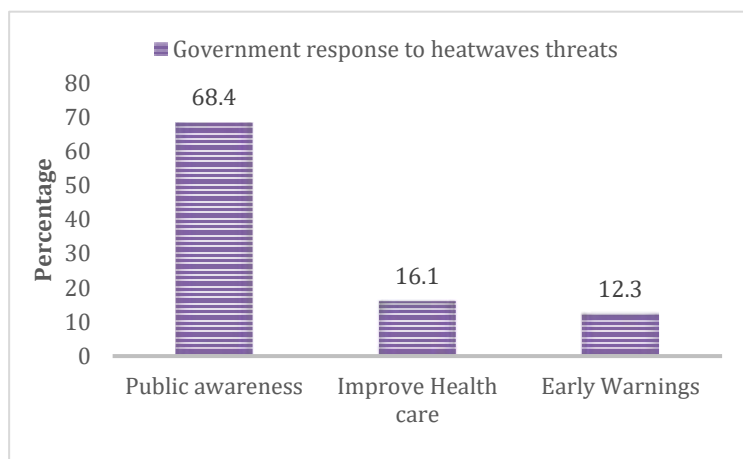


Figure 5 Government Responses to Heatwaves Threat

As far as government's response to heatwaves threat is concerned 68.4 % respondents are of the opinion that government should run public awareness campaign while 16.1 % consider improving healthcare as a viable option and 12.3 % think that government should issue early warning about upcoming heatwaves.

It can be concluded from the survey that:

- High temperatures and heat waves cause health problems, such as cardiac diseases and respiratory problems, etc.
- Extreme weather events such as heat waves and drought badly impact the agriculture sector, resulting in low crop production and a food shortage.
- The livestock suffer from heat waves, consequently leading to death of animals and low milk and meat production.
- Cost of doing business gets increased due to power outages, reduced working hours, and supply chain disruptions.

Conclusion

Heat waves are a threat globally, as everyone is being affected by intense heat and extreme temperatures. Burning of fossil fuels and carbon emissions, especially from developed countries, are causing climate change in other parts of the world. The changes in the climate patterns over the past two decades have severely impacted the overall economic conditions of countries, as several climate-related disasters are taking a toll on the country's economy. The unprecedented rainfalls, storms, earthquakes, and floods have resulted in the loss of billions of dollars, with millions of people being displaced from their houses and thousands of people losing their jobs because of harsh weather conditions. The heat waves have badly affected the South-Asian region of the world, as the countries here are most vulnerable to climate change. The catastrophic flood of 2022 in Pakistan and the heat wave of 2023 in Pakistan and India are perfect examples of how climate change is affecting countries devastatingly. Many people are directly or indirectly suffering from intense heat and high temperatures. The heat waves are causing severe health problems like cardiac issues and breathing disorders in people. During the hot summer season, people suffer from heat stroke. The heat is not only affecting individuals, but it is also affecting other fields of life such as agriculture, and economy. Livestock and animals are also suffering from the deadly effects of heat waves. With the average temperature of the world increasing, these consequences are unavoidable. Therefore, governments all over the world should take proper initiatives to minimize the harmful effects of intense heat. The governments should develop national action plans to tackle the deadly heat waves to protect the people from its devastating effects. There is need to take measures to save the environment from further degradation. A sustainable approach to the environment, by using proper management and usage of resources, will make the planet livable.

Recommendations

The government should encourage development of new varieties of seeds and crops which are heat resistant, drought tolerant, high yielding, and less vulnerable to climate change.

There is a need for introduction and development of better breeds of livestock which are less prone to heat waves and have high milk and meat productivity.

Heatwaves can have devastating effects on human health if precautionary measures are not taken. Therefore, public awareness campaign should be launched to educate the general public and train health care personnel about heatwaves related health issues and precautionary measures to be taken to deal with the threat of heatwaves, in addition to ensuring adequate supply of good quality medicines, vaccines and safe drinking water to the general public particularly during heatwaves.

Another policy option for mitigating the threat of heatwaves is to initiate and vigorously pursue reforestation and afforestation programs. Moreover, people should be educated about the significance of forests in mitigating heat waves through awareness campaigns run by media and multinational companies under corporate social responsibility. Furthermore, laws and regulations banning illegal forest cutting, illegal trade in timber and prohibiting conversion of forest land into non-forest uses should be introduced and enforced.

To prevent the effects of intense heat and urban heat islands, green spaces like green roofs and vegetation around buildings should be developed in cities to reduce the heat emitted from buildings.

Reliance on non-renewable energy resources is harming the environment. Instead, hydro power generation and renewable energy sources should be given preference to reduce carbon

emissions. Moreover, ways and means should be devised to safely transition from non-renewable to renewable energy sources like solar energy, wind power, and geothermal energy by promoting renewable energy technologies, developing infrastructure to ensure home solar installation by providing net metering.

Similarly, mitigating options for transport sector include the promotion of mass transit system and fuel-efficient public transport system. Moreover, public awareness campaign should be launched for ensuring proper vehicle maintenance for reduction in emissions and fuel efficiency. Electric vehicles should be promoted through the development of required infrastructure and provision of incentives. Furthermore, government should focus on transit-oriented development, thereby reducing GHG emissions.

Energy efficiency should be improved in buildings through standardization of building and construction codes. A proper ventilation system should be introduced to reduce the usage of air conditioners, which will reduce the emission of CFCs in return for radiant cooling. Moreover, building designs with better insulation and maximum use of natural light should be promoted. Finally, capacity of disaster management institutions and coordination among them should be enhanced to deal with extreme weather events such as heat waves.

Implementing the above recommendations will not only mitigate the impact of heat waves but also enable individuals and communities to adapt to heat stress leading to healthier population, food security, economic growth, and sustainable development.

References

- Arctic Ice Project. Arctic Ice Project. https://www.arcticiceproject.org/climate-interventionnecessity/?gad_source=1&gclid=Cj0KCQjw9vqyBhCKARIsAIIcLMHbQj95TeSjsNs_hLQbAB-024-01990-8_1W8xrLHuvOxIRfvUhY9iAIEK3EBvwzwLUaAqGuEALw_wcB
- AJLabs. (2023). Mapping the hottest temperatures around the world. *Al Jazeera*. <https://www.aljazeera.com/news/2023/7/5/what-is-the-highest-temperature-ever-recorded-in-yourcountry-2>
- Allianz, (2024)./ *Global boiling: Heatwave may have cost 0.6pp of GDP*. Allianz.com.
- Arasu, S. (2023). *Heat wave in Asia made 30 times more likely because of climate change, scientists say* / AP News. AP News. <https://apnews.com/article/climate-change-heat-wave-south-asia-indiabangladesh-laos-thailand-9343bb3fafbbd1ca737129d43a2574f6>
- Arctic ice project. (2023). *The Necessity of Climate Intervention: Why immediate action is critical*
- Baker, P. (2023). *189 million people per year affected by extreme weather in developing - - Oxfam Canada*. Oxfam Canada. <https://www.oxfam.ca/news/189-million-people-per-year-affected-byextreme-weather-in-developing-countries-as-rich-countries-stall-on-paying-climate-impact-costs/>
- Borden, K. A., & Cutter, S. L. (2008). Spatial patterns of natural hazards mortality in the United States. *International Journal of Health Geographics*, 7(1), 64. <https://doi.org/10.1186/1476-072x7-64>
- Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, 527(7577), 235–239. <https://doi.org/10.1038/nature15725>
- Center for Climate and Energy Solutions. (2023). *Heat Waves and Climate Change - Center for Climate and Energy Solutions*. <https://www.c2es.org/content/heat-waves-and-climate-change/>
- Center for Climate and Energy Solutions. (2023, July 14). *Heat Waves and Climate Change*. <https://www.c2es.org/content/heat-waves-and-climate-change/>

- Chauhan, S. S., Zhang, M., Osei-Amponsah, R., Clarke, I., Sejian, V., Warner, R., & Dunshea, F. R. (2023). Impact of heat stress on ruminant livestock production and meat quality, and strategies for amelioration. *Animal Frontiers*, 13(5), 60–68. <https://doi.org/10.1093/af/vfad046>
- Climate Analytics. (2015). *Global warming reaches 1°C above preindustrial, warmest in more than 11000 years*. Climate Analytics. <https://climateanalytics.org/publications/global-warming-reaches-1cabove-preindustrial-warmest-in-more-than-11000-years>
- Climate Analytics, (2023). *Feasibility of limiting warming to 1.5 and 2°C*. (2023, December 7). <https://climateanalytics.org/publications/feasibility-of-limiting-warming-to-15-and-2c>
- Copernicus, (2024). *Warmest February on record, the 9th consecutive warmest month*. (n.d.). Copernicus. <https://climate.copernicus.eu/warmest-february-record-9th-consecutive-warmestmonth>
- Copernicus, (2024). *Warmest January on record, 12-month average over 1.5°C above preindustrial*. (2024). Copernicus. <https://climate.copernicus.eu/warmest-january-record-12-month-averageover-15degc-above-preindustrial>
- Copernicus. (2024). *Global temperature record streak continues - April 2024 was the hottest on record*. (2024). Copernicus. <https://climate.copernicus.eu/copernicus-global-temperature-recordstreak-continues-april-2024-was-hottest-record>
- Copernicus. (2024). *March 2024 – 10th consecutive record warm month globally*. (2024). Copernicus. <https://climate.copernicus.eu/march-2024-10th-consecutive-record-warm-monthglobally>
- Cred. (2023). *Annual reports*. <https://www.emdat.be/categories/adsr/>
- Das, R., Sailo, L., Verma, N., Bharti, P., Saikia, J., Imtiwati, N., & Kumar, R. (2016). Impact of heat stress on health and performance of dairy animals: A review. *Veterinary World/Veterinary World*, 9(3), 260–268. <https://doi.org/10.14202/vetworld.2016.260-268>
- Dell, M., Jones, B. F., & Olken, B. A. (2012). Temperature Shocks and Economic Growth: Evidence from the Last Half Century. *American Economic Journal. Macroeconomics/American Economic Journal, Macroeconomics*, 4(3), 66–95. <https://doi.org/10.1257/mac.4.3.66>
- Depietri, Y., Renaud, F. G., & Kallis, G. (2011). Heat waves and floods in urban areas: a policyoriented review of ecosystem services. *Sustainability Science*, 7(1), 95–107. <https://doi.org/10.1007/s11625-011-0142-4>
- Donatti, C. I., Nicholas, K., Fedele, G., Delforge, D., Speybroeck, N., Moraga, P., Blatter, J., Below, R., & Zvoleff, A. (2024). Global hotspots of climate-related disasters. *International Journal of Disaster Risk Reduction*, 104488. <https://doi.org/10.1016/j.ijdr.2024.104488>
- Esper, J., Torbenson, M., & Büntgen, U. (2024). 2023 summer warmth unparalleled over the past 2,000 years. *Nature*. <https://doi.org/10.1038/s41586-024-07512-y>
- European Environment Agency's. (2023). *Economic losses from weather- and climate-related extremes in Europe*. (2023). European Environment Agency's Home Page. <https://www.eea.europa.eu/en/analysis/indicators/economic-losses-from-climate-related>
- European Geosciences Union (EGU). (2016). *1.5°C vs 2°C global warming – new study shows why half a degree matters*. <https://www.egu.eu/news/230/15c-vs-2c-global-warming-new-studyshows-why-half-a-degree-matters/>
- Global Water Forum, (2018). *June-July heatwave makes global impact on water*. (2018, October 8). Global Water Forum. <https://www.globalwaterforum.org/2018/10/08/june-july-heatwavemakes-global-impact-on-water/>
- GoP. (2022). *Ministry of Finance, Government of Pakistan*. https://www.finance.gov.pk/survey_2022.html

- Harvey, C. (2024). *Astonishing heat grips India and Pakistan*. Scientific American. <https://www.scientificamerican.com/article/astonishing-heat-grips-india-and-pakistan/>
- https://www.allianz.com/en/economic_research/insights/publications/specials_fmo/globalheatwave-implications.html
- <https://www.ilo.org/resource/news/increase-heat-stress-predicted-bring-productivity-loss-equivalent-80>
- <https://www.worldweatherattribution.org/extreme-sahel-heatwave-that-hit-highly-vulnerable-population-at-the-end-of-ramadan-would-not-have-occurred-without-climate-change/>
- https://www.worldweatherattribution.org/wp-content/uploads/India_Pak-Heatwave-scientificreport.pdf
- Huber, C. J., Eichler, A., Mattea, E., Brüttsch, S., Jenk, T. M., Gabrieli, J., Barbante, C., & Schwikowski, M. (2024). High-altitude glacier archives lost due to climate change-related melting. *Nature Geoscience*. <https://doi.org/10.1038/s41561-023-01366-1>
- Intergovernmental panel on climate change, (2024). *AR5 Synthesis Report: Climate Change 2014 — IPCC*. (2024). IPCC. <https://www.ipcc.ch/report/ar5/syr/>
- International Labour Organization. (2024). *Increase in heat stress predicted to bring productivity loss equivalent to 80 million jobs*. (2024, April 19). International Labour Organization.
- Japan International Research Center for Agricultural Sciences, JIRCAS. (2024). 1005. observed trends in recent extreme weather. In *Japan International Research Center for Agricultural Sciences / JIRCAS*. <https://www.jircas.go.jp/en/program/proc/blog/20240424>
- Kovats, R. S., & Hajat, S. (2008). Heat Stress and Public Health: A Critical review. *Annual Review of Public Health*, 29(1), 41–55. <https://doi.org/10.1146/annurev.publhealth.29.020907.090843>
- L., Marghidan, C. P., Kapoor, A., Aalst, M. V., Raju, E., Li, S., Sun, J., Vecchi, G., Yang, W., Hauser, M., Schumacher, D. L., Seneviratne, S. I., Harrington, L. J., & Otto, F. E. L. (2023). Climate Change made devastating early heat in India and Pakistan 30 times more likely.
- Lu, Y., & Kueppers, L. (2015). Increased heat waves with loss of irrigation in the United States. *Environmental Research Letters*, 10(6), 064010. <https://doi.org/10.1088/1748-9326/10/6/064010>
- National Ocean Service. (2024). *What are El Nino and La Nina?* (n.d.). <https://oceanservice.noaa.gov/facts/ninonina.html>
- National Disaster Management Authority, Pakistan.
- National Oceanic and Atmospheric Administration. (2024). *Last month was Earth's warmest March on record*. (2024, April 12). National Oceanic and Atmospheric Administration. <https://www.noaa.gov/news/last-month-was-earths-warmest-march-on-record>
- National Oceanic and Atmospheric Administration. (2024). *April 2024 was Earth's warmest on record*. (2024, May 14). National Oceanic and Atmospheric Administration. <https://www.noaa.gov/news/april-2024-was-earths-warmest-on-record>
- NOAA's National Weather Service. (2024). *What is the heat index?* <https://www.weather.gov/ama/heatindex>
- Perkins, S. (2013). Global temperatures are close to 11,000-year peak. *Nature*. <https://doi.org/10.1038/nature.2013.12564>
- *Proceedings of the National Academy of Sciences of the United States of America*, 107(21), 9552–9555. <https://doi.org/10.1073/pnas.0913352107>
- R., Vautard, V., Philip, S., Kew, S., Vahlberg, M., Singh, R., Arrighi, J., Heinrich, D., Thalheimer,
- Ritchie, H., Rosado, P., & Roser, M. (2024, March 12). *Natural disasters*. Our World in Data. <https://ourworldindata.org/natural-disasters>

- Roxy, M., Saranya, J., Modi, A., Anusree, A., Cai, W., Resplandy, L., Vialard, J., & Frölicher, T. L. (2024). Future projections for the tropical Indian Ocean. In *Elsevier eBooks* (pp. 469–482). <https://doi.org/10.1016/b978-0-12-822698-8.00004-4>
- Saric, I., Freedman, A., & Knutson, J. (2022). Heat wave kills more than 2,000 people in Spain and Portugal. *Axios*. <https://www.axios.com/2022/07/18/heat-wave-europe-death-toll>
- Sharma, A., Andhikaputra, G., & Wang, Y. (2022). Heatwaves in South Asia: characterization, consequences on human health, and adaptation strategies. *Atmosphere*, 13(5), 734. <https://doi.org/10.3390/atmos13050734>
- Sherwood, S. C., & Huber, M. (2010). An adaptability limit to climate change due to heat stress.
- Stone, B., Gronlund, C. J., Mallen, E., Hondula, D., O'Neill, M. S., Rajput, M., Grijalva, S., Lanza, K., Harlan, S., Larsen, L., Augenbroe, G., Krayenhoff, E. S., Broadbent, A., & Georgescu, M. (2023). How Blackouts during Heat Waves Amplify Mortality and Morbidity Risk. *Environmental Science & Technology*, 57(22), 8245–8255. <https://doi.org/10.1021/acs.est.2c09588>
- UN News, (2022). *WMO warns of frequent heatwaves in decades ahead*. (2022, July 21). <https://news.un.org/en/story/2022/07/1122822>
- United States Institute of Peace. (2023). *How heat waves are destabilizing Asia*. (2023). <https://www.usip.org/publications/2023/06/how-heat-waves-are-destabilizing-asia>
- US EPA. (2024). *Future of Climate Change | Climate Change Science | US EPA*. (n.d.). <https://climatechange.chicago.gov/climate-change-science/future-climate-change#ref2>
- US EPA. (2024). *Heat Island Effect | US EPA*. (2024, March 18). US EPA. <https://www.epa.gov/heatislands>
- Usgcrp. (2018). *Fourth national climate assessment*. <https://nca2018.globalchange.gov/chapter/1/>
- Waidelich, P., Batibeniz, F., Rising, J., Kikstra, J. S., & Seneviratne, S. I. (2024). Climate damage projections beyond annual temperature. *Nature Climate Change*. <https://doi.org/10.1038/s41558->
- Walsh, L., & Skeaping, O. (2022). *Cost of delay: Why finance to address Loss and Damage must be agreed at COP27*. (2022). <https://www.lossanddamagecollaboration.org/publication/cost-of-delay-why-finance-to-address-loss-and-damage-must-be-agreed-at-cop27>
- World Weather Attribution. (2018). *Trends in weather extremes* – <https://www.worldweatherattribution.org/trends-in-weather-extremes-february-2018/>
- World Bank Group. (2022). Pakistan: Flood Damages and Economic Losses Over USD 30 billion and Reconstruction Needs Over USD 16 billion - New Assessment. *World Bank*. <https://www.worldbank.org/en/news/press-release/2022/10/28/pakistan-flood-damages-and-economic-losses-over-usd-30-billion-and-reconstruction-needs-over-usd-16-billion-new-assessme>
- World Weather Attribution. (2024). *Extreme Sahel heatwave that hit highly vulnerable population at the end of Ramadan would not have occurred without climate change*.
- Yadav, N., Rajendra, K., Awasthi, A., Singh, C., & Bhushan, B. (2023). Systematic exploration of heat wave impact on mortality and urban heat island: A review from 2000 to 2022. *Urban Climate*, 51, 101622. <https://doi.org/10.1016/j.uclim.2023.101622>
- Zachariah, M., Arulalan, T., Rao, K. A., Saeed, F., Jha, R., Dhasmana, M. K., Mondal, A., Bonnet,
- Zhang, W., Clark, R., Zhou, T., Li, L., Li, C., Rivera, J., Zhang, L., Gui, K., Zhang, T., Li, L., Pan, R., Chen, Y., Tang, S., Huang, X., & Hu, S. (2024). 2023: Weather and Climate Extremes Hitting the Globe with Emerging Features. *Advances in Atmospheric Sciences*. <https://doi.org/10.1007/s00376-024-4080-3>