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Abnormal Rainfall in Maharashtra: Reasons and Remedies

Dr. Rajale V. L.
Head & Asst. Professor,
Dept. of Geography,
NKSPT's Arts, Science & Commerce College,
Bandnapur, District Jalna (MS)

Introduction:

Rainfall is vital for human life and other creatures, serving as the primary source of freshwater for drinking, agriculture, and ecosystems. It replenishes rivers, lakes, and groundwater, ensuring water availability for human consumption and hygiene. In Maharashtra, where agriculture employs over 50% of the population, rainfall directly supports crops like rice, sugarcane, and cotton, sustaining livelihoods and food security. Erratic rainfall, as seen in recent decades, disrupts farming, leading to crop failures and economic distress. For other creatures, rainfall maintains habitats like forests, wetlands, and rivers, critical for biodiversity. Aquatic species, such as fish in the Krishna and Godavari rivers, depend on consistent water flows for survival. Excessive rainfall can cause flooding, endangering human lives and displacing wildlife, as seen in the 2005 Mumbai floods. Conversely, deficient rainfall leads to droughts, reducing water for drinking and irrigation, impacting both humans and animals. Rainfall also regulates temperatures, creating habitable conditions for diverse species. It supports plant growth, providing food and shelter for herbivores and pollinators. In urban areas, rainfall affects infrastructure, with poor drainage exacerbating flood risks, harming human safety. For migratory birds in Maharashtra's wetlands, timely rainfall ensures breeding grounds. Abnormal rainfall patterns, driven by climate change, threaten these delicate balances, affecting ecosystems and human societies. Thus, rainfall's timing, quantity, and distribution are crucial for sustaining life across species.

Maharashtra State:

Maharashtra, located in western India, spans 307,713 km², making it the third-largest state by area. It features a diverse geography with the Western Ghats, a UNESCO World Heritage Site, running parallel to its 720-km Arabian Sea coastline, and the Deccan Plateau covering much of its interior. The state has 36 districts, with major rivers like Godavari and Krishna supporting agriculture. Its climate varies from tropical monsoon to semi-arid, with annual rainfall ranging from 7,500 mm in the Ghats to under 600 mm in rain-shadow regions. As of 2025, Maharashtra's population is estimated at 128.66 million, with a density of 419 people/km². About 45% live in urban areas, with Mumbai, the state capital, housing over 20 million in its metropolitan region. Pune, Nagpur, and Nashik are other major urban centers. The literacy rate is around 82.3%, and Marathi is the official language, with Hindi and English widely used. The

state is ethnically diverse, with significant Maratha, Kunbi, and tribal populations like Gonds and Warlis. Urbanization and migration continue to shape its demographic landscape, with Mumbai being a global financial hub.

Reasons for abnormal rainfall in Maharashtra state:

Abnormal rainfall in Maharashtra over the last 20 years, characterized by excessive, deficient, or erratic precipitation, has been influenced by a combination of natural and anthropogenic factors. Below are 10 prime reasons:

1. **Climate Change and Global Warming**
   Rising global temperatures have intensified monsoon variability, leading to extreme rainfall events in Maharashtra. Warmer Arabian Sea waters increase moisture surges, causing heavy downpours, as seen in the 2005 Mumbai floods. A three-fold rise in widespread extreme rainfall events has been noted from 1901–2015. This results in both flooding and prolonged dry spells. en.wikipedia.org
2. **El Niño-Southern Oscillation (ENSO) Variability**
   El Niño and La Niña phases disrupt monsoon patterns, causing deficient or excessive rainfall. El Niño often weakens the monsoon, leading to droughts, while La Niña can enhance rainfall, as predicted for 2025. Neutral ENSO conditions, as in 2025, still show La Niña-like atmospheric patterns affecting rainfall. This variability has caused erratic monsoon seasons in Maharashtra. mid-day.com
3. **Indian Ocean Dipole (IOD) Influence**
   The IOD, in its positive or negative phases, impacts monsoon intensity in Maharashtra. A neutral IOD, as forecasted for 2025, can still lead to unpredictable rainfall patterns. Positive IOD phases enhance rainfall, while negative phases suppress it, contributing to abnormal seasons. This has led to both flooding and deficient rains over the past two decades. mid-day.com
4. **Orographic Effects of Western Ghats**
   The Western Ghats cause orographic rainfall, with windward areas like Amboli receiving up to 7,500 mm annually. However, leeward regions like Central Maharashtra experience rain-shadow effects, leading to deficient rainfall. Variations in monsoon wind strength amplify these disparities, causing abnormal rainfall distribution. This geographical factor has been consistent over the last 20 years. shaalaa.comclubmahindra.com
5. **Urbanization and Land Use Changes**
   Rapid urbanization in cities like Mumbai has reduced permeable surfaces, exacerbating flooding during heavy rains. Reclamation of mangroves and wetlands, as seen in the Bandra-Kurla complex, has destroyed natural water buffers. This contributed to the

2005 floods, where 944 mm fell in 24 hours. Urban sprawl continues to worsen rainfall impacts. en.wikipedia.org

6. **Deforestation and Environmental Degradation**
   Deforestation in the Western Ghats has disrupted local microclimates, altering rainfall patterns. Loss of forest cover reduces moisture retention, leading to erratic precipitation. Between 1995 and 2005, Mumbai lost 40% of its mangroves, intensifying flood impacts. This degradation contributes to both heavy flooding and reduced rainfall in some areas. en.wikipedia.org
7. **Inadequate Drainage Infrastructure**
   Mumbai's outdated drainage system, designed for 25 mm/hour, cannot handle extreme rainfall events like the 2005 deluge (944 mm in 24 hours). Clogged drains and lack of floodgates exacerbate flooding in urban areas. This infrastructure failure amplifies the impact of abnormal rainfall. Upgrades proposed in 1990 remain unimplemented, worsening the situation. en.wikipedia.org
8. **Monsoon Trough Positioning**
   The monsoon trough's position significantly affects rainfall distribution in Maharashtra. When it remains south of its normal position, as in 2019, it leads to prolonged and excessive rainfall. This caused 1,329 mm of rain between June and September 2019, 33% above normal. Such shifts contribute to abnormal rainfall patterns. indianexpress.com
9. **Cyclonic Systems in the Arabian Sea and Bay of Bengal**
   Cyclonic circulations over the Arabian Sea and Bay of Bengal drive heavy rainfall in Maharashtra. These systems, as noted in 2022 and 2025 forecasts, bring intense rain spells, causing floods. Their increased frequency due to warmer sea surfaces has led to abnormal rainfall. Conversely, weaker systems result in deficient monsoons. timesofindia.indiatimes.comndtv.com
10. **Anthropogenic Aerosol Pollution**
    High aerosol levels from industrial and vehicular emissions can suppress or enhance rainfall. Aerosols may weaken monsoon winds, leading to deficient rainfall in some years. Conversely, they can seed clouds, causing intense downpours, as seen in urban areas like Mumbai. This has contributed to erratic rainfall patterns over the past 20 years.

Remedies to Regularize Rainfall in Maharashtra State:

1. **Reforestation of Western Ghats**
   Reforesting degraded areas of the Western Ghats can stabilize local microclimates and enhance orographic rainfall. Planting native species like teak and bamboo will improve

moisture retention. This can mitigate erratic rainfall patterns observed over the past 20 years.

2. **Watershed Management Programs**
   Implementing watershed management in rural areas, like the Jal Yukta Shivar program, conserves rainwater and recharges groundwater. Check dams and contour trenches reduce runoff and stabilize soil moisture. This ensures consistent water availability during deficient monsoons.
3. **Urban Green Infrastructure**
   Developing green roofs and urban forests in cities like Mumbai can reduce heat islands and regulate local rainfall. Permeable pavements can manage excess runoff during heavy rains. This counters the flooding seen in events like the 2005 Mumbai deluge.
4. **Improved Drainage Systems**
   Upgrading Mumbai's drainage infrastructure to handle at least 50 mm/hour rainfall can prevent urban flooding. Regular desilting and modern floodgates are essential for low-lying areas. This addresses the infrastructure failures highlighted during extreme rainfall events.
5. **Climate-Resilient Agriculture**
   Promoting drought-resistant crops like millets and rainwater harvesting on farms can buffer against erratic monsoons. Drip irrigation reduces water wastage in rain-shadow regions like Marathwada. This supports farmers facing rainfall variability.
6. **Mangrove and Wetland Restoration**
   Restoring mangroves and wetlands around Mumbai can act as natural buffers against flooding. These ecosystems absorb excess rainfall and stabilize coastal climates. Their loss since 1995 has worsened flood impacts in urban areas.
7. **Regional Weather Forecasting Models**
   Investing in localized weather forecasting using AI can predict monsoon trough shifts and cyclonic systems. Accurate forecasts help farmers and authorities prepare for abnormal rainfall. This counters unpredictable patterns like the 2019 excessive rains.
8. **Aerosol Pollution Control**
   Reducing industrial and vehicular aerosol emissions through stricter regulations can minimize their impact on monsoon winds. Cleaner air reduces cloud-seeding effects that cause intense downpours. This addresses erratic rainfall linked to pollution over the past two decades.
9. **Inter-Basin Water Transfer**
   Transferring water from surplus basins like the Godavari to deficit areas like Marathwada can balance water availability. Small-scale interlinking projects ensure

equitable distribution during uneven monsoons. This mitigates drought impacts in rain-shadow regions.

10. **Community Rainwater Harvesting**
    Mandating rainwater harvesting in urban and rural buildings can capture excess monsoon rains for dry periods. Community-managed storage systems ensure water security in low-rainfall areas. This reduces dependence on erratic rainfall patterns.

Conclusion:

Irregular rainfall in Maharashtra, marked by erratic monsoons, floods, and droughts, disrupts agriculture, urban life, and ecosystems, as seen in the 2005 Mumbai floods and Marathwada's water crises. Climate change, urbanization, and deforestation exacerbate these issues, causing economic losses and threatening 65% of the state's agriculture-dependent population. Extreme events, like 944 mm of rain in 24 hours in 2005, highlight infrastructure deficiencies. Solutions include reforestation of the Western Ghats to stabilize microclimates and enhance orographic rainfall. Upgrading Mumbai's drainage to handle 50 mm/hour can mitigate urban flooding. Watershed management and rainwater harvesting ensure water security in rain-shadow regions like Marathwada. Promoting climate-resilient crops and drip irrigation supports farmers during deficient monsoons. Restoring mangroves and wetlands acts as a natural buffer against floods. AI-driven weather forecasting can predict erratic patterns, aiding preparedness. These measures collectively aim to regularize rainfall impacts, fostering sustainable development and resilience across Maharashtra.

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