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Climate Extremes and Indian Monsoon: Understanding the Impact of Super El-Nino

Dr. Nawaz Ahmed
Assistant Professor of Geography, Shri Krishan Chander Govt. Degree College Poonch
Assad-Ullah Khan
Associate Professor of Chemistry, Shri Krishan Chander Govt. Degree College Poonch

Abstract
The emerging possibility of a Super El Nino event during 2026 has generated serious concern among climate scientists, meteorologists, and policy planners worldwide. Rising sea surface temperatures (SSTs) across the Pacific Ocean, combined with weakening trade winds and abnormal atmospheric circulation, indicate the potential development of a strong El Nino episode that may intensify into a Super El Nino. Such events have historically been associated with severe climatic disruptions, including droughts, floods, wildfires, agricultural losses, and food insecurity. India remains particularly vulnerable because of its heavy dependence on the southwest monsoon, which contributes nearly 70 percent of annual rainfall. This paper examines the scientific basis of El Nino and Super El Nino phenomena, analyses historical case studies, evaluates the potential impact on India's monsoon system, and discusses the role of the Indian Ocean Dipole as a climatic modifier. The study further explores implications for agriculture, water resources, economy, and climate adaptation strategies in the context of global warming.

Keywords: *Climate, El Nino, Drought, IOD, Scarcity, agriculture, sea surface temperature.*

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I. Introduction

Climate change is making the Indian monsoon more volatile and extreme, shifting from long dry spells to intense, short-duration downpours, increasing floods and droughts. While overall rainfall has not increased significantly, rising atmospheric moisture-fuelled by warming oceans-causes erratic behavior, impacting agriculture and causing disasters, particularly in Central India and the Himalayas. Climate variability has become one of the defining challenges of the twenty-first century. Rising greenhouse gas concentrations, increasing global temperatures, melting glaciers, and warming oceans are intensifying extreme weather events across the planet. Among the most influential climate phenomena affecting global weather systems is the El Nino-Southern Oscillation (ENSO).

In 2026, global sea surface temperatures have approached near record levels, raising fears of the emergence of a Super El Nino event. Scientists from the World Meteorological Organization and the European Centre for Medium-Range Weather Forecasts warn that continued warming in the equatorial Pacific Ocean could significantly disturb atmospheric circulation patterns. India, whose agriculture, and water security depend largely upon the southwest monsoon, faces substantial risks under such climatic conditions. Historical evidence shows that strong El Nino years often correspond with deficient monsoon rainfall, drought conditions, and agricultural stress.

Objectives of the study

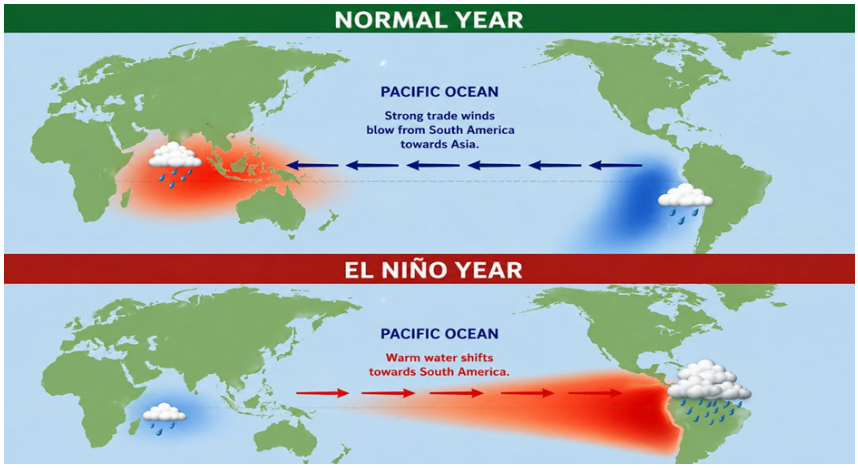
This paper aims to examine:

a) The scientific mechanism of El Nino and Super El Nino
b) Historical occurrences and impacts
c) Relationship between El Nino and Indian monsoon variability
d) The role of the Indian Ocean Dipole
e) Socio-economic and environmental implications for India
f) Adaptation and mitigation strategies

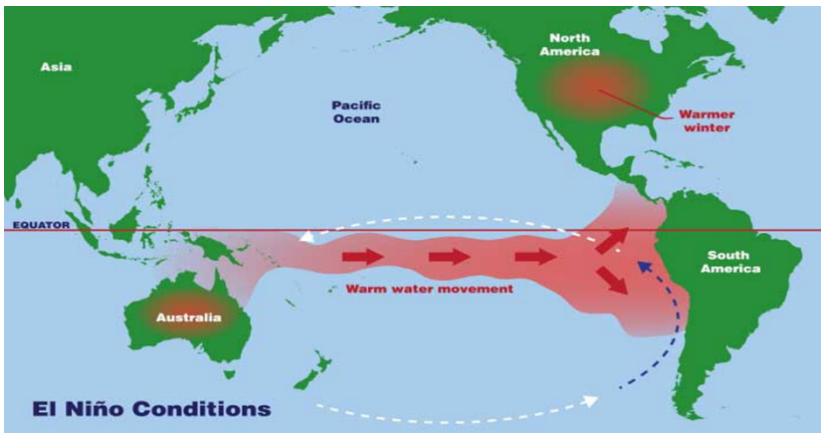
Conceptual Framework of El Nino

Normal Pacific Ocean Conditions: Under normal Pacific Ocean conditions, strong trade winds blow from east to west across the equatorial Pacific Ocean, pushing warm surface waters toward the western Pacific near Indonesia and Australia. This creates a region of low pressure and heavy rainfall in the western Pacific, while

the eastern Pacific near the coast of South America remains relatively cool due to the upwelling of cold, nutrient-rich water from deeper ocean layers. The atmospheric circulation associated with this system, known as the Walker Circulation, helps maintain stable weather patterns and supports the normal functioning of the El Nino-Southern Oscillation cycle. These normal conditions play a crucial role in regulating global climate and sustaining the Indian Monsoon system.



El Nino Conditions: Under El Nino conditions, the trade winds over the equatorial Pacific Ocean weaken or sometimes reverse, allowing warm surface waters to spread eastward toward the coast of South America. This suppresses the normal upwelling of cold, nutrient-rich water in the eastern Pacific, causing sea surface temperatures to rise significantly. The shift in oceanic and atmospheric circulation weakens the Walker Circulation and alters global weather patterns, leading to heavy rainfall and floods in the eastern Pacific region while causing droughts and reduced rainfall in countries such as India, Australia, and Indonesia. These abnormal conditions strongly influence the Indian Monsoon and contribute to climatic extremes across the world.



Super El Nino Conditions: Under Super El Nino conditions, the warming of sea surface temperatures in the central and eastern Pacific Ocean becomes exceptionally intense, causing a major disruption in global atmospheric and oceanic circulation systems. Trade winds weaken drastically or may reverse completely, while the Walker Circulation collapses or shifts eastward, resulting in severe climatic anomalies worldwide. These conditions often produce extreme floods in the Americas and intense droughts, heatwaves, forest fires, and water shortages in regions such as India, Australia, Southeast Asia, and Africa. A Super El Nino can significantly weaken the Indian Monsoon, reduce rainfall, and adversely affect agriculture, food security, water resources, and the economy on a large scale. A Super El Nino represents the extreme phase of El Nino.

Temperature Threshold

Where: ΔSST = increase in Sea Surface Temperature above average.
A normal El Nino requires warming of approximately 0.5°C, whereas a Super El Nino exceeds 2°C.

Historical Super El Nino Events and their impacts

Super El Nino of 1982-83

The 1982-83 El Nino was one of the strongest El Nino events of the 20th century, caused by abnormal warming of sea surface temperatures in the central and eastern Pacific Ocean. It disrupted global weather patterns and led to severe droughts in countries such as India, Australia, Indonesia, and parts of Africa, while causing devastating floods in Peru, Ecuador, and the southern United States. The event affected agriculture, fisheries, water resources, and economies worldwide, resulting in billions of dollars in damage and highlighting the strong connection between oceanic and atmospheric systems.

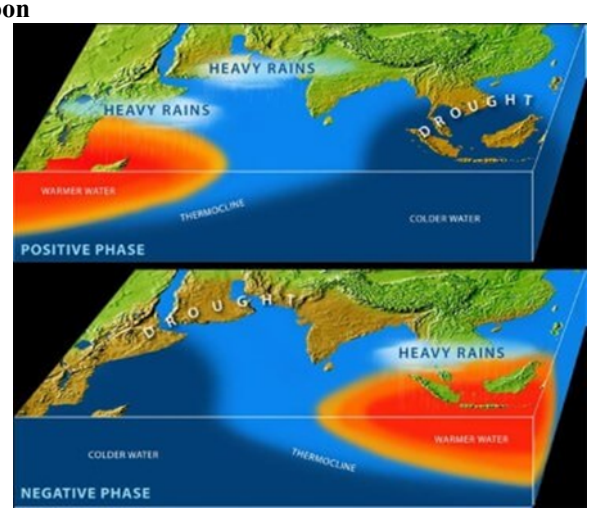
Super El Nino of 1997-98

It was one of the most intense Super El Nino events marked by exceptionally warm sea surface temperatures in the Pacific Ocean. It caused widespread climatic disturbances across the globe, including severe droughts and forest fires in Indonesia and Australia, weak monsoon conditions in parts of Asia, and heavy floods in Peru, Ecuador, and East Africa. The event severely affected agriculture, fisheries, public health, and economies, leading to massive financial losses and increased awareness about climate variability and disaster preparedness worldwide. India escaped severe drought largely because of a strong positive Indian Ocean Dipole.

Super El Nino of 2015-16

The 2015-16 El Nino was among the strongest Super El Nino events in recorded history, driven by unusually high sea surface temperatures in the equatorial Pacific Ocean. It triggered extreme weather conditions worldwide, including droughts in India, southern Africa, and Southeast Asia, severe coral bleaching in tropical oceans, and intense floods in parts of South America and the United States. The event disrupted agriculture, reduced crop production, worsened water scarcity, and increased food insecurity in many regions, while also contributing to record global temperatures and highlighting the growing influence of climate change on El Nino intensity.

El Nino and Indian Monsoon



The relationship between El Nino and the Indian Monsoon is generally inverse, meaning that a strong El Nino often weakens the Indian summer monsoon. During El Nino years, the warming of the central and eastern Pacific Ocean alters atmospheric circulation patterns, particularly the Walker Circulation, which reduces the moisture-bearing winds reaching the Indian subcontinent. As a result, India may experience below-normal rainfall, drought conditions, declining agricultural productivity, water shortages, and stress on the rural economy. However, the impact is not always uniform, as other climatic factors such as the Indian Ocean Dipole and regional atmospheric conditions can influence the final monsoon outcome.

El Nino significantly affects the Indian Monsoon by weakening the southwest monsoon circulation and reducing rainfall over many parts of India. During El Nino years, warmer sea surface temperatures in the Pacific Ocean disturb global atmospheric patterns, leading to weaker moisture transport toward the Indian subcontinent. This often results in delayed monsoon onset, below-normal rainfall, droughts, reduced agricultural production,

water scarcity, lower hydropower generation, and economic stress, particularly in agriculture-dependent regions. Strong El Nino events have historically been associated with major drought years in India, although the intensity of impact may vary due to other climatic factors such as the Indian Ocean Dipole and local weather conditions.

Monsoon Forecast for the year 2026: Probability Analysis

The southwest monsoon season of 2026 is projected to be below normal**,** primarily due to the increasing probability of the development of a strong to potentially "Super" El Nino event in the Pacific Ocean. According to the India Meteorological Department (IMD), India is likely to receive around 92% of the Long Per Indian Ocean Dipole Average (LPA) rainfall during June–September 2026, which falls in the "below normal" category.

Current global climate models from National Oceanic and Atmospheric Administration (NOAA) and the World Meteorological Organization (WMO) indicate a 61-70% probability of El Niño development between May and July 2026, with persistence likely through the end of the year.

Climatic Scenario	Estimated Probability	Expected Impact on Indian Monsoon
Strong/Super El Niño Development	60-70%	Suppressed monsoon rainfall, delayed onset, drought risk
Below-Normal Monsoon (<96% LPA)	60-66%	Reduced agricultural productivity and water stress
Normal Monsoon	25-30%	Uneven rainfall distribution possible
Above-Normal Monsoon	<10%	Low probability under current ENSO conditions
Positive Indian Ocean Dipole (INDIAN OCEAN DIPOLE) Support	30-40%	Partial recovery of rainfall in late monsoon season

The probability maps released by IMD suggest that Central India, north western India, and parts of the Deccan Plateau may face higher chances of rainfall deficiency during the core monsoon months. The weakening of the Indian monsoon during El Nino years occurs because warming in the central and eastern Pacific Ocean alters the Walker Circulation and weakens moisture transport toward the Indian subcontinent. This often results in delayed monsoon onset, long dry spells, reduced seasonal rainfall, increased heatwave frequency and higher evapotranspiration losses.

P= ×100

Where:

P = Probability percentage

f= Frequency of occurrence of an event

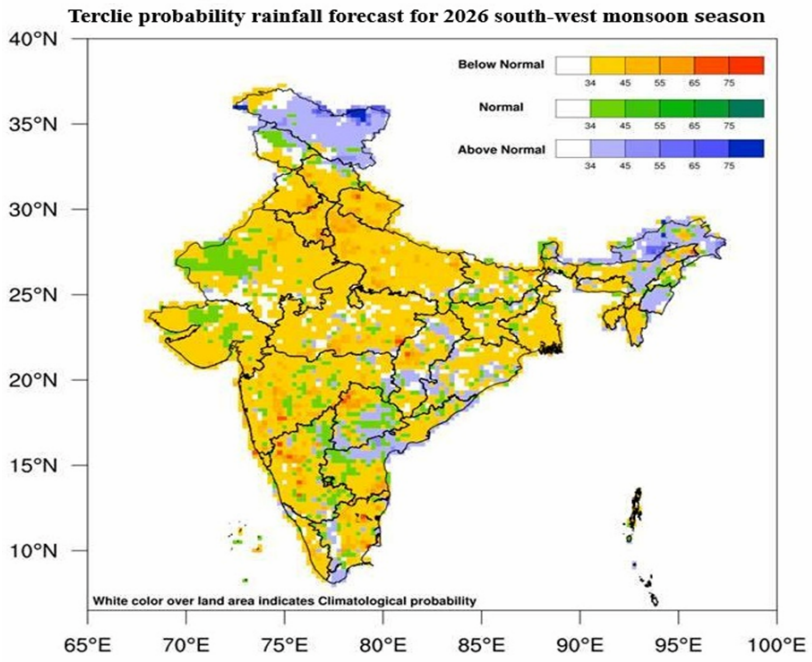
N = Total number of observations or model runs

Climate scientists are also concerned that rising global sea surface temperatures may intensify ENSO events under global warming conditions, increasing the probability of extreme monsoon variability in South Asia.

Probability of Severe Monsoon Deficit

Historical Probability: 16%

2026 Estimated Probability: 35%



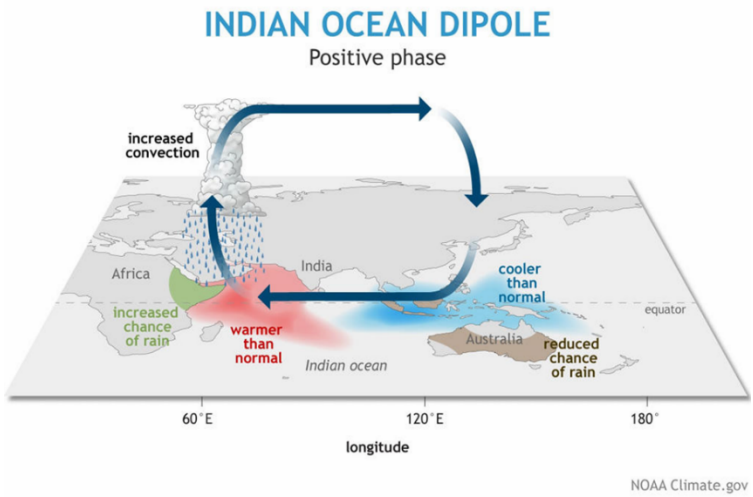
Source: Press Information Bureau-PIB, Govt. of India

Indian Ocean Dipole and Its Role

The Indian Ocean Dipole is the potential buffer used to measures the temperature difference between the western and eastern halves of the Indian Ocean. When the western side is warmer, scientists call it a positive Indian Ocean Dipole, and it tends to push extra moisture towards India, sometimes offsetting El Nino's drying influence. This is precisely what happened in 1997, when a powerful positive Indian Ocean Dipole neutralised a Super El Nino and saved India from drought.

The Indian Ocean Dipole acts as a natural counterweight to El Nino's drying effect on India. In 1997, a strong positive Indian Ocean Dipole saved India from drought despite a raging Super El Nino. In 2026, the Indian Ocean Dipole remains neutral and offers no such protection. However, IMD reports that the Indian Ocean Dipole is currently in a neutral state, meaning neither side of the Indian Ocean is significantly warmer than the other. A positive phase is only expected towards the tail end of the monsoon season, arriving too late to meaningfully protect July and August, which are the two months that matter most for Indian agriculture. As Burgess put it simply: "We just keep seeing extremes. Every month we have more data that climate change is creating these extreme events."

For India, 2026 may be one such extreme.



Source: NOAA Climate.gov

Agriculture Under Threat

El Nino-Southern Oscillation is expected to become particularly strong in 2026, raising concerns about a possible "Super El Nino" and its severe effects on Indian agriculture. According to different Climate agencies and recent forecasts the 2026 southwest monsoon may remain below normal, with rainfall projected around 92% of the Long Per Indian Ocean Dipole Average, increasing the risk of drought-like conditions across many agricultural regions of India. A weak monsoon could reduce soil moisture, delay sowing, lower groundwater recharge, and negatively affect major crops such as rice, wheat, pulses, maize, sugarcane, and cotton. Rising temperatures and prolonged heat waves may further increase crop stress, pest attacks, and irrigation demand. Rain-fed farming areas in states like Maharashtra, Rajasthan, Karnataka, and Telangana are considered especially vulnerable. Experts also warn that reduced agricultural production may lead to food inflation, farmer distress, water shortages, and economic pressure on rural communities. Although improved irrigation systems, crop diversification, and government preparedness may reduce some risks compared to earlier El Nino years, the possible Super El Nino of 2026 remains a serious climatic threat to India's agricultural productivity and food security.

Environmental Consequences

The environmental consequences of a Super El Nino-Southern Oscillation can be severe and widespread, particularly in countries like India that depend heavily on monsoon rainfall. A strong El Nino event may lead to reduced rainfall, prolonged droughts, rising temperatures, heat waves, forest fires, declining river and groundwater levels, and loss of soil moisture. These changes can damage ecosystems, increase land degradation and desertification, and disturb aquatic and terrestrial habitats. Irregular weather conditions may also intensify air pollution, glacier melting, and water scarcity, while affecting wildlife migration and agricultural sustainability. In coastal regions, altered ocean temperatures can disrupt marine ecosystems and fisheries. Overall, Super El Nino creates environmental imbalance by increasing climate extremes and placing additional stress on natural resources and ecosystems.

Climate Change and Intensifying El Nino

Climate change is increasingly linked with the intensification and greater frequency of strong El Nino-Southern Oscillation events across the globe. Rising global temperatures and warming ocean surfaces, particularly in the Pacific Ocean, enhance the accumulation of heat energy that can strengthen El Nino conditions. Scientists suggest that climate change may increase the probability of extreme events, leading to more severe disruptions in global weather patterns in future. These intensified events can cause stronger droughts, heat waves, irregular monsoons, floods, wildfires, and agricultural losses in many regions, including India. In the Indian context, climate change combined with a stronger El Nino can weaken the southwest monsoon, reduce crop productivity, increase water scarcity, and threaten food security. Thus, the interaction between climate change and intensifying El Nino events represents a major challenge for environmental sustainability, disaster management, and climate-resilient development worldwide.

Scientific Interpretation of El Nino-Southern Oscillation

The scientific interpretation of El Nino-Southern Oscillation explains it as a large-scale ocean-atmosphere interaction occurring in the tropical Pacific Ocean. During a Super El Nino event, sea surface temperatures in the central and eastern Pacific become abnormally warmer than normal, which disrupts atmospheric pressure systems and weakens the trade winds. This disturbance alters global circulation patterns, including the Walker Circulation, leading to significant climatic anomalies across different parts of the world. In India, the weakening of the Walker Circulation reduces the strength of the southwest monsoon winds. Scientists interpret these events as part of natural climate variability, but recent research indicates that global warming and rising ocean temperatures may intensify the frequency and severity of extreme El Nino episodes. Therefore, Super El Nino is scientifically understood as a complex climatic phenomenon driven by coupled oceanic and atmospheric processes with far-reaching environmental and socio-economic impacts.

Adaptation and Mitigation Strategies

Agricultural Adaptation: To reduce the adverse impacts of Super El Nino and weak monsoon conditions, agricultural adaptation strategies are essential. The cultivation of drought-resistant and short-duration crop varieties can help farmers withstand rainfall deficits and rising temperatures. Efficient irrigation systems such as drip and sprinkler irrigation improve water-use efficiency and reduce wastage. Crop diversification, including the adoption of millets, pulses, and mixed farming practices, minimizes the risk of complete crop failure and enhances food security during climatic uncertainties.

Water Resource Management: Effective water resource management plays a crucial role in coping with reduced monsoon rainfall associated with El Nino events. Rainwater harvesting structures help conserve seasonal rainfall for future use, particularly in drought-prone areas. Scientific reservoir management ensures

equitable distribution of water for agriculture, domestic use, and hydropower generation. Groundwater recharge through check dams, recharge wells, and watershed development programs can improve water availability and strengthen long-term water security.

Climate Forecasting: Advanced climate forecasting systems are vital for disaster preparedness and climate adaptation. Improved early warning systems enable governments and farmers to prepare for droughts, floods, and monsoon irregularities in advance. Satellite monitoring provides real-time information on sea surface temperatures, rainfall patterns, and atmospheric conditions. In addition, AI-based monsoon prediction models enhance forecasting accuracy by analyzing large climatic datasets, helping policymakers and agricultural sectors make informed decisions.

Policy Measures: Strong policy interventions are necessary to minimize socio-economic losses caused by climate variability. Farmer insurance schemes can provide financial protection against crop failures and climate-related disasters. Investment in climate-resilient infrastructure, including irrigation networks, flood control systems, and drought management facilities, strengthens adaptive capacity. Sustainable land management practices such as afforestation, soil conservation, and integrated watershed management help maintain ecological balance and improve resilience against extreme climatic events.

II. Conclusion

The possibility of a Super El Nino in 2026 represents a major climatic threat with global and regional implications. India, owing to its monsoon-dependent economy and agriculture, remains especially vulnerable to rainfall deficits associated with El Nino conditions.

Historical evidence demonstrates that Super El Nino events have repeatedly triggered severe droughts, crop failures, heatwaves, and economic losses. Although the Indian Ocean Dipole can sometimes offset these impacts, current forecasts suggest limited protection during the crucial monsoon months of 2026.

The emerging climate scenario highlights the urgent need for: Climate resilience, sustainable agriculture, scientific forecasting and International cooperation on climate change mitigation As global warming continues to intensify ocean temperatures, extreme climatic events like Super El Nino may become more frequent and more destructive in the future.

References

[1]. World Meteorological Organization Reports On ENSO And Global Climate.
[2]. India Meteorological Department Monsoon Forecast Report 2026.
[3]. IPCC Assessment Reports On Climate Change.
[4]. Berkeley Earth Climate Data Reports.
[5]. Copernicus Climate Change Service Climate Bulletins.
[6]. Intergovernmental Panel On Climate Change (2023). Climate Change 2023: Synthesis Report. Geneva: IPCC.
[7]. India Meteorological Department (2024). Monsoon And ENSO Relationship Reports. New Delhi, India.
[8]. National Oceanic And Atmospheric Administration (2025). El Niño/Southern Oscillation (ENSO) Diagnostic Discussion. United States.
[9]. Rasmusson, E. M. & Carpenter, T. H. (1983). "The Relationship Between Eastern Equatorial Pacific Sea Surface Temperatures And Rainfall Over India And Sri Lanka." Monthly Weather Review, 111(3), 517-528.
[10]. Webster, P. J. Et Al. (1998). "Monsoons: Processes, Predictability, And The Prospects For Prediction." Journal Of Geophysical Research, 103(C7), 14451–14510.
[11]. Food And Agriculture Organization (2022). Climate Change And Food Security. Rome, Italy.
[12]. World Meteorological Organization (2023). State Of The Global Climate Report. Geneva, Switzerland.
[13]. United Nations Environment Programme (2021). Adaptation Gap Report. Nairobi, Kenya.