

El Niño and Global Change: Impact, Challenges, and Sustainable

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What is El-Nino?

El Niño is one of the most influential natural climate phenomena affecting weather patterns, ecosystems, agriculture, water resources, biodiversity, and economies worldwide.

In the era of global climate change, the frequency, intensity, and impacts of El Niño events have become increasingly significant. Rising greenhouse gas emissions, warming oceans, melting glaciers, and changing atmospheric circulation are amplifying climate extremes, making societies more vulnerable to floods, droughts, heat waves, forest fires, and food insecurity.

This keynote lecture discusses **the science behind El Niño, its relationship with global climate change, its environmental and socio-economic impacts, and sustainable solutions that can enhance resilience and promote sustainable development.**

EXTREME WEATHER MANIFESTATIONS



NORMAL CONDITIONS



Strong easterly
trade winds



Warm water
accumulates
near Indonesia

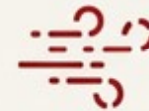


Cold
nutrient-rich
water upwells
near Peru



High fish
productivity

EL NIÑO CONDITIONS



Trade winds
weaken
significantly



Warm water
mass shifts
eastward



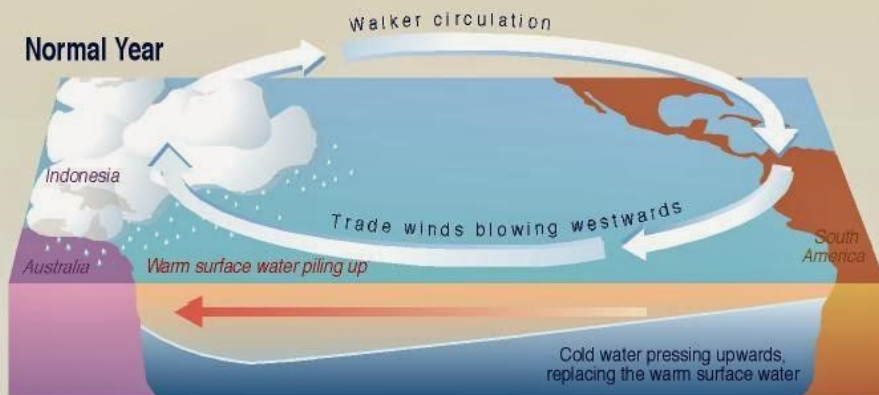
Upwelling
decreases;
Eastern Pacific
warms



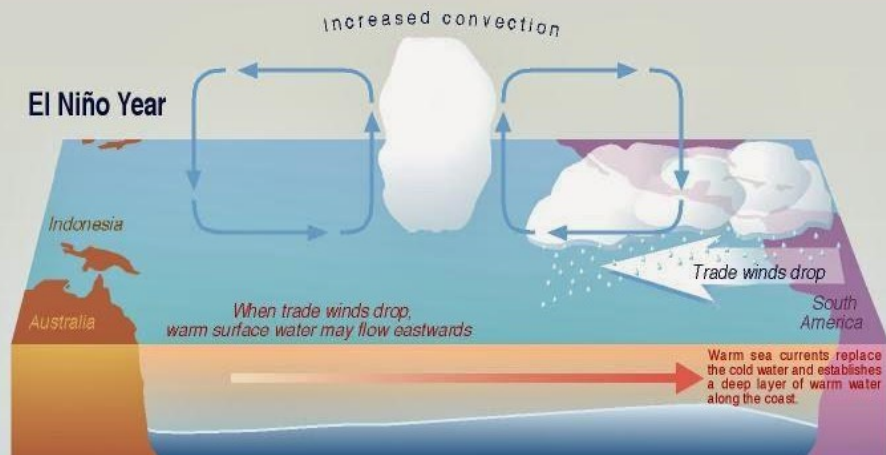
Global
atmospheric
circulation
alters

El Niño Phenomenon (ENSO)

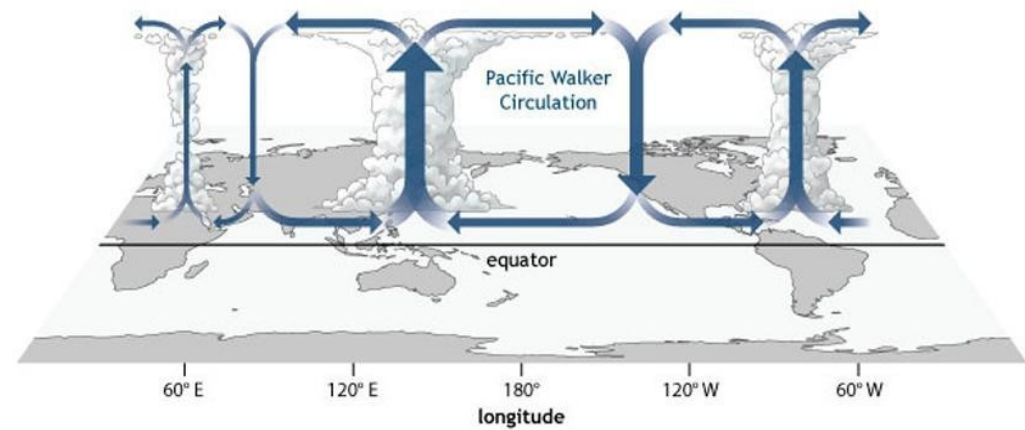
Normal Year



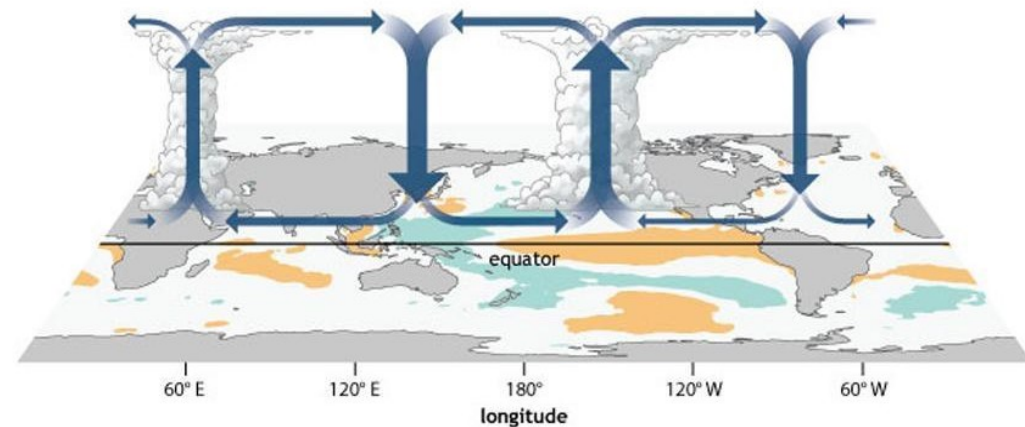
El Niño Year



Neutral conditions

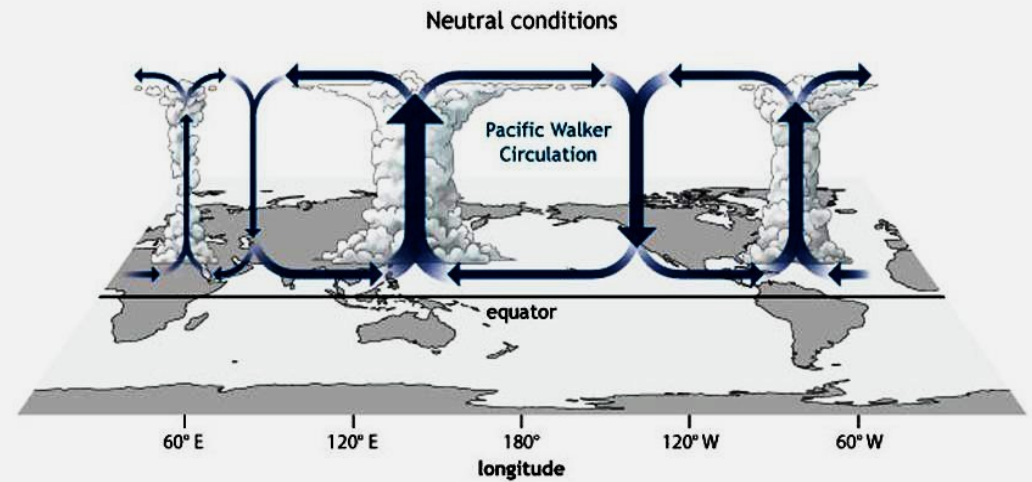
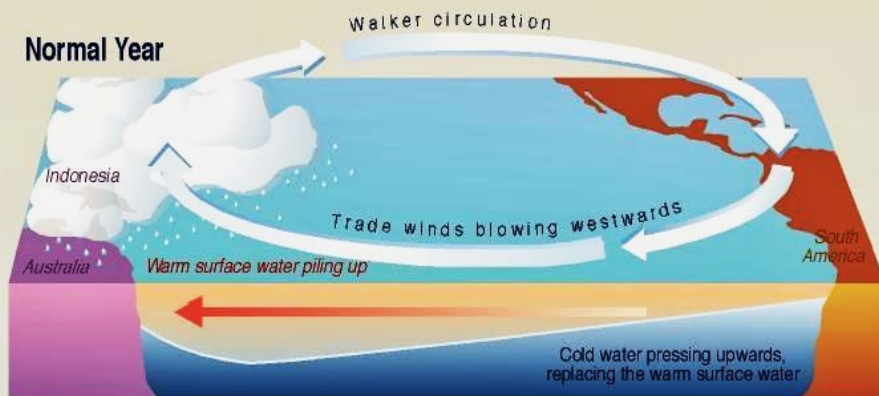


El Niño conditions



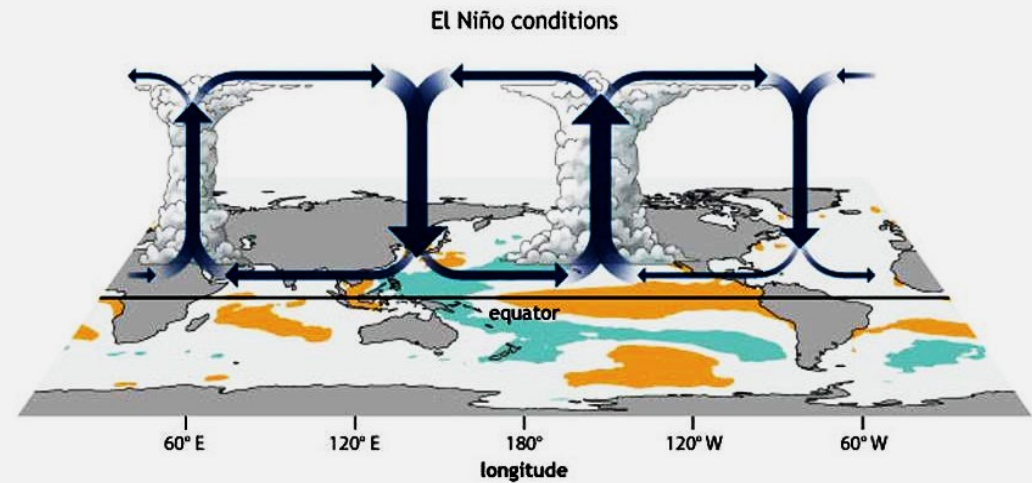
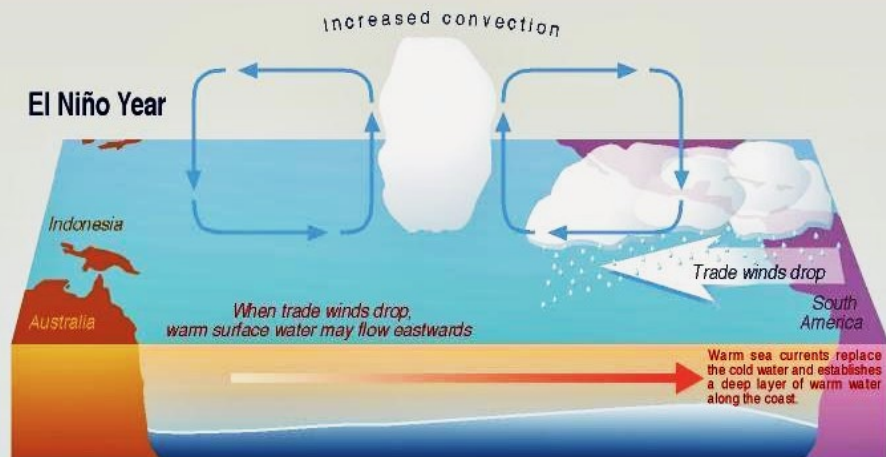
El Niño Phenomenon (ENSO)

Normal Year



NOAA Climate.gov

El Niño Year



NOAA Climate.gov

1. Introduction

The Earth's climate system is controlled by complex interactions between the atmosphere, oceans, land, cryosphere, and biosphere. Among these interactions, the **El Niño–Southern Oscillation (ENSO)** is the strongest natural climate oscillation affecting global weather.

El Niño is characterized by an abnormal warming of sea surface temperatures over the **central and eastern tropical Pacific Ocean**. This warming alters atmospheric circulation, influencing rainfall and temperature patterns across the globe.

Major El Niño events occurred during:

1982–83: 10 millions

1997–98: >100 millions

2015–16: >60 millions

2023–24: >100 millions

Each event caused billions of dollars in economic losses and affected millions of people worldwide.

1.1 Introduction

Major El Niño Events and Their Impact (Short)

Year	Strength	Key Impacts
1982–83	Very Strong	Severe floods in Peru & Ecuador, droughts in Australia & Indonesia, economic losses of US\$4–8 billion .
1997–98	Super El Niño	One of the strongest on record; floods, droughts, wildfires, coral bleaching, US\$30–45 billion losses, ~24,000 deaths.
2015–16	Super El Niño	Contributed to the warmest year (2016), severe droughts, Indonesian fires, global coral bleaching, US\$10–20+ billion losses.
2023–24	Very Strong	Record global temperatures, extreme heat, floods, droughts, widespread coral bleaching, economic losses estimated in tens of billions of US dollars .

2. Understanding El Niño

Normal Conditions

- Strong easterly trade winds
- Warm water accumulates near Indonesia
- Cold nutrient-rich water upwells near Peru
- High fish productivity
- Normal rainfall distribution

During El Niño

- Trade winds weaken
- Warm water shifts eastward
- Upwelling decreases
- Eastern Pacific becomes warmer
- Global atmospheric circulation changes

3. El Niño and Global Climate Change

Although El Niño is a natural climate phenomenon, global warming is influencing its characteristics.

Climate Change Contributes Through

- Warmer ocean temperatures
- Increased atmospheric moisture
- Enhanced evaporation
- More frequent marine heatwaves
- Greater climate variability

Recent studies suggest that extreme El Niño events may become more frequent under continued greenhouse gas emissions.

4. Global Impacts of El Niño

A. Agriculture

- Crop failures
- Reduced wheat production
- Rice yield reduction
- Water scarcity
- Food inflation

B. Water Resources

- Severe droughts
- Reservoir depletion
- Reduced groundwater recharge
- Hydropower reduction

C. Biodiversity

- Coral bleaching
- Fish migration
- Forest degradation
- Wildlife habitat loss

D. Human Health

- Heat stress
- Vector-borne diseases
- Water-borne diseases
- Malnutrition

5. Extreme Weather Events

El Niño influences:

- Floods
- Droughts
- Heat waves
- Tropical cyclones
- Forest fires
- Landslides

Examples include:

- California floods
- Australian droughts
- Amazon forest fires
- **Indian monsoon variability**
- Southeast Asian haze





New york- Heavy Downpour
9 July 2026-[VIDEO](#)



6. Impacts on the Himalayas

The Himalayan region is among the world's most climate-sensitive environments.

Major concerns include:

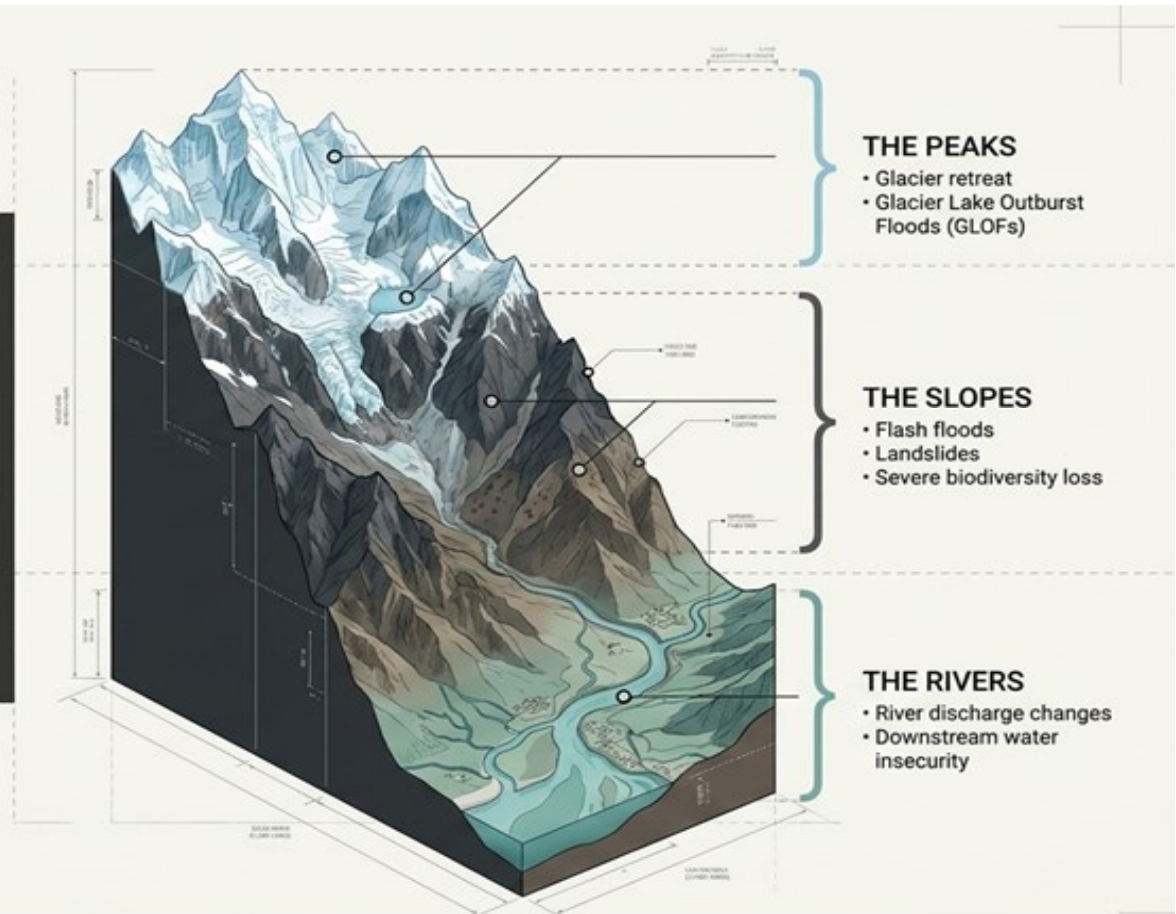
- Glacier retreat
- Glacier Lake Outburst Floods (GLOFs)
- Flash floods
- Landslides
- River discharge changes
- Biodiversity loss
- Water insecurity

These impacts threaten the livelihoods of millions who depend on Himalayan rivers.

6.1 Regional Impact on the Himalayas

REGIONAL VULNERABILITY: THE HIMALAYAS

The Himalayas are among the world's most climate-sensitive environments. These cascading impacts directly threaten the livelihoods millions dependent on Himalayan river systems.



7. El Niño and India

India experiences significant monsoon variability during El Niño years.

Typical impacts:

- Weak southwest monsoon
- Reduced agricultural productivity
- Drinking water shortages
- Increased temperatures
- Higher electricity demand
- Increased forest fire risk

However, **every El Niño event** does not produce identical impacts because the **Indian Ocean Dipole and other climate oscillations** also influence monsoon behavior.

8. Economic Consequences

Global economic impacts include:	(In 2024 in India)
• Agricultural losses	4.24 lakh hectares loss
• Supply chain disruptions	Heavily Disrupted
• Increased food prices	7–8% inflation
• Insurance losses	₹1.72 lakh crores
• Infrastructure damage	₹ 1000 crores
• Reduced GDP growth	1 to 2%
• Increased disaster management costs->	₹ 1000 crores

The World Bank estimates that severe climate events cause hundreds of billions of dollars in annual global losses.

9. Sustainable Solutions

9.1 Renewable Energy

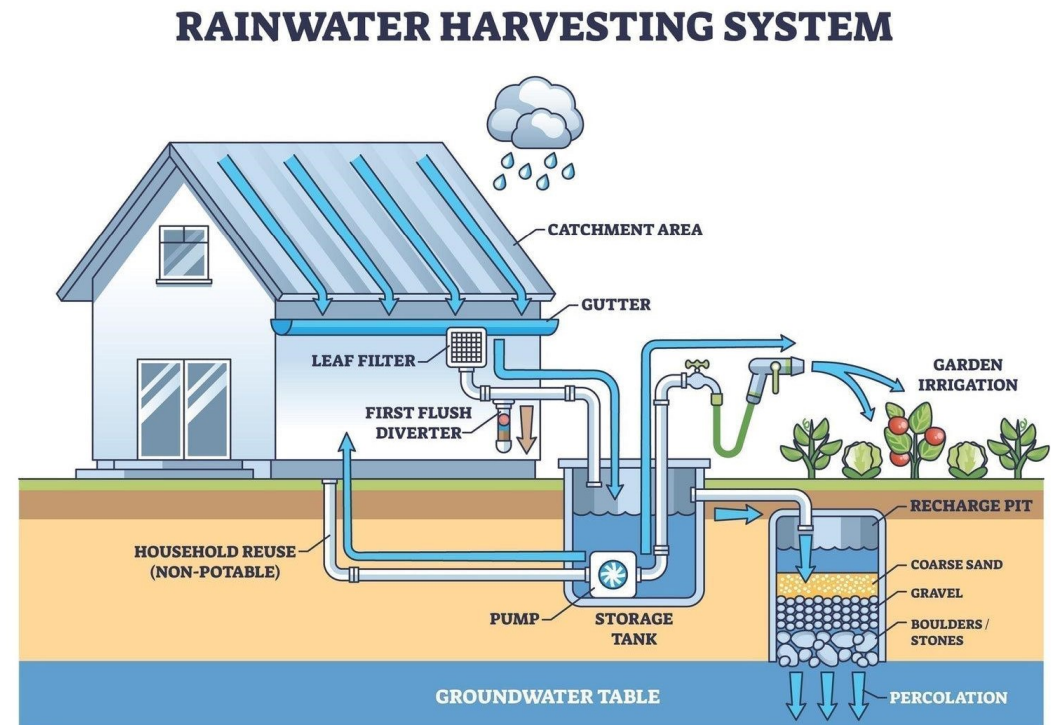
- Solar power
- Wind power
- Hydropower optimization
- Green hydrogen



9. Sustainable Solutions

9.2 Water Management

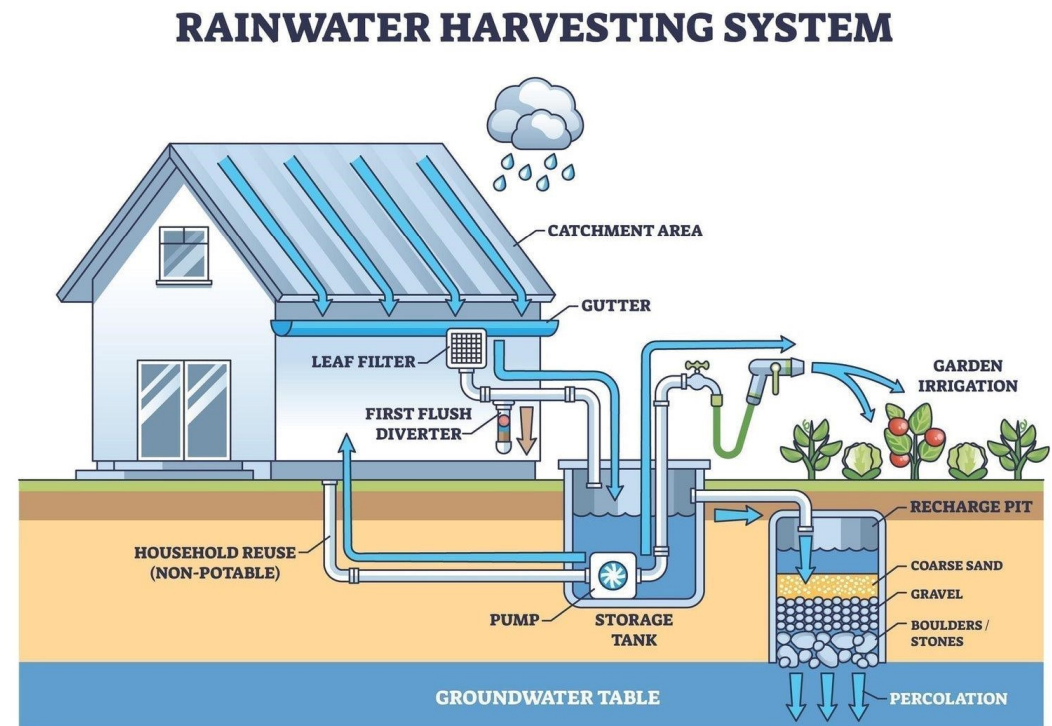
- Rainwater harvesting
- Watershed management
- Micro-irrigation
- Aquifer recharge
- Smart irrigation



9. Sustainable Solutions

9.2 Water Management

- Rainwater harvesting
- Watershed management
- Micro-irrigation
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10. Role of Emerging Technologies

Modern technologies can significantly reduce climate risks.

Important technologies include:

- Artificial Intelligence
- Machine Learning
- Internet of Things (IoT)
- Remote Sensing
- GIS
- Big Data Analytics
- Digital Twin Models
- Climate Modelling
- Supercomputing

11. Policy Recommendations

Governments should prioritize:

- Carbon emission reduction
- Renewable energy expansion
- Climate-resilient infrastructure
- Integrated river basin management
- Glacier monitoring programs
- Nature-based solutions
- Sustainable urban planning
- Climate education
- International cooperation
- Community participation

12. Future Research Directions

Future research should focus on:

- AI-assisted climate prediction
- Glacier dynamics
- Carbon sequestration
- Sustainable energy systems
- Climate adaptation strategies
- Water–Energy–Food Nexus
- Climate-resilient mountain ecosystems
- Nature-based disaster mitigation

13. Conclusion

El Niño is no longer merely an oceanic phenomenon; it has become a global challenge affecting environmental sustainability, food security, water resources, public health, and economic stability.

While it is a naturally occurring climate oscillation, anthropogenic (caused by humans or human activities), climate change is amplifying many of its impacts. Building resilience requires integrating scientific understanding with sustainable policies, technological innovation, ecosystem restoration, and community engagement.

By investing in renewable energy, climate-smart agriculture, early warning systems, and international collaboration, we can **reduce vulnerabilities** and foster a more sustainable and resilient future.

Key Take-Home Messages

- El Niño is a major driver of global climate variability.
- Global warming is increasing the severity of climate extremes associated with El Niño.
- Climate resilience depends on science-based policy, technological innovation, and sustainable resource management.
- Protecting mountain ecosystems and glaciers is essential for global water security.
- Achieving the United Nations Sustainable Development Goals requires coordinated action across governments, academia, industry, and communities.

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