

# TRANSFORMING EARTH SCIENCE

WITH  
EMERGING TECHNOLOGIES  
FOR  
A RESILIENT PLANET

Chief Editor  
Sanjay Nagarkar

Editor  
Madhuri Gulave



# **Transforming Earth Science with Emerging Technologies for a Resilient Planet**

**Sanjay Nagarkar  
Madhuri Gulave**



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# **Transforming Earth Science with Emerging Technologies for a Resilient Planet**

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## Preface

*The present edited volume, “Transforming Earth Science with Emerging Technologies for a Resilient Planet,” is a comprehensive scholarly effort that brings together diverse research contributions addressing some of the most pressing environmental, geographical, and technological challenges of our time. In an era marked by rapid climate change, resource depletion, and socio-economic transformations, the integration of emerging technologies with Earth science has become not only relevant but essential for building a resilient and sustainable future.*

*This book is a collection of fifty-two research chapters contributed by academicians, researchers, and practitioners from various domains of geography, environmental science, and allied disciplines. The chapters collectively explore a wide range of themes including agricultural transformation, climate change impacts, groundwater assessment, renewable energy, geospatial technologies, environmental monitoring, and socio-economic dynamics. A significant strength of this volume lies in its regional focus—particularly on Maharashtra—while simultaneously addressing global environmental concerns through scientific approaches and innovative methodologies.*

*Several contributions in this book emphasize the application of advanced tools such as Remote Sensing, GIS, GeoAI, drone technology, and data-driven models in understanding spatial patterns and environmental processes. Studies on groundwater potential zones, soil fertility, land use changes, and river basin management demonstrate how geospatial technologies can support effective planning and decision-making. At the same time, chapters on climate change, agricultural vulnerability, and farmers’ perceptions highlight the human dimension of environmental change and the need for adaptive strategies.*

*The volume also addresses the growing importance of sustainable energy systems, environmental protection, and clean technologies. Discussions on solar energy integration, energy storage systems, and renewable resources provide valuable insights into pathways for sustainable*

*development. Additionally, interdisciplinary perspectives such as the role of artificial intelligence in climate studies, disaster management, and education reflect the evolving nature of scientific research in the 21st century.*

*Another noteworthy aspect of this book is its focus on rural development and regional studies, including settlement patterns, migration trends, tourism development, and agricultural productivity. These studies offer grounded, empirical insights that are crucial for policy formulation and local-level planning. The inclusion of research on marginalized communities and rural economies further strengthens the social relevance of this volume.*

*The editors believe that this book will serve as a valuable resource for students, researchers, policymakers, and practitioners engaged in Earth science, geography, environmental studies, and sustainable development. It aims to bridge the gap between theoretical knowledge and practical application by showcasing innovative research and region-specific case studies.*

*We express our sincere gratitude to all the contributors for their scholarly efforts and dedication. We also acknowledge the support of reviewers, institutions, and all those who have directly or indirectly contributed to the successful completion of this volume.*

*It is our hope that this book will inspire further research, encourage interdisciplinary collaboration, and contribute meaningfully to the global discourse on sustainability and resilience.*

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# Transforming Earth Science with Emerging Technologies for a Resilient Planet

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# Geographical Analysis of Agricultural Transformation in Indapur Taluka, Pune District, Maharashtra

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## Abstract

Indapur Taluka, situated in the eastern region of Pune district, represents a semi-arid landscape that has experienced notable agricultural changes in recent years. This study investigates the physical and socio-economic characteristics of the taluka, with a focus on land use dynamics, irrigation practices, and crop diversification. The area is marked by irregular and limited rainfall, resulting in a strong dependence on irrigation sources such as the Bhima River and Nira River.

Over the past decade, agricultural practices have shifted from subsistence-based cropping systems to the cultivation of commercial crops, particularly banana and sugarcane. This transition has been facilitated by improved irrigation infrastructure, technological innovations, and better access to markets. Nevertheless, issues such as water scarcity, climatic uncertainty, and rising input costs continue to pose significant challenges to sustainable agriculture.

The study relies on both primary and secondary data sources, including field surveys, official reports, and agricultural statistics. The results emphasize the importance of efficient water utilization and the adoption of sustainable farming techniques. This research contributes to localized geographical studies and provides valuable insights for planning in semi-arid regions.

**Keywords:** Agricultural Geography, Cropping Pattern, Irrigation, Semi-arid Region, Land Use Transformation

## Introduction

Geography offers a holistic approach to understanding the interaction between environmental and human systems. In rural settings, agricultural activities are largely influenced by natural factors such as climate, soil characteristics, and water availability, along with socio-economic conditions.

Indapur Taluka, the largest administrative unit within Pune district, provides an ideal setting to study these interactions. Traditionally, agriculture in this region was predominantly rain-fed, with crops like jowar, bajra, and wheat forming the backbone of the farming system. However, recent developments in irrigation and changes in market demand have significantly altered agricultural practices. Farmers are increasingly shifting towards high-value commercial crops, resulting in substantial modifications in land use patterns. This study seeks to evaluate the geographical determinants of these transformations and assess their long-term sustainability.

### **Objectives**

The primary objectives of this study are:

- To examine the physical geographical features of Indapur Taluka
- To analyze changes in land use and cropping patterns
- To assess irrigation practices and water resource utilization
- To identify major challenges affecting agricultural sustainability

### **Study Area**

Indapur Taluka is located in the eastern part of Pune district and falls within a semi-arid climatic zone. It is bordered by the districts of Solapur district, Satara district, and Ahmednagar district. The region is traversed by important rivers such as the Bhima River and Nira River, which serve as key sources of irrigation.

The climate is characterized by high temperatures and relatively low rainfall, with an annual average ranging from 400 to 600 mm. The dominant soil type is black cotton soil, known for its fertility but highly dependent on moisture availability. Agriculture forms the backbone of the local economy, with a majority of the population engaged in farming and related activities.

### **Methodology**

The present study is based on a combination of primary and secondary data sources.

- **Primary Data:** Collected through field surveys, farmer interviews, and direct observation of agricultural activities
- **Secondary Data:** Obtained from census data, government publications, agricultural reports, and scholarly articles

Analytical methods such as statistical evaluation and comparative analysis were used to identify patterns in land use and cropping systems. Although

Geographic Information System (GIS) techniques can enhance spatial analysis, the present study mainly adopts descriptive and analytical approaches.

### **Physical Geography**

The physical setting of Indapur Taluka plays a crucial role in shaping its agricultural practices. The region experiences a semi-arid climate with hot summers, moderate winters, and unpredictable rainfall patterns. Such climatic variability often leads to instability in agricultural production.

The soils are predominantly regur (black cotton soils), which are rich in nutrients and capable of retaining moisture. However, these soils present management challenges as they become hard when dry and sticky under wet conditions.

Water availability is limited, and agriculture largely depends on irrigation systems supported by rivers, canals, wells, and borewells. The Bhima River and Nira River are the primary water sources in the region.

### **Agricultural Pattern**

Agricultural practices in Indapur Taluka have evolved considerably over time. Traditionally, farmers cultivated drought-resistant crops such as jowar, bajra, and pulses, which required minimal water and were suited to the semi-arid environment.

With the expansion of irrigation facilities, there has been a transition towards water-intensive and commercially viable crops such as sugarcane and banana. Banana cultivation, in particular, has gained prominence due to its higher economic returns and increasing demand in the market.

The adoption of modern agricultural technologies, including drip irrigation, fertigation, and improved crop varieties, has further accelerated this transformation. While these innovations have enhanced productivity, they have also contributed to increased input costs.

### **Irrigation and Water Resources**

Irrigation is a key factor in the agricultural development of Indapur Taluka. The availability of water from the Bhima River and Nira River has enabled farmers to intensify agricultural production.

The main sources of irrigation include:

- Canal systems
- Wells and borewells
- Lift irrigation projects

Water-saving technologies such as drip irrigation are increasingly being adopted to improve efficiency. However, despite these advancements, water scarcity remains a significant issue, especially during dry seasons. Excessive groundwater extraction has resulted in declining water tables, raising concerns about long-term sustainability.

### **Challenges and Issues**

Despite agricultural advancements, several challenges persist in Indapur Taluka:

- 1. Water Scarcity:** Farmers often face shortages of water due to low and uneven rainfall. This makes them heavily dependent on irrigation sources, which are becoming less reliable as groundwater levels decline.
- 2. Climate Variability:** Unpredictable weather patterns, including irregular rains and extreme temperatures, make farming risky. These changes disturb normal crop cycles and can lead to lower yields or crop damage.
- 3. Increasing Input Costs:** The prices of essential farming inputs like seeds, fertilizers, and labor are continuously rising. This increases the cost of farming and reduces the overall profit for farmers.
- 4. Soil Degradation:** Continuous farming and excessive use of chemicals harm soil health. Over time, the soil loses its fertility, leading to reduced agricultural productivity.
- 5. Market Instability:** Fluctuating market prices and lack of stable selling platforms create uncertainty for farmers. They often struggle to get fair prices for their produce, affecting their income stability.

### **Discussion**

The agricultural transformation observed in Indapur Taluka reflects wider patterns of rural development in semi-arid regions. While the shift to commercial crops has improved income levels, it has also increased reliance on water resources.

Technological advancements have boosted productivity but have introduced environmental concerns, particularly regarding water depletion and soil health. Therefore, it is essential to adopt a balanced approach that integrates economic growth with environmental sustainability. Strategies such as crop diversification, efficient irrigation practices, and sustainable land management are critical for achieving long-term agricultural stability.

### **Conclusion**

Indapur Taluka exemplifies a rapidly evolving agricultural landscape. The transition from traditional farming to commercial agriculture has brought

economic advantages but has also introduced new challenges.

### **1. Improved Water Management Techniques**

Achieving sustainability requires better management of water resources. Methods like drip irrigation, rainwater collection, and efficient storage help minimize water loss and ensure a steady supply for crops, even in dry conditions.

### **2. Promotion of Climate-Resilient Crops**

Growing crops that are tolerant to drought, heat, and unpredictable rainfall can help farmers cope with changing climate conditions. These crops provide more reliable yields and reduce the chances of crop failure.

### **3. Effective Policy Support from the Government**

Supportive government measures such as subsidies, financial assistance, insurance schemes, and infrastructure development play a vital role in promoting sustainable agriculture and reducing farmers' risks.

### **4. Increased Awareness among Farmers Regarding Sustainable Practices**

Spreading knowledge about eco-friendly farming methods like crop rotation, organic farming, and soil conservation helps farmers maintain productivity while protecting natural resource. This study underscores the significance of localized geographical research in guiding regional planning and sustainable development.

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2. Official reports issued by the Zilla Parishad, Pune
3. Scholarly publications focusing on agriculture in Maharashtra
4. Research studies related to irrigation practices and semi-arid agricultural systems

# Management of Soil Salinity of Shrigonda Taluka for Irrigated Land

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## Abstract

Soil salinity is a key constraint on agricultural productivity in irrigated environments, especially semi-arid areas. Shrigonda taluka in Ahmednagar district, Maharashtra, is an important agricultural region where irrigation is frequently used for sugarcane, wheat, and horticulture crops. Continuous watering without sufficient drainage and soil management has resulted in the buildup of soluble salts in agricultural fields. Soil salinity lowers fertility, disrupts nutrient balance, and restricts crop productivity. Therefore, effective management of saline soils is crucial for sustained agriculture. This study report examines the origins, effects, and management solutions for soil salinity in Shrigonda taluka's irrigated areas. The study focuses on irrigation management, drainage improvement, soil amendments, and crop selection for salinity control. The use of integrated soil and water management strategies has the potential to greatly improve soil health and agricultural output in the region.

## Introduction

Agriculture is the lifeblood of the rural economy in many regions of Maharashtra. Shrigonda taluka in Ahmednagar district is notable for its irrigated agriculture and crop farming, including sugarcane, wheat, and vegetables. However, increased reliance on irrigation and groundwater extraction has resulted in a number of environmental issues, the most significant of which is soil salinity.

Soil salinity is defined as the accumulation of soluble salts in the soil, including sodium, calcium, magnesium, and chloride. When salt concentrations become too high, they inhibit plant growth and diminish crop yield. Even when there is enough water in the soil, salinity has an impact on plants' ability to absorb water and nutrients. Crops may fail totally in extreme conditions. Shrigonda taluka, a semi-arid region, is particularly susceptible to soil salinity

due to high evaporation rates, little rainfall, and poor irrigation techniques. As a result, identifying the causes and implementing appropriate management measures are critical for ensuring agricultural productivity and sustainable land use.

### **Study Area: Shrigonda Taluka**

Shrigonda Taluka in Maharashtra's Ahmednagar district is in the semi-arid Deccan Plateau climate zone. The region experiences modest rainfall, primarily during the southwest monsoon. Agriculture in the area is primarily reliant on irrigation from wells, borewells, and canal systems.

The soils in the region are primarily black cotton soils (regur soils), which are high in clay concentration. These soils are often rich, but have poor drainage properties. Continuous irrigation, due to their great water-holding capacity, can produce waterlogging and salt accumulation.

The expansion of irrigated agriculture in the last few decades has increased agricultural production, but it has also created problems such as soil salinity and declining soil fertility. Therefore, scientific soil and water management practices are necessary to maintain sustainable agriculture in Shrigonda taluka.

### **Causes of Soil Salinity**

Soil salinity in Shrigonda taluka's irrigated lands is influenced by both natural and human influences. Excessive irrigation is one of the leading culprits. When farmers apply more water than is needed, the excess evaporates from the soil surface, leaving behind dissolved salts. Over time, these salts build up in the root zone. Poor drainage is another key consideration. Salts cannot be rinsed out of the soil profile in locations with poor drainage systems. Instead, they remain in the soil, gradually increasing their concentration.

The use of saline groundwater for irrigation also increases soil salinity. Groundwater in semi-arid environments typically contains dissolved salts. Continuous usage of such water promotes salt accumulation in the soil. Climatic circumstances are also an important factor. High temperatures and intense sunlight cause quick evaporation, resulting in salt buildup on the soil surface. These factors together accelerate the process of soil salinization in irrigated areas.

Table: Major Causes of Soil Salinity

<b>Cause</b>	<b>Description</b>
Excess Irrigation	Application of more irrigation water than required leading to salt accumulation.

Poor Drainage	Lack of proper drainage prevents removal of salts from soil.
Saline Groundwater	Irrigation using water containing dissolved salts.
High Evaporation	Hot climate increases evaporation leaving salts on soil surface.

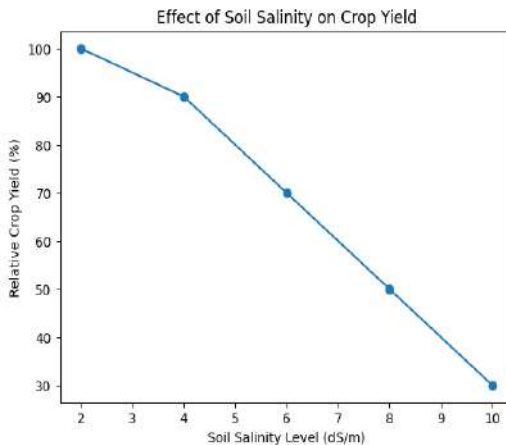
**Effects of Soil Salinity on Agriculture**

Soil salinity has a major impact on agricultural output and soil health. High salt concentrations limit plants' ability to absorb water from the soil. As a result, even when there is enough water, plants are stressed in ways comparable to drought.

Salinity also has an impact on soil structure, scattering soil particles and limiting soil permeability. This leads to inadequate aeration and limited root development. Furthermore, salinity reduces the availability of critical nutrients including nitrogen, potassium, and phosphorus.

Crop production falls dramatically in saline soils. Sensitive crops may exhibit signs such as poor germination, stunted growth, leaf burn, and decreased output. Farmers in saline locations frequently experience economic losses due to falling agricultural yields.

**Relationship between Soil Salinity and Crop Yield**



**Management of Soil Salinity**

To effectively regulate soil salinity, physical, chemical, and biological methods must be used in conjunction. Proper irrigation management is vital. Farmers should use irrigation water based on crop requirements and avoid over-

irrigation. Using micro-irrigation technologies like drip irrigation can save water and prevent salt formation. Improvements to drainage systems are another key method. Surface and subsurface drainage systems serve to remove surplus water and dissolved salts from the soil.

In saline soils, the application of soil additives such as gypsum can improve soil structure while decreasing sodium content. Organic matter, such as farmyard manure, compost, and green manure, boosts soil fertility and microbial activity. Farmers can efficiently manage saline soils by cultivating salt-tolerant crops and using crop rotation strategies. Crops that can tolerate salt include barley, cotton, and certain wheat cultivars

### **Conclusion**

Soil salinity is a major environmental issue in the irrigated agricultural lands of Shrigonda taluka. The problem is primarily caused by excessive irrigation, inadequate drainage, saline groundwater, and high evaporation rates. Soil salinity, if not managed appropriately, can have a negative impact on agricultural production.

However, the issue can be addressed by integrated soil and water management approaches. Efficient irrigation, increased drainage, soil additives, and salt-tolerant crops can considerably reduce salinity issues. Sustainable soil management is crucial for achieving long-term agricultural productivity and environmental stability in Shrigonda taluka. With adequate planning, farmer awareness, and scientific management practices, saline soils can be restored and used for agricultural purposes.

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# Assessment of the Soil and Water Analysis of Saradwadi Village in Shirur Tahsil of Pune district, Maharashtra

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## Abstract

The sustainable management of the soil and water resources is essential for maintaining environmental balance in rural regions. The present study examines the assessment of soil and water quality in Saradwadi village in Shirur tahsil of the Pune District, Maharashtra, India. The main objective of the study is to evaluate the physicochemical characteristics of soil and groundwater and to understand their suitability for agricultural use. Water and Soil samples were collected from different locations in the village and analysed using FFM software techniques. Important parameters such as pH, electrical conductivity (EC), organic carbon, nitrogen, phosphorus, potassium for soil, and pH, total dissolved solids (TDS), hardness, alkalinity, and major ions for water were examined. The result indicates soil and water is totally polluted across the study area. In some locations, soil nutrients were found to be moderate for crop cultivation, while maximum areas showed signs of nutrient deficiency and salinity. Water quality analysis revealed that most groundwater samples are not suitable for irrigation and domestic purposes, though certain parameters in some locations approach permissible limits. The study highlights the need for scientific soil management practices, balanced fertilizer use, and regular monitoring of water quality to ensure sustainable agricultural development in Saradwadi village. The findings of this research provide useful insights for farmers, local planners, and policymakers to improve sustainable resource management in the region.

**Keywords:** Sustainable Management, Soil, Water and FFM

## Introduction

Soil and water are the most important natural resources that support agricultural production.<sup>1</sup> Hence water and soil quality directly influences crop growth, soil fertility, and the sustainability of farming systems. In recent years, increasing population pressure, intensive agricultural practices, excessive use of chemical

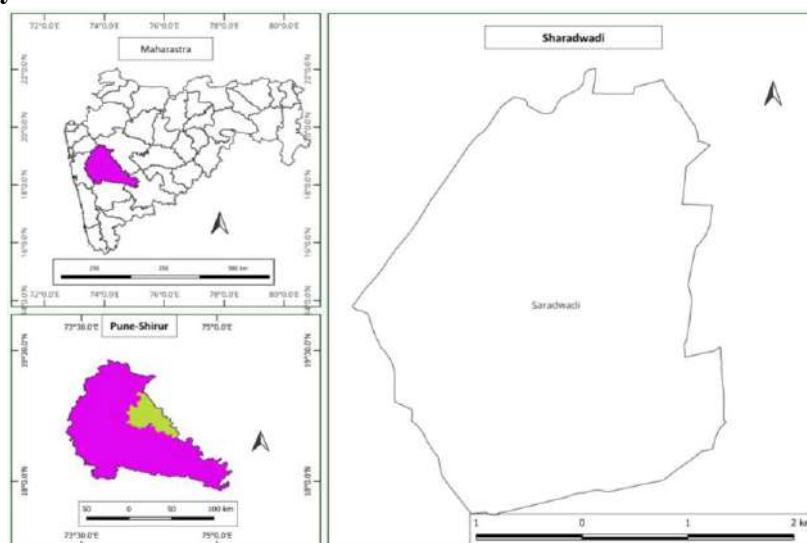
fertilizers, and improper water management have led to changes in soil properties and deterioration of water quality in many rural areas. Therefore, regular assessment of soil and water quality is essential for sustainable agricultural development and effective resource management.<sup>2</sup>

Soil analysis provides valuable information about nutrient availability, soil reaction, salinity, and overall fertility status, which helps farmers adopt suitable cropping patterns and balanced fertilizer application. Similarly, water quality analysis helps in determining the suitability of water for irrigation and domestic use by examining parameters such as pH, electrical conductivity, total dissolved solids, hardness, and major chemical ions. These parameters play a crucial role in maintaining soil health and crop productivity.<sup>3,4</sup>

The present study focuses on the assessment of soil and water quality in Saradwadi Village, which is located in Shirur tehsil of Pune district. Agriculture is the primary occupation of the villagers, and the productivity of crops largely depends on the quality of soil and availability of groundwater resources. However, variations in soil nutrients and groundwater characteristics may affect agricultural sustainability in the region.

Therefore, the present study aims to analyse the physicochemical properties of soil and water in Saradwadi village and evaluate their suitability for agricultural use. The findings of this study will help in understanding the current status of soil fertility and water quality and will provide useful suggestions for better soil management, efficient water use, and sustainable agricultural practices in the study area.

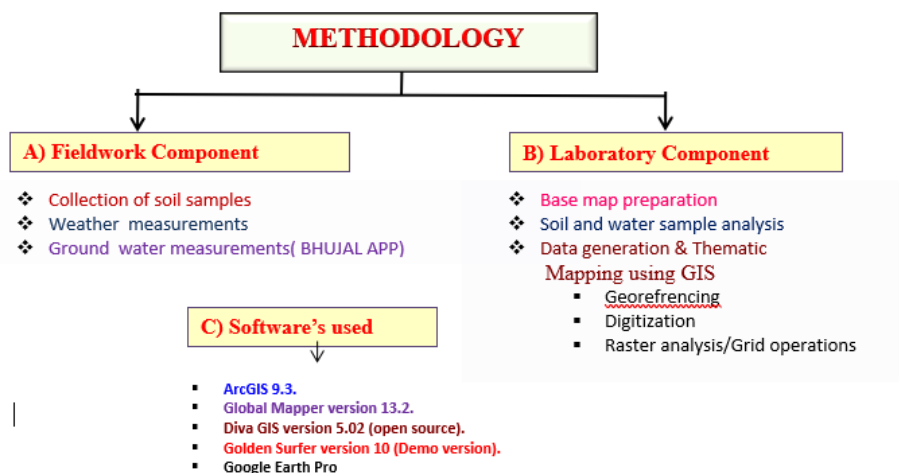
## 1. Study Area



**Fig No.1. Location Map of the study Area**

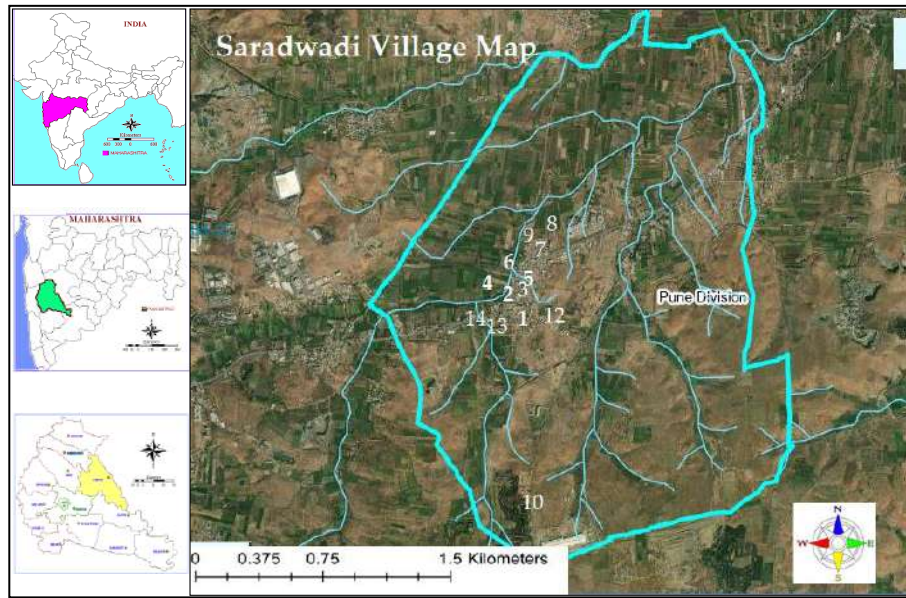
## Methodology

Following Methodology is adopted for the analysis of Soil and water of the Saradwadi



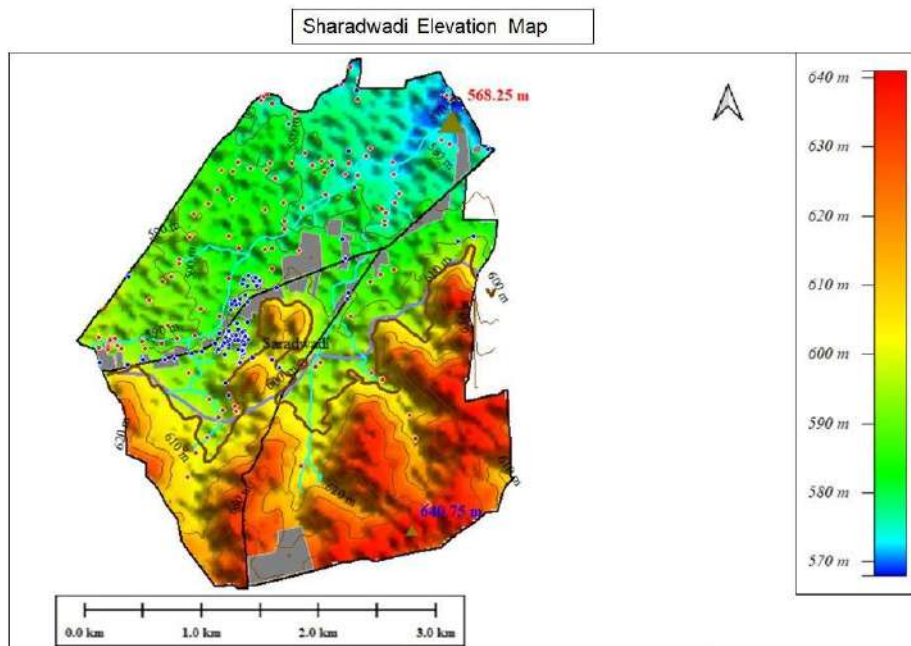
## Result

The analysis of soil and water samples collected from different locations in Saradwadi Village revealed variations in their physicochemical characteristics. The soil analysis showed that the pH values ranged from slightly alkaline to moderately alkaline, which is typical for soils developed over basaltic formations of the Deccan Plateau. Electrical conductivity values were generally within the permissible limits, indicating that most of the soils are non-saline and suitable for agricultural activities. The organic carbon content in many samples was found to be moderate, suggesting the need for improved organic matter management through the use of farmyard manure, compost, and crop residues. The macronutrient analysis indicated that nitrogen levels were generally low to moderate, which is common in cultivated soils due to continuous cropping and insufficient organic inputs. Phosphorus levels ranged from moderate to high in some areas due to the regular application of phosphate fertilizers, while potassium content was mostly adequate because of the mineral composition of the parent basaltic rocks.

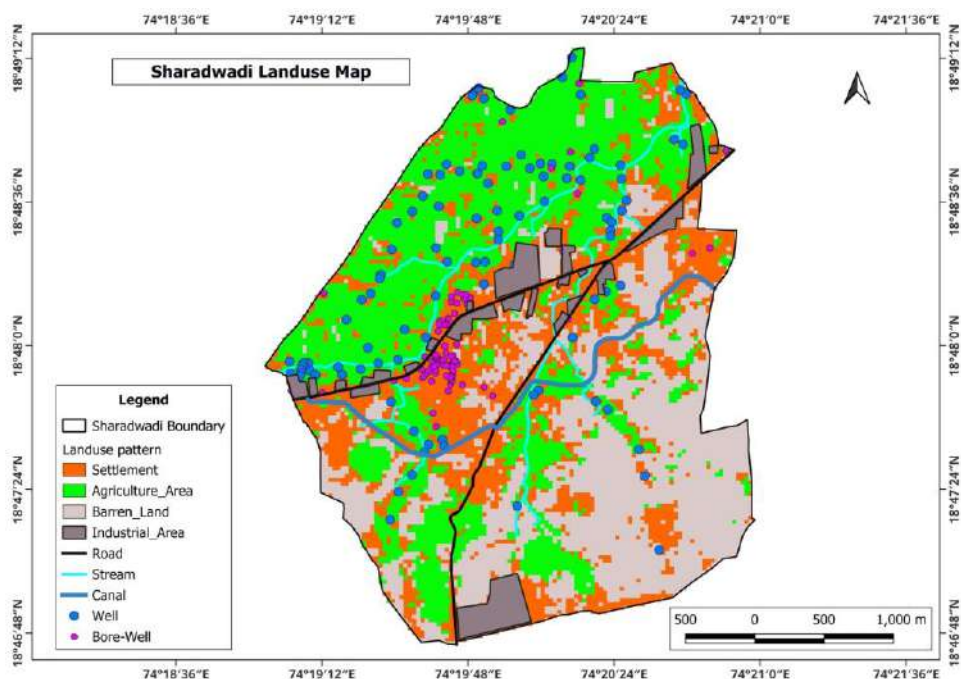


**Fig.4. Drainage map and Water Sample GPS Locations**

Water quality analysis showed that the pH of groundwater samples was within the acceptable range, indicating slightly alkaline nature. The total dissolved solids (TDS), hardness, and alkalinity values were generally within permissible limits for irrigation and



**Fig. No.5. DEM map of Saradwadi village**



**Fig.No.6 LULC map of Saradwadi Village**

domestic purposes. However, in a few locations, relatively higher TDS and hardness values were observed, which may be associated with local geological conditions and groundwater extraction patterns.

Overall, the results suggest that the soil and water resources of Saradwadi village are generally not suitable for agricultural use, though some areas require improved soil fertility management and regular monitoring of groundwater quality. Adoption of balanced fertilizer application, organic farming practices, and efficient irrigation management can further enhance soil health and ensure sustainable agricultural productivity in the region.

The Land Use and Land Cover (LULC) pattern of Saradwadi Village reflects the dominance of agricultural activities, which form the backbone of the village economy. Most of the land in the village is utilized for agricultural purposes, including both irrigated and rainfed farming. Major crops grown in the area include sugarcane, wheat, jowar, bajra, and vegetables, depending on the availability of irrigation and seasonal rainfall.

Saradwadi village area is affected by industrial region. A significant portion of the land is classified as cropland, supported by irrigation sources such as wells, borewells, and nearby canal systems. Built-up areas include residential houses, roads, schools, and other village infrastructure, which occupy a relatively small

part of the total land area. Fallow land is also observed in certain parts of the village, particularly during the non-cropping season or in areas with limited irrigation facilities.

### **Recommendations**

Finally, here attempt was made to give reliable remedial measures to combat further groundwater contamination in Saradwadi. These include

- Proper treatment and disposal of the industrial and municipal effluent.
- Proper drainage for the domestic and agricultural wastes.
- Less usage of chemical and hazardous fertilizers.
- Villagers should be encouraged to switch to organic farming by using domestic waste and also promote in-site farming.
- Proper and hygienic maintenance of the sanitary conditions of the area. And above all, the inhabitants should be aware of the situation and should be given proper knowledge to improve their own hygienic habits. The public should train to protect potable water from further contamination.

Further research should be carried out for a detailed study on groundwater quality and to find out some more efficient remedial measures to overcome the groundwater contamination problem in Saradwadi.

### **Conclusion**

The present study on soil and water analysis in Saradwadi Village highlights the current status of soil fertility and groundwater quality in the agricultural landscape of the village. The results indicate that the ground water of the Saradwadi is polluted and soils of the study area are generally slightly alkaline and moderately fertile, with adequate potassium and moderate phosphorus levels, while nitrogen content in some locations is comparatively low. The electrical conductivity values suggest that the soils are mostly non-saline and suitable for crop cultivation.

The groundwater analysis shows that most of the water samples fall within permissible limits for irrigation and domestic use, although slight variations in parameters such as total dissolved solids and hardness were observed at certain locations. These variations are influenced by geological conditions and agricultural practices in the region.

The Land Use and Land Cover (LULC) pattern of the village indicates that agriculture is the dominant land use, supported by irrigation through wells, borewells, and seasonal rainfall. The study emphasizes the importance of

balanced fertilizer use, organic matter management, and regular monitoring of soil and water quality to maintain long-term agricultural productivity.

Overall, the findings suggest that the soil and water resources of Saradwadi village are suitable for sustainable agricultural development but more efforts are required for proper Soil and water management. Proper soil and water management practices consists efficient irrigation methods, and conservation measures should be adopted. Such practices will help improve soil health, maintain water quality, and support sustainable farming in the region.

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# **Sustainable and Renewable Energy Resources: A Pathway Towards Sustainable Development**

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## **Abstract**

The rapid growth of global energy demand, coupled with environmental degradation and climate change, has intensified the need for sustainable energy systems. Renewable energy resources provide environmentally friendly and economically viable alternatives to fossil fuels. This research paper examines the concept of sustainable energy, major renewable energy resources, environmental and socio-economic benefits, key implementation challenges, and future prospects. The study is based on secondary data from international energy organizations and policy reports. The findings indicate that renewable energy is central to achieving climate goals, enhancing energy security, and promoting long-term sustainable development.

**Keywords:** Renewable energy, sustainable development, solar energy, wind power, climate change, energy security

## **Introduction**

Energy is fundamental to economic growth and human development. Industrialization, urbanization, and technological advancement have significantly increased global energy consumption. Historically, fossil fuels such as coal, oil, and natural gas have dominated the global energy system. However, these resources are finite and are the primary contributors to greenhouse gas emissions.

Scientific assessments by the Intergovernmental Panel on Climate Change (2022) confirm that fossil fuel combustion is the leading cause of global warming. Rising temperatures, extreme weather events, and environmental degradation highlight the urgent need to transition toward sustainable energy

sources. Renewable energy offers a practical and long-term solution to these challenges.

### **Concept of Sustainable Energy**

Sustainable energy refers to energy systems that meet present needs without compromising future generations. It is based on three pillars:

- Environmental Protection
- Economic viability
- Social equity

According to the International Energy Agency (2024), renewable energy deployment is critical for achieving global net-zero emissions targets. Sustainable energy systems reduce carbon footprints while ensuring affordable and reliable energy access.

### **Literature Review**

Extensive research has been conducted on renewable energy transitions. The International Renewable Energy Agency (2023) highlights that renewable energy capacity has grown rapidly over the past decade, particularly in solar and wind sectors. Their reports emphasize declining technology costs and increasing employment opportunities in the renewable energy industry.

The Global Wind Energy Council (2023) reports steady global growth in wind power capacity, with offshore wind emerging as a significant contributor to future expansion.

Scholarly studies also identify key barriers such as high capital investment, intermittency issues, storage limitations, and grid integration challenges. Policy-driven frameworks and technological advancements are widely recognized as essential for accelerating renewable energy adoption.

In India, policy initiatives under the Ministry of New and Renewable Energy have contributed significantly to expanding renewable energy capacity. Literature indicates that India is emerging as a major global player in solar energy production.

### **Research Methodology**

#### **Research Design**

This study follows a descriptive and analytical research design to examine renewable energy resources and their role in sustainable development.

## **Data Sources**

The research is based on secondary data collected from:

- International energy agency reports
- Government policy documents
- Academic research journals
- Renewable energy statistical databases

Major institutional references include:

- International Energy Agency
- Intergovernmental Panel on Climate Change
- International Renewable Energy Agency

## **Data Analysis Techniques**

- Comparative analysis of renewable vs. fossil fuels
- Trend analysis of capacity growth
- Policy evaluation framework

## **Limitations**

The study relies on secondary data and may not include the most recent unpublished statistics.

## **Major Renewable Energy Resources**

- 1. Solar Energy:** In Solar energy mostly using photovoltaic panels and solar thermal systems. It is abundant, clean, and increasingly cost-effective. Technological advancements have significantly reduced installation costs over the past decade.
- 2. Wind Energy:** Wind turbines convert kinetic energy into electricity. Wind power is one of the fastest-growing renewable energy sources globally and is particularly effective in coastal and open regions.
- 3. Hydropower:** Hydropower generates electricity using flowing water. It provides reliable baseload power but requires careful environmental management.
- 4. Biomass Energy:** Biomass energy utilizes organic materials such as agricultural waste and animal residues to generate heat and electricity. It supports rural energy needs and waste management.

5. **Geothermal Energy:** Geothermal power utilizes underground heat to generate electricity. It provides continuous energy supply but is geographically limited.

### **Environmental and Socio-Economic Benefits**

1. **Climate Change Mitigation:** Renewable energy significantly reduces carbon emissions. Rapid deployment is essential to meet global climate targets.
2. **Energy Security:** Domestic renewable energy production reduces dependence on imported fuels and enhances national security.
3. **Employment Generation:** The renewable energy sector generates employment in manufacturing, installation, maintenance, and research sectors.
4. **Public Health Benefits:** Reducing fossil fuel combustion lowers air pollution and improves public health outcomes.

### **Challenges in Renewable Energy Development**

Despite its advantages, renewable energy faces several challenges:

- High initial capital costs
- Intermittent energy supply
- Storage technology limitations
- Grid integration barriers
- Land acquisition concerns

Addressing these issues requires policy reforms, investment in storage technologies, and modernization of grid infrastructure.

### **Renewable Energy Scenario in India**

India has emerged as one of the fastest-growing renewable energy markets globally. National initiatives promote solar parks, wind farms, rooftop solar installations, and green hydrogen production. India aims to significantly increase its non-fossil fuel capacity by 2030, demonstrating strong commitment to sustainable energy transition.

### **Future Prospects**

The future of renewable energy lies in:

- Advanced battery storage systems
- Smart grid integration

- Green hydrogen production
- Artificial intelligence-based energy forecasting
- Hybrid renewable systems

Continuous innovation and investment will accelerate global clean energy transformation.

## **Conclusion**

Renewable energy resources are central to sustainable development and climate change mitigation. Transitioning from fossil fuels to renewable energy is not only environmentally necessary but also economically advantageous. Although challenges exist, technological advancements, supportive policies, and international cooperation will ensure a sustainable and low-carbon energy future.

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# Assessment of Agricultural Vulnerability Using Climate and Socio-Economic Indicators: A Descriptive Analysis of Karjat Taluka, Maharashtra

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## Abstract

Agriculture in semi-arid regions is increasingly affected by climate fluctuations and socio-economic challenges, resulting in heightened vulnerability. This study presents a spatial analysis of agricultural vulnerability in Karjat taluka of Ahilyanagar district, Maharashtra, by combining climate-related and socio-economic indicators within a Geographic Information System (GIS) framework. Key variables such as rainfall variability, temperature patterns, soil characteristics, irrigation availability, landholding size, and literacy rates were examined to understand spatial differences in vulnerability. The results indicate that vulnerability is most pronounced in rainfed areas with weaker socio-economic conditions, while regions with better irrigation and infrastructure show comparatively lower vulnerability. The study demonstrates the significance of integrating environmental and socio-economic factors and highlights the usefulness of geospatial tools in guiding climate-resilient agricultural planning.

**Keywords:** Agricultural vulnerability, Spatial analysis, Climate variability, Socio-economic indicators, GIS, Karjat taluka

## Introduction

In India, agriculture plays a vital role in sustaining rural livelihoods, especially in semi-arid regions where climatic uncertainties are a major concern. Over recent years, increasing irregularities in rainfall, rising temperatures, and frequent drought events have intensified pressures on agricultural systems. These environmental stresses are further aggravated by socio-economic

constraints such as fragmented landholdings, inadequate irrigation, and limited access to resources and technology.

Ahilyanagar district (previously known as Ahmednagar) in Maharashtra is considered one of the drought-prone regions, with Karjat taluka facing significant vulnerability due to its reliance on monsoon rainfall and uneven irrigation distribution. Agricultural vulnerability in such regions is influenced not only by climate variability but also by socio-economic conditions that determine farmers' ability to adapt.

Geographic Information Systems (GIS) provide an effective platform to examine these interrelated factors spatially. By integrating multiple datasets, spatial analysis helps in identifying vulnerable regions and supporting targeted policy interventions.

This study aims to present a descriptive spatial assessment of agricultural vulnerability in Karjat taluka by incorporating both climate and socio-economic indicators.

### **Study Area**

Karjat taluka is situated in the southern part of Ahilyanagar district in Maharashtra, India. It falls within the rain shadow region of the Western Ghats and experiences a semi-arid climate marked by low and inconsistent rainfall. The topography mainly consists of plateau areas with gentle slopes, and the dominant soil type is black cotton soil, which retains moisture to a moderate extent.

Agriculture is the primary livelihood activity in the region, with a majority of farmers practicing rainfed farming. Major crops include kharif crops such as bajra, soybean, and pulses, and rabi crops like wheat, gram, and jowar. Irrigation facilities are limited and unevenly distributed, relying on wells, borewells, and canal systems in certain locations.

### **Data and Methodology**

#### **Data Sources**

The analysis is based on secondary data obtained from various sources, including:

- Meteorological data on rainfall and temperature
- Soil and land resource databases
- Land Use/Land Cover (LULC) data derived from satellite imagery
- Digital Elevation Model (DEM) for terrain assessment

- Socio-economic data from census and district statistics

### **Indicator Framework**

Agricultural vulnerability was assessed using a set of indicators organized into three primary dimensions: exposure, sensitivity, and adaptive capacity. Each dimension highlights a specific aspect that contributes to the overall vulnerability of farming systems.

#### **Exposure (Climate Factors)**

This component represents the degree to which agriculture is affected by climatic conditions. It includes indicators such as changes in rainfall patterns, temperature variations, and the occurrence of droughts, all of which have a direct impact on crop performance and productivity.

#### **Sensitivity (Environmental Factors)**

Sensitivity describes how agricultural systems react to environmental and climatic stresses. It is determined by factors like soil characteristics, land slope, and land use patterns. Regions with fragile soils, uneven terrain, or unsuitable land use tend to be more susceptible to damage.

#### **Adaptive Capacity (Socio-Economic Factors)**

Adaptive capacity refers to the capability of farmers to adjust to and manage climatic risks. It is influenced by socio-economic conditions such as availability of irrigation, size of landholdings, education levels, and access to infrastructure. Greater adaptive capacity enables farmers to better withstand and recover from adverse condition

#### **Analytical Approach**

All spatial datasets were processed and analyzed using GIS software. The data layers were standardized using normalization techniques to ensure uniformity. A descriptive analytical approach was used to examine spatial variations in each indicator. A composite vulnerability index was generated by combining exposure, sensitivity, and adaptive capacity indicators. Based on the index values, the study area was classified into different levels of vulnerability

### **Results and Discussion**

#### **• Climate Variability and Exposure**

The study reveals that Karjat taluka experiences considerable rainfall variability, with irregular monsoon patterns and frequent dry spells. Even

though the total annual rainfall may appear adequate, its uneven temporal distribution often results in drought-like conditions affecting crop production. Additionally, a gradual increase in temperature has been observed, contributing to higher evapotranspiration and heat stress.

These climatic factors significantly increase the exposure of agricultural systems, particularly in rain-dependent areas.

- **Environmental Sensitivity**

Environmental characteristics strongly influence agricultural sensitivity in the region. Areas with shallow soils and sloping terrain are more susceptible to runoff and soil erosion, which reduces moisture availability. The plateau-dominated landscape further intensifies drought vulnerability.

Land use practices also affect sensitivity. Regions practicing monocropping are more vulnerable to climatic shocks compared to areas with diversified cropping systems.

- **Socio-Economic Factors and Adaptive Capacity**

Socio-economic conditions play a crucial role in determining farmers' resilience. The findings indicate that small and marginal farmers are more vulnerable due to limited financial resources and restricted access to irrigation facilities.

Irrigation availability is a key factor enhancing adaptive capacity. Areas with access to water sources such as canals, wells, and borewells demonstrate greater resilience. Additionally, higher literacy levels and better access to infrastructure, including transportation and markets, contribute positively to adaptive capacity.

- **Spatial Distribution of Vulnerability**

The combined analysis of climate and socio-economic indicators reveals distinct spatial patterns:

- **High Vulnerability Zones:** Predominantly rainfed areas with high climate variability, poor soil conditions, and limited socio-economic resources.
- **Moderate Vulnerability Zones:** Areas with moderate environmental stress and partial access to irrigation and infrastructure.
- **Low Vulnerability Zones:** Regions with better irrigation facilities, diversified agriculture, and stronger socio-economic conditions.

## **Discussion**

Results emphasize that agricultural vulnerability in Karjat taluka arises from the interaction of climatic stressors and socio-economic limitations. While climate variability increases exposure, the ability of farmers to adapt depends largely on socio-economic factors.

The study highlights that improvements in irrigation infrastructure, promotion of crop diversification, and enhancement of socio-economic conditions can significantly reduce vulnerability. Spatial analysis using GIS proves to be a valuable tool for identifying priority areas and guiding policy decisions.

## **Conclusion**

This study provides a detailed descriptive spatial analysis of agricultural vulnerability in Karjat taluka by integrating climate and socio-economic indicators. The findings indicate that vulnerability is highest in rainfed and socio-economically weaker regions, whereas areas with better irrigation and infrastructure show greater resilience.

The research underscores the importance of combining environmental and socio-economic perspectives in vulnerability assessment. Geospatial tools offer significant potential for supporting informed decision-making and developing targeted adaptation strategies.

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# **Agricultural Land Use and Vulnerability Assessment in Daund Taluka, Pune District Using Remote Sensing**

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## **Abstract**

Agriculture in Daund Taluka, Pune District, is heavily influenced by climatic variability, soil characteristics, and water availability. The region experiences a semi-arid climate with irregular and unpredictable rainfall, making irrigation and adaptive agricultural practices essential for crop productivity. Over the years, cropping patterns have shifted, with commercial crops gaining prominence and modern agricultural techniques being increasingly adopted. Understanding agricultural vulnerability, land use dynamics, and cropping trends is critical for promoting sustainable agriculture and improving the socio-economic well-being of farmers.

## **Study Area**

Daund Taluka is located in the eastern part of Pune District in Maharashtra, India. The region has undulating terrain, diverse soil types, and semi-arid climatic conditions. Agricultural productivity is highly dependent on canal irrigation as well as seasonal monsoon rainfall. Spatial variation in water availability, soil quality, and socio-economic factors such as landholding size and infrastructure access influence cropping patterns, farming strategies, and adaptive capacity across the taluka.

## **Materials and Methods**

### **Data Collection**

This study utilized satellite imagery, including NDVI (Normalized Difference Vegetation Index) data, to assess vegetation density, crop health, and land use patterns. Socio-economic and environmental data were sourced from government reports, district census handbooks, and published research articles. Historical irrigation and cropping records were analyzed to identify temporal trends and understand the evolution of land use in the taluka.

### **Vulnerability Indicator Framework**

Agricultural vulnerability was evaluated using a framework comprising three dimensions:

- **Exposure (Climatic Factors):** Rainfall variability, temperature fluctuations, and frequency of drought events.
- **Sensitivity (Environmental Factors):** Soil characteristics, slope of land, and land use patterns.
- **Adaptive Capacity (Socio-Economic Factors):** Access to irrigation, landholding size, literacy levels, and infrastructure availability.

This framework enabled the identification of regions that are highly susceptible to environmental and climatic stresses, as well as areas capable of coping with and adapting to adverse conditions.

### **Agricultural Land Use Patterns**

Agricultural land use in Daund Taluka is largely determined by water availability and soil characteristics:

- **Irrigated Crops:** Sugarcane and wheat dominate areas with canal irrigation due to their high-water requirements and consistent yields.
- **Rainfed Crops:** Drought-tolerant crops such as jowar, bajra, and pulses are cultivated in areas with limited rainfall.
- **Commercial Crops:** Cotton cultivation is increasing, motivated by higher economic returns, resulting in a gradual shift from traditional food crops.
- **Mixed Cropping:** Farmers practice intercropping to reduce risks associated with climate variability and fluctuating market prices.

Satellite imagery analysis highlights spatial variations in vegetation density, reflecting differences in crop health and productivity. Denser vegetation is observed in irrigated areas, while drought-prone zones exhibit sparser growth.

### **Vegetation Analysis Using NDVI**

NDVI analysis provided critical insights into crop conditions and vegetation cover:

- High vegetation density was recorded in irrigated regions, indicating healthy crop growth.
- Moderate vegetation was observed in rainfed areas, suggesting limited water availability affects crop vigor.
- Low vegetation was noted in drought-affected zones, reflecting stressed crops.

These patterns highlight the crucial role of irrigation in sustaining agriculture

and the spatial heterogeneity of crop health across the taluka. Seasonal NDVI variations also provide insights into temporal changes in crop growth, aiding planning and resource allocation.

### **Trends in Cropping Patterns**

Remote sensing data revealed several trends:

- Expansion of cotton cultivation in areas previously under traditional crops.
- Decline in land devoted to conventional food crops, reflecting a shift toward higher-value commercial crops.
- Growth in irrigated agriculture as farmers invest in water management infrastructure to stabilize yields and reduce dependency on rainfall.

These trends indicate that economic incentives and water accessibility are significant drivers of changes in land use and cropping patterns.

### **Advantages of Remote Sensing**

Remote sensing provides multiple benefits for agricultural monitoring:

- **Large-Scale Monitoring:** Enables observation of extensive agricultural areas efficiently.
- **Reduced Field Surveys:** Minimizes labor-intensive and time-consuming ground surveys.
- **Early Detection of Crop Stress:** NDVI and other indices detect water, nutrient, or pest-related stress before visible symptoms appear.
- **Support For Precision Farming:** Spatial data aids in optimizing irrigation, fertilizer application, and crop planning.
- **Disaster Management:** Monitors droughts, floods, and other climatic hazards, facilitating timely intervention.

These advantages make remote sensing indispensable for sustainable agricultural planning, efficient resource management, and enhancing resilience to climatic risks.

### **Discussion and Policy Implications**

The findings of this study have important implications for agricultural planning and policy-making:

- **Water Resource Management:** The dependence on irrigation highlights the need for efficient water management systems. Promoting micro-irrigation techniques such as drip and sprinkler systems can enhance water use efficiency and reduce pressure on canal networks.

- **Climate-Resilient Crops:** Regions with high climatic vulnerability require the promotion of drought-tolerant and short-duration crop varieties. This can help farmers adapt to rainfall variability and reduce the risk of crop failure.
- **Support for Mixed Cropping:** Encouraging mixed cropping systems can enhance resilience by diversifying income sources and reducing the risks associated with market fluctuations or crop-specific climatic damage.
- **Technology Adoption:** Remote sensing and NDVI-based monitoring should be integrated into routine agricultural extension services. Real-time crop health monitoring can inform irrigation scheduling, fertilizer application, and pest management decisions.
- **Market and Economic Incentives:** Policies supporting fair pricing, market access, and subsidies for commercial crops can guide cropping choices while ensuring food security and farmer income stability.
- **Disaster Preparedness:** Early warning systems using remote sensing can improve disaster response to droughts and floods, minimizing crop losses and supporting farmer resilience.

Implementing these strategies can strengthen agricultural sustainability, enhance productivity, and reduce vulnerability in semi-arid regions like Daund Taluka.

## **Conclusion**

Agriculture in Daund Taluka is strongly influenced by irrigation, soil quality, and socio-economic conditions. Irrigated areas favor water-intensive crops such as sugarcane and wheat, while rainfed areas cultivate drought-resistant crops such as jowar, bajra, and pulses. Commercial crops, particularly cotton, are expanding, and mixed cropping remains an important risk mitigation strategy.

NDVI-based vegetation analysis confirms the vital role of irrigation in maintaining crop health and productivity. Remote sensing enables large-scale monitoring, early detection of crop stress, precision farming, and disaster preparedness. Integrating satellite data with socio-economic and environmental indicators provides a comprehensive understanding of agricultural vulnerability and land use dynamics. These insights are critical for guiding sustainable agricultural practices, efficient resource allocation, and climate adaptation strategies in the region.

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# Assessing the Environmental Impacts of Climate Change: A Pathway toward Resilient Ecosystems

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## Abstract

Climate change remains one of the most pressing environmental challenges of the 21st century, significantly altering the Earth's ecological balance. Recent assessments by the Intergovernmental Panel on Climate Change indicate that global temperatures have already increased by approximately 1.2°C above pre-industrial levels (2023), with projections suggesting a likely breach of the 1.5°C threshold within the next decade. This study examines the environmental impacts of climate change, including biodiversity loss, water scarcity, land degradation, ocean warming, and public health risks, while exploring pathways toward resilient ecosystems through sustainable adaptation and mitigation strategies. Using updated secondary data from global climate reports and Indian case studies, the paper highlights the role of ecosystem-based adaptation (EbA), technological innovation, and policy integration. The findings suggest that although climate change poses irreversible risks, strategic governance and community-driven approaches can significantly enhance ecological resilience.

**Keywords:** Climate Change, Ecosystem Resilience, Biodiversity, Sustainability, Adaptation, Environmental Policy

## Introduction

Climate change represents a global environmental crisis with far-reaching consequences. According to the World Meteorological Organization, 2023 was the warmest year on record, with global temperatures approximately 1.45°C above pre-industrial levels. This warming has intensified extreme weather events, including heatwaves, floods, and cyclones, disrupting ecosystems and human livelihoods. India faces acute vulnerabilities due to its diverse

geography. The Himalayan region is experiencing accelerated glacier melt, while coastal regions such as the Sundarbans are threatened by rising sea levels. Monsoon variability further exacerbates water stress and agricultural instability. This paper evaluates environmental impacts and proposes integrated strategies for building resilient ecosystems.

### **Review of Literature**

Several studies have highlighted the multidimensional impacts of climate change on the environment. According to Stern (2006), unchecked climate change could lead to economic losses equivalent to 5–20% of global GDP annually due to environmental degradation. Parmesan and Yohe (2003) found that over 50% of species have shifted their range or seasonal behavior due to changing temperature regimes.

Hansen et al. (2019) emphasize that land degradation, deforestation, and greenhouse gas (GHG) emissions have accelerated climate feedback loops. The UNEP Emissions Gap Report (2023) warns that current mitigation pledges are insufficient to prevent a 2.5°C to 3°C rise by the end of the century.

Indian research, such as TERI (2020) and MoEFCC (2022), suggests that agriculture, forests, and coastal ecosystems are among the most vulnerable sectors. However, the incorporation of ecosystem-based adaptation (EbA) and climate-smart technologies offers promising results for restoring environmental balance.

### **Objectives of the Study**

- To evaluate environmental impacts of climate change using recent global and regional data.
- To analyze ecological and socio-economic vulnerabilities.
- To assess effectiveness of resilience-building strategies.
- To recommend policy measures for sustainable environmental governance.

### **Methodology**

This study employs a descriptive and analytical research design, relying primarily on secondary data sources such as IPCC Assessment Reports, UNEP and UNDP publications, government reports, and peer-reviewed journals. Comparative environmental data from 2000–2023 were analyzed to assess trends in temperature rise, CO<sub>2</sub> emissions, deforestation rates, and biodiversity loss. Case studies of India's mangrove restoration and Himalayan ecosystem conservation were included to illustrate practical adaptation measures.

## Environmental Impacts of Climate Change

- **Biodiversity Loss:** Climate change alters habitats, forcing species to migrate or face extinction. The IUCN estimates that one in four mammals and one in eight bird species are at risk due to changing climates. Coral reefs, sensitive to temperature fluctuations, are undergoing mass bleaching events globally.
- **Water Resource Depletion:** Glacier retreat in the Himalayas is occurring at unprecedented rates. Major rivers like the Ganga River and Brahmaputra River support over 600 million people, now facing long-term water insecurity.
- **Soil Degradation and Desertification:** Frequent droughts and erratic rainfall accelerate soil erosion, nutrient depletion, and land degradation, particularly in semi-arid regions like Rajasthan. The UNCCD (2022) identifies land-use change and deforestation as key contributors to carbon loss.
- **Ocean Warming and Coastal Impacts:** Global mean sea level has risen by 20 cm since 1900, with acceleration in recent decades. Coastal ecosystems like the Sundarbans face severe risks including: Salinity intrusion, Habitat loss, Climate-induced migration
- **Air Quality and Public Health:** Climate change worsens air pollution. According to the World Health Organization: Air pollution causes 7 million deaths annually, Rising temperatures increase ozone formation and respiratory diseases,

### *Conceptual Diagram: Climate Change and Ecosystem Resilience Framework*



## **Pathways Toward Resilient Ecosystems**

- **Ecosystem-Based Adaptation (EbA):** EbA integrates biodiversity and ecosystem services into climate adaptation strategies. Reforestation, wetland restoration, and mangrove conservation improve carbon sequestration while buffering communities against climate extremes
- **Community-Led Conservation:** Empowering local and indigenous communities in ecosystem management enhances resilience. Traditional ecological knowledge (TEK) combined with modern science supports adaptive decision-making and biodiversity conservation.
- **Policy Integration and Governance:** Mainstreaming climate resilience into environmental policy is essential. India's National Action Plan on Climate Change (NAPCC) and State Action Plans (SAPCCs) provide frameworks for coordinated action, but their implementation must be strengthened through adequate funding and monitoring.
- **Green Technology and Innovation:** Technologies such as: Renewable energy, Carbon capture, Precision agriculture ...are essential for reducing emissions and improving resilience. Innovations like solar irrigation, micro-forestry, and bioengineering offer scalable climate solutions.
- **Education and Awareness:** Integrating climate literacy into curricula fosters eco-conscious behavior. Universities and training institutions play a key role in developing future leaders for sustainable environmental governance.

## **Policy Implications**

Policymakers should focus on:

- Strengthening environmental monitoring and early warning systems.
- Incentivizing green infrastructure and sustainable land-use planning.
- Integrating climate resilience into regional and local development plans.
- Enhancing international collaboration for research, technology transfer and financing.

## **Conclusion**

Climate change presents an unprecedented challenge to global ecosystems, demanding collective, science-based, and inclusive responses. Building resilient ecosystems requires more than conservation—it demands integration of ecological, social, and technological approaches. By embracing ecosystem-based adaptation, promoting green innovation, and strengthening policy implementation, societies can pave a sustainable pathway toward environmental

resilience. The balance between human progress and ecological preservation remains the foundation for a livable planet.

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# Spatial Analysis of Groundwater Potential Zones in Karjat Taluka, District Ahilyanagar (Maharashtra)

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## Abstract

Groundwater serves as a crucial resource in semi-arid regions where surface water availability is scarce. This study focuses on the spatial assessment of groundwater potential zones in Karjat Taluka of Ahilyanagar district, Maharashtra. The region is characterized by irregular and low rainfall, making groundwater the main source for both domestic and agricultural needs. By applying geospatial tools such as Geographic Information System (GIS) and remote sensing, multiple thematic layers—namely geology, geomorphology, slope, drainage density, land use/land cover, and rainfall—were integrated to identify groundwater potential zones. The analysis categorizes the area into high, moderate, and low groundwater potential zones. Findings indicate that low-lying areas and river basins possess high groundwater potential, whereas upland and rocky terrains show poor potential. The study emphasizes the need for scientific groundwater management and watershed-based approaches to ensure sustainable utilization of water resources.

## Introduction

Groundwater plays a vital role in supporting agriculture, drinking water supply, and rural livelihoods, particularly in semi-arid regions. In areas where rainfall is insufficient and surface water sources are limited; groundwater becomes the most dependable resource.

Karjat Taluka, located in Ahilyanagar district, experiences semi-arid climatic conditions and frequent droughts. Increasing population pressure and growing agricultural demands have led to over-exploitation of groundwater resources. Hence, identifying areas with varying groundwater potential is essential for efficient water resource planning and management.

Spatial modeling using GIS and remote sensing offers a systematic and effective approach to analyze the factors influencing groundwater occurrence

and distribution. This study aims to delineate groundwater potential zones in Karjat Taluka using geospatial techniques.

### **Objectives of the Study**

- To examine the factors influencing groundwater availability in Karjat Taluka.
- To generate thematic layers using GIS tools.
- To identify groundwater potential zones through spatial modeling techniques.
- To recommend strategies for sustainable groundwater management.

### **Study Area**

Karjat Taluka is situated in the central part of Ahilyanagar district and lies within the Deccan Plateau region. The area receives an average annual rainfall of 400 mm to 700 mm, which is highly erratic and unevenly distributed.

The geological structure is dominated by Deccan Trap basalt formations, and the terrain consists of plateaus, uplands, and river basins. Agriculture is mainly rain-dependent, while groundwater extracted through wells and borewells is widely used for irrigation purposes.

### **Methodology**

The study employs GIS and remote sensing techniques for spatial modeling. The methodology involves the following steps:

#### **Data Collection**

- Satellite imagery for land use/land cover analysis
- Topographic maps for slope and drainage patterns
- Geological maps
- Rainfall data records

#### **Preparation of Thematic Layers**

The following thematic layers were generated:

- Geology
- Geomorphology
- Slope
- Drainage density
- Land use/land cover
- Rainfall

## **Weighted Overlay Technique**

Each thematic layer was assigned a weight based on its importance in groundwater occurrence. These layers were integrated using a weighted overlay analysis in GIS to delineate groundwater potential zones.

## **Factors Affecting Groundwater Potential**

- **Geology**

Groundwater storage in the study area is largely governed by the presence of basaltic rock formations. Water is primarily retained in fractures, joints, and weathered zones within these rocks, making them key contributors to aquifer potential.

- **Geomorphology**

The geomorphic characteristics of the region strongly influence groundwater availability. Low-lying areas such as valleys and plains facilitate water accumulation and enhance recharge, whereas uplands, hills, and elevated terrains exhibit limited groundwater potential due to reduced storage capacity.

- **Slope**

Slope plays a critical role in controlling infiltration and runoff. Gentle slopes promote water percolation into the subsurface, leading to higher groundwater potential. In contrast, steep slopes accelerate surface runoff, limiting the opportunity for groundwater recharge.

- **Drainage Density**

Drainage density serves as an important indicator of recharge potential. Regions with low drainage density allow greater infiltration, enhancing groundwater replenishment. Conversely, areas with high drainage density experience rapid runoff, which reduces the amount of water available for groundwater recharge.

- **Land Use/Land Cover**

Land use and vegetation cover influence the infiltration capacity of the soil. Forested and vegetated areas facilitate maximum groundwater recharge due to enhanced percolation. Agricultural lands provide moderate recharge, while built-up and impervious surfaces significantly restrict infiltration, thereby decreasing groundwater potential.

- **Rainfall**

Rainfall is the primary source of groundwater recharge in the study region. Areas receiving higher precipitation exhibit better groundwater potential, while

regions with lower rainfall are more vulnerable to water scarcity due to limited recharge.

### Groundwater Potential Zones

Based on spatial analysis, Karjat Taluka can be categorized into three groundwater potential zones:

- **High Potential Zone:** These areas are mainly located in river basins and low-lying regions. They are characterized by gentle slopes, thick soil cover, and high infiltration capacity, resulting in significant groundwater recharge.
- **Moderate Potential Zone:** These zones are typically found in plateau regions with moderate slopes and soil depth. Groundwater recharge is limited compared to high potential zones.
- **Low Potential Zone:** These areas are located in upland and hilly regions. They have steep slopes, rocky terrain, and poor infiltration capacity, leading to low groundwater availability.

Factor	Condition	Groundwater Potential
Geology	Fractured basalt	High
Slope	Gentle	High
Drainage Density	Low	High
Land Use	Vegetation/Agriculture	Moderate to High
Rainfall	Higher rainfall	High
Terrain	Rocky and steep uplands	Low

### Spatial Interpretation of Groundwater Potential

The spatial distribution of groundwater potential in the study area varies according to topography, geology, and geomorphic features. The northern upland regions display low groundwater potential, primarily due to the combination of rocky terrain and steep slopes, which limit water infiltration and storage. The central plateau zones exhibit moderate groundwater potential, reflecting a balance between gently sloping areas that allow some infiltration and less permeable surfaces that restrict recharge. In contrast, the southern river basin regions demonstrate high groundwater potential, as flat landforms, alluvial deposits, and favorable soil and vegetation cover facilitate effective water percolation and aquifer replenishment.

## **Discussion**

The study highlights that groundwater potential in Karjat Taluka is unevenly distributed and is strongly influenced by physical factors such as geology, slope, and land use. River basin areas offer favorable conditions for groundwater recharge, whereas upland regions face water scarcity due to poor infiltration. The application of GIS-based spatial modeling provides a reliable and efficient method for identifying groundwater potential zones and supports better decision-making for water resource management.

## **Conclusion**

Groundwater is a vital resource in Karjat Taluka, where surface water availability is limited. Spatial modeling effectively identifies areas with varying groundwater potential. High potential zones are concentrated in river basins, while upland regions exhibit low potential.

Implementing sustainable groundwater management practices, such as artificial recharge and watershed development, is essential to ensure long-term water security in the region.

## **Suggestions for Enhancing Groundwater Resources**

To improve groundwater availability and ensure sustainable water management, several measures can be implemented in the study area:

- **Construction of Check Dams and Percolation Tanks:** Small-scale water retention structures can slow runoff, increase water infiltration, and recharge local aquifers, particularly in semi-arid regions.
- **Adoption of Rainwater Harvesting Techniques:** Collecting and storing rainwater from rooftops and surface areas can supplement groundwater supplies and reduce dependence on external water sources.
- **Implementation of Watershed Management Programs:** Integrated watershed development initiatives, including soil conservation and water retention measures, can enhance recharge and maintain hydrological balance.
- **Regulation of Groundwater Extraction:** Controlled pumping and enforcement of sustainable withdrawal limits can prevent overexploitation and ensure long-term aquifer stability.
- **Promotion of Afforestation:** Planting trees and increasing vegetative cover enhances soil infiltration, reduces runoff, and contributes to the natural replenishment of groundwater resources.

These strategies collectively support the sustainable management of groundwater, mitigate water scarcity, and enhance the resilience of agriculture and local ecosystems to climatic variability.

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# The Green Transition: Balancing Energy Security with Global Sustainability Goals

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## Abstract

The worldwide transition to sustainable energy systems, often known as the green transition, is critical in combating climate change and environmental deterioration. However, this transition must be matched with energy security, which assures that energy supplies are available, affordable, and reliable. This study investigates the complex relationship between energy security and sustainability goals, focusing on critical issues such as renewable energy intermittency, geopolitical dependencies, and economic limits. It also investigates strategies such as technical innovation, legislative frameworks, and international cooperation that can aid in a balanced transition. The report underlines the necessity for a diverse energy mix and inclusive policy measures to achieve long-term sustainability while maintaining energy stability.

## Introduction

Energy is critical to economic development, industrialization, and social progress. For decades, the world's energy systems have relied mainly on fossil fuels like coal, oil, and natural gas. While these resources have aided growth, they have also considerably increased greenhouse gas emissions and environmental deterioration. Climate change, primarily caused by carbon emissions, has produced an urgent need for a shift to cleaner and more sustainable energy systems.

The green transition is the global shift away from fossil fuels and toward renewable energy sources like solar, wind, hydro, and biomass. This transition is critical for meeting global sustainability goals, particularly those set out in multilateral frameworks such as the United Nations Sustainable Development Goals (SDGs). However, the transition raises problems in terms of energy security, which includes guaranteeing a secure and uninterrupted energy supply.

Balancing energy security with sustainability is a difficult issue, particularly in emerging countries where energy consumption is fast increasing. This study examines the key concerns, obstacles, and options for striking this balance.

## **Understanding Energy Security and Sustainability**

- **Energy Security**

Energy security is the constant availability of energy at affordable rates. It has numerous dimensions, including physical resource availability, infrastructure reliability, and protection against external disturbances such as geopolitical wars or natural disasters. Energy security also entails diversifying energy sources to reduce reliance on a particular source or location.

- **Sustainable Goals**

Sustainability in energy is concerned with lowering environmental impacts while satisfying current and future energy demands. The United Nations Sustainable Development Goal 7 (SDG 7) emphasizes ensuring universal access to affordable, dependable, sustainable, and modern energy sources. It encourages the use of renewable energy, enhanced energy efficiency, and universal energy access.

Balancing these two goals necessitates careful planning, since quick transitions to renewables without suitable infrastructure might jeopardize energy security.

## **Drivers of the Green Transition**

- **Climate Change and Environmental Concerns**

Climate change is a key driver of the green transition. Rising global temperatures, melting glaciers, and catastrophic weather events emphasize the need to cut carbon emissions. Transitioning to renewable energy helps to reduce these environmental dangers.

- **Technological Advancements**

Advances in renewable energy technologies have considerably cut costs and increased efficiency. Solar panels, wind turbines, and battery storage devices have become more accessible and reliable, promoting widespread adoption.

- **Policy Initiatives and Global Agreements**

International agreements, such as the Paris Agreement, have pushed countries to set emissions reduction targets and invest in clean energy. Governments around the world are establishing laws, subsidies, and incentives to encourage the

development of renewable energy.

- **Economic Opportunities**

The green shift has economic benefits, such as employment creation in renewable energy industries, improved investment prospects, and less reliance on imported fossil fuels. It also encourages sustainable industrial expansion.

### **Challenges in Balancing Energy Security and Sustainability**

- **Intermittency and Reliability Issues**

Renewable energy sources such as solar and wind are weather dependent, resulting in swings in energy generation. This variability makes it difficult to maintain a consistent energy source.

- **High Initial Investment Costs**

The move to renewable energy necessitates substantial upfront investments in infrastructure, technology, and system upgrades. Developing countries may confront budgetary difficulties while implementing this technology.

- **Dependence on Critical Minerals**

Lithium, cobalt, and rare earth elements are essential minerals used in renewable energy technology. Dependence on these resources may result in new geopolitical threats and supply chain weaknesses.

- **Existing Fossil Fuel Dependency**

Many countries continue to rely significantly on fossil fuels for energy generation. Moving away from these sources may damage established sectors and economies.

- **Social and Employment Challenges**

The decline of fossil fuel sectors could result in employment losses, necessitating worker retraining and social support mechanisms to enable a fair transition.

### **Strategies for Balancing Energy Security and Sustainability**

- **Diversified Energy Mix**

Adopting a diverse energy portfolio that includes both renewable and transitional energy sources can help to provide energy stability during the transition period.

- **Energy Storage Technologies**

Batteries and other energy storage technology can store excess renewable energy and provide backup during times of low generation.

- **Grid Modernization and Smart Technologies**

Smart grids improve energy distribution efficiency and enable more effective integration of renewable energy sources into the power system.

- **International Cooperation**

Global collaboration is critical for sharing technology, expertise, and financial resources. Developed countries can help developing nations with their transition efforts.

### **Case Study: India's Energy Transition**

India is a perfect example of balancing energy security with sustainability. The country's population and economy are rapidly developing, resulting in increased energy demand. At the same time, it intends to reduce carbon emissions and increase renewable energy capacity.

India has achieved significant advances in solar and wind energy development. Initiatives like the National Solar Mission aim to considerably expand renewable energy capacity. The country has ambitious goals, including generating 500 GW of non-fossil fuel energy capacity by 2030.

### **Role of Innovation and Emerging Technologies**

Technological innovation is essential for making the green transition while maintaining energy security. Emerging technologies include:

- AI improves energy efficiency and enhances grid management.
- Green hydrogen is a clean alternative fuel for industry and transportation.
- Carbon Capture and Storage (CCS) reduce emissions from fossil fuel power plants.
- Improved battery technologies for better energy storage and reliability.

These inventions assist to close the gap between sustainability and energy security.

### **Policy Recommendations**

To properly balance energy security and sustainability goals, the following approaches are recommended:

- Strengthen renewable energy policy and targets.
- Invest in infrastructure and grid upgrading.

- Encourage research and development in clean technology.
- Provide a fair transition for staff impacted by the shift.
- Promote public-private partnerships.
- Strengthen international cooperation and funding systems.

## **Conclusion**

The green transition is critical to building a sustainable, low-carbon future. However, it must be carefully regulated to avoid jeopardizing energy security. A balanced approach combining renewable energy, technical innovation, and robust policy frameworks is critical.

To overcome the transition's obstacles, countries must develop diverse energy plans, invest in infrastructure, and promote global collaboration. The success of the green transition is dependent on long-term planning, inclusive policies, and commitment from governments, companies, and society around the world. By combining energy security and sustainability goals, the world may achieve a cleaner, more resilient, and equitable energy future.

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# Innovation in Science and Technology: Transforming Contemporary Geographic Research

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## Abstract

Innovation in science and technology has fundamentally reshaped geographic research over the past few decades. Tools such as Geographic Information Systems (GIS), remote sensing, artificial intelligence (AI), Global Navigation Satellite Systems (GNSS), big data analytics, and cloud computing have revolutionized spatial data collection, analysis, modeling, and visualization. These technologies enable geographers to investigate complex environmental and socio-economic phenomena at multiple scales with improved accuracy and efficiency. This paper reviews the historical evolution of technological innovation in geography, examines key applications in environmental monitoring, urban planning, agriculture, and disaster management, and discusses emerging challenges and future prospects. The study is based on a systematic review of scholarly literature and institutional reports. Findings suggest that technological innovation has transformed geography from a descriptive discipline into an analytical and predictive science essential for sustainable development.

**Keywords:** Geographic Information Systems, remote sensing, artificial intelligence, spatial analysis, geospatial technology, innovation

## Introduction

Geography is fundamentally concerned with spatial relationships, environmental processes, and human–environment interactions. Traditionally, geographic inquiry relied heavily on field surveys, manual cartography, and descriptive regional analysis. However, technological advancements have transformed the discipline into a data-driven and analytical science (Gregory, 2000).

The development of Geographic Information Systems (GIS), satellite-based remote sensing, and digital mapping technologies has expanded the scope of geographic research (Longley et al., 2015). These innovations allow researchers to integrate spatial and non-spatial datasets, conduct predictive modeling, and support policy decision-making in areas such as climate change, urban development, and resource management.

This paper explores the role of scientific and technological innovation in transforming contemporary geographic research.

### **Objectives**

The study is guided by the following objectives:

- To examine the role of innovation in science and technology in transforming contemporary geographic research, with emphasis on GIS, remote sensing, artificial intelligence, GNSS, and cloud-based platforms.
- To evaluate the applications of emerging geospatial technologies in environmental monitoring, urban planning, agriculture, and disaster management in the context of sustainable development.

### **Research Methodology**

#### **Research Design**

This study adopts a descriptive-analytical research design based on a systematic review of academic literature, institutional reports, and technological documentation.

#### **Methods of Analysis**

The methodology includes

- Systematic review of peer-reviewed journal articles and academic books
- Thematic classification of technological innovations
- Comparative evaluation of traditional and modern geographic techniques
- Application-based assessment across thematic domains

#### **Conceptual Framework**

The conceptual framework of this study follows the sequence:

Technological Innovation → Spatial Data Collection → Spatial Analysis & Modeling → Decision Support Systems → Sustainable Development Outcomes

#### **Data Sources**

The study relies primarily on secondary data sources:

- Satellite imagery from Landsat and Sentinel missions

- Cloud-based geospatial platforms such as Google Earth Engine
- Peer-reviewed journals and academic books
- Reports from NASA, ESA, USGS, and United Nations agencies

## **Technological Innovations in Geography**

- **Geographic Information Systems (GIS)**

GIS is a computer-based system used for capturing, storing, analyzing, and visualizing spatial data (Burrough & McDonnell, 1998). It enables multi-layered spatial analysis and supports decision-making in urban planning, environmental management, and public health.

Modern web-based GIS platforms allow real-time data sharing and collaborative spatial analysis (Goodchild & Janelle, 2010).

- **Remote Sensing**

Remote sensing involves acquiring information about the Earth's surface without physical contact through satellite or airborne sensors (Jensen, 2007). Multi-temporal satellite imagery enables monitoring of land use changes, vegetation cover, and climate-related processes.

Advancements in multispectral, hyperspectral, and LiDAR technologies have improved mapping accuracy and environmental assessment capabilities (Xie et al., 2008).

- **Artificial Intelligence and Machine Learning**

AI and machine learning techniques are increasingly integrated with GIS and remote sensing to automate land-cover classification, hazard prediction, and urban growth modeling (Mayer & Pullar, 2020). Deep learning algorithms enhance image interpretation and pattern recognition.

- **GNSS and GPS Technologies**

GNSS technologies provide precise geolocation data essential for mapping and field surveys (Teunissen & Montenbruck, 2017). Differential GPS and RTK systems enhance positional accuracy for engineering and cadastral applications.

- **Big Data and Cloud Computing**

Cloud computing platforms enable large-scale geospatial data processing and storage. Big data sources, including mobile location data and sensor networks, contribute to real-time spatial analytics and urban monitoring.

## **Applications in Geographic Research**

- **Environmental Monitoring**

Remote sensing supports the monitoring of deforestation, glacier retreat, and desertification (Turner et al., 2015). GIS-based models assist in climate change impact assessments.

- **Urban Planning and Smart Cities**

Geospatial technologies support smart city development by optimizing infrastructure planning, traffic management, and service delivery (Batty et al., 2012).

- **Precision Agriculture**

Spatial technologies improve crop monitoring, soil assessment, and irrigation management, contributing to sustainable agricultural practices (Reidsma et al., 2009).

- **Disaster Risk Management**

GIS and remote sensing are widely used in hazard mapping, vulnerability analysis, and post-disaster damage assessment (Cutter et al., 2008).

### **Challenges and Ethical Considerations**

Technological innovation also presents challenges:

- High implementation costs
- Need for technical expertise
- Data privacy and ethical concerns (Crawford & Finn, 2014)
- Digital divide in developing regions

Addressing these challenges requires open-source platforms, training programs, and ethical data governance.

### **Future Prospects**

Emerging technologies such as IoT, 3D GIS, autonomous drones, and real-time satellite monitoring are expected to further enhance geographic research. Integration of AI-driven spatial analytics will support predictive modeling and sustainable planning.

### **Conclusion**

Innovation in science and technology has fundamentally transformed geography. From analog surveys and hand-drawn maps to digital geospatial analytics and AI-driven models, the discipline has expanded its ability to explore, explain, and predict spatial phenomena. Technologies such as GIS, remote sensing, GNSS, AI, cloud computing, and big data analytics have

enhanced geographic research and supported applications in environmental science, urban planning, agriculture, disaster risk management, and climate studies.

However, these advancements also raise challenges related to data privacy, ethical governance, technological access, and capacity building. Addressing these concerns will require interdisciplinary collaboration, open data initiatives, and investment in education and infrastructure.

The future of geographic research lies in the integration of emerging technologies that enable real-time, high-resolution, and multidimensional spatial analysis. As the world confronts global challenges such as climate change, urbanization, and resource scarcity, geography will continue to play a central role in informing sustainable solutions.

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# Farmers' Perception of Climate Change and Its Impact on Cropping Decisions

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## Abstract

Climate change has become a major concern for agricultural sustainability across the globe. Since farming activities are closely tied to climatic conditions, farmers are particularly vulnerable to changes in temperature, rainfall, and extreme weather events. This paper explores how farmers perceive climate change and how these perceptions influence their cropping choices. Drawing on existing empirical studies and field-based observations, the analysis reveals that farmers' awareness, socio-economic conditions, and access to information play a critical role in shaping their adaptive responses. The study finds that perceived climatic shifts often lead farmers to modify crop selection, adopt resilient varieties, diversify production, and adjust management practices. It concludes that incorporating farmers' perceptions into agricultural policies is essential for promoting climate-resilient farming systems.

**Keywords:** Climate change, farmer perception, cropping patterns, adaptation, agriculture

## Introduction

Agriculture is highly dependent on climatic factors, making it one of the most vulnerable sectors to climate variability and long-term environmental changes. In countries such as India, where a significant share of the population depends on agriculture for livelihood, even slight variations in climate can have substantial impacts. Climate change is evident through rising temperatures, unpredictable rainfall, and an increased occurrence of extreme events such as droughts and floods.

Farmers' understanding and interpretation of these changes play a vital role in determining their responses. Perception refers to how individuals interpret environmental changes based on their experiences and available knowledge. These perceptions influence their readiness to adopt adaptive strategies.

Therefore, analyzing farmers' perceptions is crucial for designing effective interventions aimed at enhancing agricultural resilience.

### **Literature Review**

A growing body of literature has examined how farmers perceive climate change and how they respond to it. Many studies indicate that farmers recognize noticeable changes in climatic conditions, particularly increasing temperatures and irregular rainfall patterns. For example, research conducted in coastal regions of India showed that a majority of farmers observed delayed monsoons and reduced rainfall.

Similarly, studies in semi-arid regions such as Bundelkhand highlight that farmers associate climate variability with declining agricultural productivity and increased livelihood risks. In most cases, farmers rely on personal experience rather than scientific data to understand climatic trends.

However, perceptions are not always accurate. Research in developed countries has demonstrated that farmers sometimes misinterpret climatic changes, which can lead to ineffective or inappropriate adaptation measures. Such discrepancies emphasize the importance of aligning local perceptions with scientific evidence.

### **Objectives of the Study**

This study aims to:

- Examine how farmers perceive climate change.
- Identify the factors influencing these perceptions.
- Analyze the effect of climate perceptions on cropping decisions.
- Suggest policy interventions to support climate-resilient agriculture.

### **Methodology**

The study is based on a comprehensive review of secondary data, including peer-reviewed journal articles, institutional reports, and case studies. It covers findings from diverse agro-climatic regions, particularly in developing countries. Both qualitative and quantitative insights are synthesized to identify patterns in perception and adaptive behavior among farmers.

### **Farmers' Perception of Climate Change**

#### **Observed Changes in Climate**

Farmers commonly report several noticeable changes in climatic conditions:

- **Temperature:** An increase in average temperatures and longer summer seasons.

- **Rainfall:** Irregular rainfall patterns, reduced total precipitation, and delayed monsoon onset.
- **Extreme Events:** Greater frequency of droughts, floods, and storms.

In many cases, these perceptions align with recorded climate data, particularly regarding temperature trends. However, perceptions of rainfall often vary due to its unpredictable nature.

### **Level of Awareness**

Awareness of climate change differs among farmers depending on their education, access to information, and interaction with extension services. Farmers with better access to climate-related information tend to have a more accurate understanding of environmental changes.

### **Socio-economic Determinants**

Socio-economic characteristics such as income level, farm size, access to credit, and institutional support significantly influence how farmers perceive climate risks. Farmers with greater resources are generally more capable of recognizing and responding to climate-related challenges.

### **Impact of Perception on Cropping Decisions**

Farmers' perceptions of climate change have a direct influence on their agricultural practices and decision-making processes.

### **Crop Diversification**

To reduce risk, farmers often diversify their crops. This involves shifting from traditional crops to those that are more tolerant to stress conditions such as drought or heat.

- **Modification of Cropping Patterns**

Farmers often modify their cropping patterns in response to changes in climatic conditions to minimize risk and optimize productivity. Adjustments may include altering sowing and harvesting schedules to better align with shifting rainfall or temperature patterns. Additionally, new crop rotations are adopted to maintain soil fertility, reduce pest and disease pressures, and improve resilience to climatic variability. Changes in cropping intensity, such as introducing additional crop cycles or intercropping, are also common strategies employed to enhance farm productivity while mitigating the adverse impacts of erratic weather. These adaptive practices reflect the dynamic nature of agricultural systems in semi-arid and climate-sensitive region

- **Use of Climate-Resilient Varieties**

Farmers increasingly adopt crop varieties that mature early, require less water, and can withstand adverse conditions. These choices are largely influenced by their perception of increasing climate uncertainty.

- **Adoption of Integrated Farming**

Integrated farming systems, which combine crop production with livestock or other activities, are becoming more common. This approach helps spread risk and ensures a more stable income.

- **Improved Water Management**

Perceived water scarcity encourages farmers to adopt better water management practices, such as efficient irrigation systems, rainwater harvesting, and soil moisture conservation techniques.

### **Constraints to Adaptation**

Although farmers are increasingly aware of the impacts of climate change, several barriers hinder their ability to implement effective adaptation strategies. Information gaps remain a major challenge, as many farmers have limited access to accurate weather forecasts, climate advisories, or knowledge about innovative farming practices.

Financial limitations further constrain adaptation, with inadequate access to credit, crop insurance, or investment resources preventing the adoption of resilient technologies.

Weak institutional support, including insufficient agricultural extension services and gaps in policy implementation, reduces the practical assistance available to farmers.

Additionally, small landholdings restrict the capacity of many farmers to invest in advanced irrigation systems, machinery, or diversified cropping patterns. Collectively, these constraints impede the translation of climate awareness into actionable adaptation measures, leaving many farming systems vulnerable to climate variability and extreme events.

### **Role of Institutions and Technology**

Institutional support is crucial in strengthening farmers' ability to adapt to climate change. Extension services, financial assistance, and access to climate information can significantly improve decision-making.

The use of digital technologies and information systems is also expanding. Mobile-based advisories and weather forecasting tools are helping farmers

make informed choices regarding cropping and resource management. Improved access to such technologies enhances their resilience to climate risks.

### **Policy Implications**

The findings suggest several important policy directions:

- **Enhancing Extension Services:** Delivering timely and accurate climate information to farmers.
- **Promoting Climate-Smart Practices:** Encouraging sustainable and resilient agricultural techniques.
- **Improving Financial Access:** Expanding credit facilities and crop insurance coverage.
- **Capacity Development:** Training farmers to understand and respond to climate information.
- **Localized Forecasting Systems:** Developing region-specific climate prediction models.

Policies should combine scientific knowledge with farmers' experiential understanding to ensure effective adaptation.

### **Conclusion**

Farmers' perception of climate change plays a key role in shaping agricultural decisions and adaptation strategies. While many farmers are aware of changing climatic conditions, their responses are influenced by socio-economic factors, access to information, and personal experiences. These perceptions lead to various adaptive measures, including crop diversification, adoption of resilient varieties, and changes in cropping practices.

However, several constraints limit their ability to respond effectively. Addressing these challenges requires strengthening institutional support, improving access to information, and enhancing financial resources.

In summary, integrating farmers' perceptions into policy frameworks is essential for building resilient agricultural systems. Future research should focus on combining behavioral insights with technological innovations to support sustainable farming under changing climatic conditions.

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# Emerging Geospatial Technologies in Geography and Environmental Studies: GeoAI, Cloud Platforms, Drones and Digital Twins for Environmental Intelligence

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## Abstract

This condensed chapter explains how emerging geospatial technologies are transforming geography and environmental studies. Using secondary evidence from institutional reports and recent literature, it focuses on GeoAI, cloud and big-data platforms, drones, and digital twins supported by IoT and real-time sensing. The evidence shows that geospatial systems now expand the scale, speed, and predictive power of environmental observation. Copernicus registered users rose from more than 380,000 in 2020 to nearly 760,000 in 2023, while cumulative downloaded Sentinel data reached 586 PiB. In India, the drone ecosystem grew from 10,010 registered drones and 63 approved training organisations in August 2023 to more than 38,500 drones and 244 training organisations by February 2026. The chapter argues that the greatest value of these technologies lies in integration: satellite archives, drone surveys, sensor streams, and AI models together support climate resilience, land governance, disaster risk reduction, biodiversity monitoring, and sustainable urban planning.

**Keywords:** GeoAI; remote sensing; drones; cloud GIS; digital twins; environmental monitoring; geography

## Introduction

Geography and environmental studies have always depended on available technologies for observing and interpreting the Earth. Today, however, the field is moving beyond conventional GIS and image interpretation toward integrated, intelligent, and near-real-time systems that combine satellites, drones, cloud computing, machine learning, sensor networks, APIs, and digital twins. This

shift is significant because environmental change is faster, more complex, and more uneven across space. Climate extremes, biodiversity loss, land-use change, groundwater stress, urban sprawl, and pollution require timely and multi-scalar evidence.

Open Earth observation archives, AI-enabled analysis, and scalable cloud platforms now allow researchers to process very large datasets, automate feature extraction, detect anomalies, model scenarios, and support evidence-based decisions. Institutional developments reinforce this transition. UN-GGIM highlights geospatial information as foundational for climate resilience and governance; Landsat and Copernicus have normalised open data access; and India's geospatial and drone policies show that geospatial systems are becoming core public infrastructure. The chapter addresses a key gap: these technologies are often discussed separately, even though their real value lies in integration.

## **Methods**

This study uses a descriptive-analytical design based entirely on secondary data. Sources were selected for credibility, recency, and relevance, with emphasis on USGS, Copernicus, UN-GGIM, UNDRR, Government of India releases, and recent review literature. The material was organised into four clusters: GeoAI, cloud/big-data geospatial platforms, UAVs, and digital twins with IoT integration. Trend indicators were extracted mainly from Copernicus statistics for 2020-2023 and India's drone ecosystem indicators for 2023 and 2026. The analysis relies on descriptive statistics, percentage change, comparative interpretation, and thematic synthesis.

## **Results and Discussion**

### **Technology Landscape**

Emerging geospatial technologies form an analytical stack rather than isolated tools. Satellites provide synoptic, repetitive, and open Earth observation; drones provide flexible ultra-high-resolution sensing; cloud platforms remove computational bottlenecks; GeoAI supports automation and prediction; and digital twins combine these streams into dynamic decision environments. Their major strength is complementarity: satellites support temporal continuity and broad coverage, drones provide local detail, cloud systems enable scale, AI improves interpretation, and digital twins support simulation and scenario testing.

**Table 1. Analytical profile of major emerging geospatial technologies**

<b>Technology</b>	<b>Primary data form</b>	<b>Typical spatial scale</b>	<b>Environmental / geographic use</b>	<b>Key limitations</b>
GeoAI	Raster, vector, sensor streams	Local to global	Automated classification, anomaly detection, prediction, spatial pattern mining	Model bias, explainability, transferability
Cloud GIS / big-data platforms	Imagery archives, APIs, geodatabases	Regional to global	Time-series analysis, reproducible workflows, collaborative processing	Dependence on connectivity, platform lock-in, skills gaps
UAV / drone sensing	RGB, multispectral, thermal, LiDAR	Plot to local landscape	Crop stress mapping, erosion, cadastral updating, habitat monitoring	Flight regulations, calibration, limited coverage per flight
Digital twins	Integrated geospatial and real-time data	Site to city / region	Scenario simulation, infrastructure monitoring, urban climate management	High integration cost, governance and cybersecurity issues
Open EO infrastructures	Satellite optical, SAR, atmospheric products	Regional to global	Land change, water monitoring, disaster response, environmental baselines	Requires data engineering and interpretation capacity

### **Expansion of Open Earth Observation Infrastructures**

Open-access Earth observation has transformed environmental research capacity. Copernicus reports show sustained growth in users and downloaded data. Registered users increased from 380,000 in 2020 to 760,000 in 2023, while cumulative downloaded data rose from 240 PiB to 586 PiB. This indicates wider adoption and deeper computational use of satellite archives. Researchers increasingly work with long time series and multi-sensor datasets instead of downloading only a few scenes. USGS data provide a similar signal: by March 2024, more than 201 million Landsat Level-1 scenes had been downloaded since free access began in 2008. Together, Landsat depth and Sentinel

frequency provide an exceptional basis for studying land change, hydrology, urban heat, agriculture, wetlands, coasts, and hazards.

**Table 2. Copernicus Sentinel data access indicators, 2020-2023**

<b>Year</b>	<b>Registered users</b>	<b>Cumulative downloaded data (PiB)</b>	<b>User growth (%)</b>	<b>Data volume growth (%)</b>
2020	380,000	240		
2021	490,000	320	28.9	33.3
2022	638,000	405	30.2	26.6
2023	760,000	586	19.1	44.7

**Growth of Drones and Close-Range Sensing in India**

Drones are moving from experimental tools to mainstream geospatial infrastructure. In geography and environmental studies, they bridge field observation and remote sensing by offering ultra-high spatial detail, flexible timing, and site-specific analysis. They are valuable for crop monitoring, erosion mapping, cadastral verification, habitat surveys, flood assessment, and infrastructure inspection. Official Indian data show rapid expansion. From August 2023 to February 2026, registered drones rose from 10,010 to more than 38,500; certified remote pilots rose from 5,500 to 39,890; and approved training organisations increased from 63 to 244. This suggests that institutional capacity is expanding alongside hardware adoption. Government use under schemes such as SVAMITVA also shows that drones are becoming part of land governance and public service delivery, not only research practice.

**Table 3. India’s drone ecosystem indicators from official sources**

<b>Indicator</b>	<b>Aug 2023</b>	<b>Feb 2026</b>	<b>Absolute change</b>	<b>Approx. multiplier</b>
Registered drones	10,010	38,500	28,490	3.8x
Certified remote pilots	5,500	39,890	34,390	7.3x
Approved training organisations	63	244	181	3.9x

**GeoAI, Cloud Platforms, and Digital Twins**

GeoAI and cloud systems transform data abundance into analytical capability. They support automated classification, object detection, flood forecasting, biodiversity monitoring, and land-cover analysis across very large spatio-temporal datasets. Cloud environments reduce the need for local storage and enable analysis where the data reside, improving speed, reproducibility, and

collaboration. Digital twins extend this logic by integrating geospatial layers, sensor feeds, and simulation models into dynamic decision systems. In urban and environmental contexts, they can be used to model flooding, heat stress, infrastructure vulnerability, drainage performance, and land-use scenarios. The broader intellectual shift is from retrospective mapping toward scenario-based governance.

### **Sectoral Applications, Governance, and Capacity**

These technologies now support physical geography, human geography, agriculture, urban studies, and disaster management. Long satellite time series reveal vegetation change, glacial retreat, shoreline dynamics, and water persistence. GeoAI helps analyse coupled human-environment systems such as mobility, service inequality, environmental justice, and climate vulnerability. Drones improve farm-level monitoring and environmental inspection, while digital twins help cities simulate flood pathways, heat exposure, and infrastructure risks. Yet technological progress alone is insufficient. Effective geospatial transformation depends on open standards, interoperable metadata, training, ethical safeguards, and institutional coordination.

### **Conclusion**

Emerging geospatial technologies are redefining both the methods and policy relevance of geography and environmental studies. The evidence shows rapid expansion in open Earth observation access, strong growth in India's drone ecosystem, and increasing reliance on GeoAI, cloud analytics, and digital twins. Their greatest strength lies in integration. Satellites provide continuity and broad coverage, drones provide local precision, cloud systems provide scale, AI provides automation and predictive power, and digital twins provide simulation. Together, they support more responsive environmental intelligence for climate resilience, land administration, hazard management, biodiversity monitoring, and urban planning. Key policy priorities are interoperability, open standards, responsible AI, privacy-aware regulation, and curriculum reform that teaches integrated geospatial workflows.

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# The Role of Teacher's in AI Era

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## Abstract

In a world where artificial intelligence (AI) and automation are rapidly transforming various aspects of our lives, the field of education is no exception. As technology continues to advance, the role of teachers is undergoing a significant evolution. The traditional image of a teacher standing in front of a classroom, delivering lectures, and imparting knowledge is gradually being reshaped by the integration of AI tools and automated systems. As AI takes care of routine tasks, educators can focus on nurturing creativity, emotional intelligence, and other uniquely human attributes that remain invaluable in education. This transformation brings forth both challenges and opportunities, ultimately shaping a new era of education.

**Keywords:** Artificial Intelligence, AI Facilitators, Ethical AI

## Introduction

The advent of AI in the field of education has certainly led to a question as to why we need teachers anymore. It is true that the AI has more knowledge than a human but there are areas where the AI will always stay behind. The most important one is Humanity. Students still require the physical presence of the teachers for better understanding. In an classroom it becomes even more important as the teacher acts as a role model for the students. But as we are progressing to the era of AI driven education, the ability to adapt is very important for the teachers. The role of teacher in this era is to adapt with the latest technology and provide best possible learning environment to the students. The entire teaching-learning process is experiencing a change and to make sure that this change happens for good, it is necessary that the teachers change themselves accordingly. The combination of AI and Human Teachers can do wonders for the students. Both the AI and Humans have limitations but they complement each other perfectly and hence the ability to adapt is very important.

## **Changing Educational Landscape**

AI technologies, such as adaptive learning software, virtual tutors, and data-driven analytics, are revolutionizing education. Educational platforms are using AI to tailor lessons to individual student needs, adjusting difficulty based on performance. AI can also automate administrative tasks, such as grading or scheduling, allowing teachers to focus on instruction. However, these tools are not a replacement for human educators but rather a complement to their work. Teachers bring emotional intelligence, creativity, and critical thinking to the classroom qualities AI cannot replicate. While AI can deliver content efficiently, teachers provide the human connection that fosters motivation, curiosity, and a love for learning. In this new era, the teacher's role is shifting from being the sole source of knowledge to a facilitator of learning, guiding students through a world rich with information and technology.

## **Roles of Teachers in the AI Era**

- **As a Facilitator (Personalized Learning)**

AI excels at analyzing student data to create customized learning paths. However, teachers are essential in interpreting these insights and ensuring they align with students' emotional and social needs.

- **Mentor (Mentors of Critical Thinking and Creativity)**

AI can provide facts and answers, but it cannot teach students how to think critically or creatively. Teachers guide students in questioning information, analyzing sources, and developing original ideas. In an age where AI-generated content is abundant, teachers play a vital role in helping students discern credible information from misinformation and encouraging them to think beyond algorithms.

- **Guide for Emotional and Social**

Learning is as much an emotional journey as it is an intellectual one. Teachers provide the empathy, encouragement, and support that students need to navigate challenges. AI lacks the ability to understand nuanced human emotions or build meaningful relationships. A teacher's ability to recognize when a student is disengaged or struggling emotionally ensures that education remains a human-centered process.

- **Guide for Ethical AI Use**

As AI becomes ubiquitous, teachers have a responsibility to educate students about its ethical implications. This includes teaching digital literacy, such as understanding data privacy,

### **Roles AI in Education**

AI can perform many tasks in education faster, more consistently, and more scalably than humans. Chief among these tasks is creating personalized learning paths. AI systems can analyze each student's strengths and weaknesses, learning speed, and preferred learning style to offer personalized content and activities. While it's practically impossible for a teacher to do this in a class of many students, AI can provide this personalization in real-time and continuously.

Automated assessment and feedback is also an area where AI excels. Beyond multiple choice tests, AI can now evaluate written answers, essays, and even problem-solving processes. This can significantly reduce the hours teachers spend on assessment and allows students to receive immediate feedback.

AI also demonstrates impressive capabilities in content generation and adaptation. It can produce instructional materials, exercises, exam questions, and explanations. It can adapt existing content for different levels and learning styles.

### **The Future Teacher: Human and AI Collaboration**

- The education of the future will not take shape as AI replacing teachers, but as a collaboration model combining the strengths of both. In this model, the teacher's role is evolving from information transmitter to learning designer, mentor, and facilitator.
- As learning designers, teachers will design rich learning experiences by effectively using AI tools. They will determine when to benefit from AI and when direct human interaction is necessary.
- In mentor and coach roles, teachers will establish personal relationships with each student to support their academic, social, and emotional development. Data provided by AI will inform this mentoring process.
- As facilitators, teachers will manage classroom discussions, coordinate collaborative projects, and create social learning environments. They will ensure balance between individualized digital learning and social learning.
- In evaluator and interpreter capacity, teachers will make sense of the data generated by AI, evaluate its context, and make pedagogical decisions based on it. Data alone has no meaning; human interpretation is required.

- This evolving role requires teachers to develop new skills. Digital and AI literacy is now becoming a fundamental competency. Teachers need to be able to use AI tools effectively, understand their limitations, and evaluate them from a critical perspective.

### **Challenges and Considerations**

Despite its benefits, AI in education raises challenges. Over-reliance on technology risks depersonalizing education, and not all schools have equal access to AI tools, potentially widening educational inequities. Teachers must advocate for equitable access and ensure that AI supports, rather than replaces, human interaction. Furthermore, the rapid pace of technological change can be overwhelming. Teachers may feel pressure to keep up with new tools while maintaining their core responsibilities. Schools and policymakers must provide adequate support, including time and resources for training, to help teachers navigate this transition.

### **Conclusion**

The role of teachers in the age of AI is more vital than ever. While AI can enhance efficiency and personalization, teachers remain the heart of education, fostering critical thinking, creativity, and emotional growth. By embracing AI as a tool and adapting to its possibilities, teachers can empower students to thrive in a technology-driven world while preserving the human connection that makes learning meaningful. As education evolves, the teacher's role will continue to be one of inspiration, guidance, and transformation.

The successful education system of the future will combine the efficiency and scalability of AI with the empathy, creativity, and inspirational capacity of human teachers. In this collaboration, students will be the winning party, not the losing one.

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# **Comparative Assessment of Different Water Quality Indices with Special Reference to the Weighted Arithmetic Water Quality Index Method**

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## **Abstract**

The sustainable management of freshwater resources, as well as the preservation of ecosystems and human health, depend on the evaluation of water quality. However, it can be challenging to assess water quality using a variety of physical, chemical, and biological factors. Many Water Quality Indices (WQIs) that combine several factors into a single numerical number that represents overall water quality have been developed in order to streamline this procedure. The Weighted Arithmetic Water Quality Index, the National Sanitation Foundation Water Quality Index (NSF-WQI), the Oregon Water Quality Index (OWQI), and the Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI) are all frequently used indices. These indices usually take into account variables including pH, total dissolved solids, nitrates, phosphates, turbidity, dissolved oxygen, and biochemical oxygen demand. Each index evaluates the suitability of water for drinking, irrigation, aquatic life, and recreation using various weighting schemes and mathematical techniques. Researchers, environmental organizations, and policymakers frequently employ water quality indices because they offer a clear and concise depiction of complicated water data. They also support water resource management choices, detect sources of contamination, and track changes in water quality over time and space. WQIs have several drawbacks despite their value, such as reliance on certain characteristics and local environmental circumstances. Therefore, proper assessment of water quality and efficient environmental management require careful selection and modification of suitable indices.

## **Introduction**

The requirement for potable water has increased due to urbanization, advanced sanitary facilities, growing populations, and home appliances. In order to avoid paying water bills, people prefer to collect groundwater that is readily available where they live. Because of this, exploitation exceeds recharging. Additionally, impermeable surfaces expand with urbanization (Shuster et al., 2005), and imperviousness increases runoff even with light precipitation, which naturally lowers groundwater recharge (Sheeder et al., 2002).

If the groundwater is not fully recharged during the rainy season, the level rises. Deep and drying aquifers exceed the permissible limits of water quality standards. Groundwater is less likely to be contaminated. (Balasubramanian et al. (2016).

Approximately half of the population on the earth rely on groundwater to meet their demands for safe drinking water (Connor, 2015). Among developing countries, India is one of the biggest exploiters of groundwater.

For a variety of water needs in both rural and urban regions, groundwater has become essential. In order to guarantee the state of groundwater quality, water quality monitoring of groundwater sources must be given the highest priority. The 2012 National Water Policy states that actions must be executed to enhance the quality of the water and that sources of domestic use of water should be periodically evaluated (National Water Policy, 2012).

Water quality is determined by a number of factors, including its physical, chemical, and biological properties. Certain metrics in many water samples are within acceptable limits, while others might be higher than what is allowed. In these situations, it becomes challenging to categorize or characterize the total water quality based just on individual metrics. As a result, it becomes difficult to describe water quality in a single, comprehensive term. By combining several water quality measures into a single numerical number, the Water Quality Index (WQI) is a useful tool for resolving this issue. This index offers a clear and comprehensible representation of the overall condition of the water and simplifies complicated data on water quality. As a result, WQI is frequently used to classify water quality and to facilitate efficient management of water resources and environmental decision-making.

## **Comparative Analysis of Different Water Quality Index**

(Chijioke, Gift, & Prince, 2021), (Talent & Muthukrishnavellaisamy, , 2020)

<b>WQI Method</b>	<b>Advantages</b>	<b>Limitations</b>
<b>Weighted Arithmetic Quality Index (WAWQI)</b>	<ul style="list-style-type: none"> <li>• An easy-to-understand popular approach.</li> <li>• Provides a variety of water quality parameters to be included.</li> <li>• Weights are given to parameters based on their significance.</li> <li>• Appropriate for assessing the quality of drinking water.</li> </ul>	<ul style="list-style-type: none"> <li>• The choice of weights could be subjective.</li> <li>• Extremely sensitive to parameters having extremely low permissible limits, which could lead to results that are exaggerated.</li> <li>• Sometimes neglects how factors interact ecologically. (<a href="#">IJERT</a>)</li> </ul>
<b>National Sanitation Foundation WQI (NSF-WQI)</b>	<ul style="list-style-type: none"> <li>• Offers a widely recognized and standardized index.</li> <li>• Combines several water parameters into a single figure.</li> <li>• Simple to understand and helpful for monitoring surface water.</li> <li>• Makes it possible to compare various sites.</li> </ul>	<ul style="list-style-type: none"> <li>• Makes use of a limited number of parameters.</li> <li>• Does not suggest if water is suitable for a specific usage.</li> <li>• Some information is lost when complex data is reduced into a single index. (<a href="#">IJERT</a>)</li> </ul>
<b>Canadian Council of Ministers of the Environment WQI (CCME-WQI)</b>	<ul style="list-style-type: none"> <li>• Flexible because many parameters can be chosen based on the requirements of the investigation.</li> <li>• Takes into account the size, frequency, and intensity of pollution incidents.</li> <li>• Beneficial for the management of water and environmental policy.</li> </ul>	<ul style="list-style-type: none"> <li>• Information concerning particular variables and how they interact may be lost.</li> <li>• Since all factors can often be equally important, accuracy may be affected.</li> </ul> <p>The creation of the index and the availability of data may have an impact on the results. (<a href="http://waterlyst.com">waterlyst.com</a>)</p>

		<ul style="list-style-type: none"> <li>• Provides decision-makers an easy-to-understand evaluation.</li> </ul>	
<b>Oregon Water Quality Index (OWQI)</b>	<b>Water Index</b>	<ul style="list-style-type: none"> <li>• Aware of the impact on the environment and variations in water quality.</li> <li>• The final index value is significantly influenced by the most degraded parameter.</li> <li>• Good for monitoring the water in rivers and streams.</li> </ul>	<ul style="list-style-type: none"> <li>• Is unable to accurately assess harmful substances like bacteria and heavy metals.</li> <li>• Unsuitable for assessing the quality of water for particular purposes.</li> <li>• Limited use outside of the region or monitoring site where it was created.</li> </ul> <p>(<a href="http://waterlyst.com">waterlyst.com</a>)</p>

### Water Quality Index

A unique and useful grading system, the Water Quality Index (WQI) summarizes the general condition of water quality into a single qualitative term. It is easier to choose the best treatment option to address related issues. (Tyagi et al., 2013; Kosha et al., 2017).

### Insight Into Weighted Arithmetic Water Quality Index (WAWQI)

One of the most used techniques for evaluating and summarizing water quality is the Weighted Arithmetic Water Quality Index (WAWQI). In 1965, Robert K. Horton made the initial proposal to reduce complicated water quality data to a single numerical value that would indicate the general state of the water. Numerous physico-chemical parameters, including pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), nitrates, turbidity, and other water quality indicators, are integrated in this technique.

The WAWQI method's basic concept is that each water quality parameter is given a weight ( $W_i$ ) according to how important it is to overall water quality as well as how it affects aquatic ecosystems and human health. For each parameter, a quality rating ( $Q_i$ ) is then determined by comparing the measured value with the standard acceptable limit suggested by agencies like the Bureau of Indian Standards or the World Health Organization. These weighted values are combined to get the overall water quality index.

### Weighted Arithmetic Water Quality Method

The weighted arithmetic water quality index is presented in the following three steps.

#### Step-1 Calculation of unit weight (Wi) factor for each parameter by using the formula

$$W_n = \frac{K}{S_n}$$

Where,

$$K = \frac{1}{\left[\left(\frac{1}{S_1} + \frac{1}{S_2} + \frac{1}{S_3} + \dots + \frac{1}{S_n}\right)\right]} = \frac{1}{\sum\left(\frac{1}{S_n}\right)}$$

$S_n$  = Standard desirable value of  $n^{\text{th}}$  parameter

On summation of all selected parameter unit weight factor  $W_i=1$ (Unity).

Unit Weight Factor  $W_n = \frac{K}{S_n}$

Where,

$K$ =Proportionality constant

$S_n$ =Standard desired value

The parameter's unit weight ( $W_n$ ) is inversely proportional to the water standard used for the corresponding parameters.

#### Step-2 Calculation of sub-index value

$$Q_i = 100 * \left[ \frac{V_n - V_i}{V_s - V_i} \right]$$

Where,

$V_n$ = Actual concentration of  $n^{\text{th}}$  parameter obtained from laboratory analysis.

$V_i$ = Ideal Value of each water quality parameter (Generally  $V_i=0$ , in most of the parameters except for  $pH=07$ )

$V_s$ =Standard desirable value of  $n^{\text{th}}$  parameters

#### Step-3 Combining step 1 and step 2, WQI is calculated as follows

$$WQI = \frac{\sum Q_i W_i}{\sum W_i}$$

Where: -

$Q_i$  = Unit weight factor \*sub-index value

$W_i$  = Sub index value is (1)

**Table 4.2: Scale of Water quality based on weighted arithmetic WQI method**  
(Brown et al.,1972)

Value of WQI	Quality of Water
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unsuitable for drinking

(Source: Compiled by Author)

### Conclusion

Variations in parameter selection and weighting schemes lead to variances in the classification of water quality, according to a comparative evaluation of various Water Quality Indices. For assessing water quality using commonly measured parameters, the Weighted Arithmetic Water Quality Index approach has proven to be simple as well as efficient. However, other indices such as NSF-WQI and CCME-WQI provide broader environmental assessment. As a result, the objectives of the investigation and the data on water quality at available determine which WQI method is appropriate.

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# From Darcy to Deep Learning: Evolution of Groundwater Potential Assessment Techniques

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## Abstract

Groundwater is fundamental component of global freshwater resources. In India, dependence on groundwater is very high with withdrawal about 230 cubic kilometres annually. This dependence highlights the urgent need of systematic assessment of groundwater potential zones, to ensure long term sustainability. The advancement from traditional, field base hydrological characterisation to revolutionary geospatial modelling has fundamentally transform our interpretive approach to groundwater potential. This study highlights a critical delineation of the methodological trajectory in aquifer mapping, especially the transition from conventional methods, geospatial and geostatistical approach to data-intensive machine Learning (ML) and Deep learning (DL). This study proposes integrated approach that enhances methodological rigor and provides adaptive insights for sustainable groundwater management and policy relevant frameworks.

## Introduction

The foundation of socio-economic development and ecological sustainability largely depend on global water resources. Groundwater has many intrinsic advantages to emerge as a crucial and reliable water source in all climatic zones, including both rural and urban areas (Kanetkar et al.,2025). Groundwater demand increased over a period of time, which resulted in improper extraction which led to water stress areas. The spatial and temporal variability of these resources along with anthropogenic pressures, increases the necessity of their systematic study. Globally, 50 % of population depends on groundwater for drinking water and 43 % for irrigation needs. In India, the situation is even more indistinct, according to groundwater assessment 2024,

estimated annual recharge at 446.9 billion cubic meters (bcm), with extraction at 245.6 bmc, corresponding to stage of extraction of 60.47% (CGWB,2026). India is the largest extractor of groundwater globally, withdrawing about 230 cubic kilometres annually. The scenario proceeds with the need for systematic groundwater studies which should be both cost and time efficient. Groundwater is not readily observable, making its assessment entirely depend on hydrological survey, geospatial modelling and advance analytical techniques. Groundwater significance lies in dual dimensions of quantity and quality. The systematic groundwater research arises from resource quantification to provide insights of aquifer characteristics, aquifer recharge-discharge for long term sustainability, groundwater quality monitoring which evaluates the suitability for drinking and other various purposes, climate and land use impact helps to understand aquifer vulnerability. This study elaborates the conceptual framework that blends hydrogeological inputs, geospatial data and machine learning models, reinforces by validation to elevate groundwater potential interpretation. This integrated approach enhances the methodological precision, uncertainty reduction and contributes actionable insights for sustainable groundwater resource management at global and local level.

## **Methodological Evolution**

Groundwater potential assessment engrossed with a varied spectrum of methods that span field-based hydrogeology, geospatial analysis, geostatistical interpretations, process-based models and machine learnings.

### **1. Conventional Hydrological Methods**

Conventional hydrological methods represented as toolkit for characterising groundwater system and aquifer evaluation. Historically, scientific study of groundwater originated in nineteenth century with foundational experiments and laws describing the flow through porous medium by Henry Darcy. Henry Darcy's experiments and formulation of Darcy's law established the basics of aquifer analysis and subsequently developed by Dupuit and Theis (Simmon,2008). The cumulative progression from Darcy's laboratory experiment to Dupuit's analytical field approximations and then to transient well test solutions by Theis formulates the historical lineage of conventional hydrological methods used today. Field-based methods start with well inventory and lithological logging. Dynamic parameters like well depth, screened interval, seasonal water -level fluctuation, yield observed and documented as traditional practice. Pumping tests provides estimates of transmissivity, hydraulic

conductivity, storage coefficient analysis and recovery curve using well observations. Temporal variability to be studied by water table mapping and time-series monitoring. Geophysical surveys like electrical resistivity, seismic refraction, electromagnetic methods, ground-penetrating radars contribute in delineating the aquifer geometry and subsurface heterogeneity (Majumdar et al., 2020). Limitations like spatial sparsity in observation well, discontinuities in record monitoring, high cost and logistic complexities of extensive field work, calibrate the necessity to progressively adopt geospatial approach in groundwater studies.

## **2. Geospatial Approach and Geostatistical Techniques**

The groundwater potential evaluation has significantly advanced by the advent of remote sensing and Geographic Information System (GIS). This approach enables the large-scale mapping through various thematic layers providing spatially and quantitatively robust insights into aquifer system. Integration of various thematic layers such as slope, drainage density, geology, geomorphology, land use-landcover, soil results in delineation of groundwater potential zones. Multi-Criteria Decision Analysis (MCDA) methods like Analytical Hierarchy Process (AHP), Multi-Influencing factors (MIF) (Pande et al., 2021, Kanetkar et al., 2025) are widely used in India and abroad. This approach based on assigning the relative weights to controlling factors to generate composite maps that highlights groundwater potential zones. Lineament analysis enhances the identification of fracture zones and recharge areas, making this approach more effective in arid and semi-arid areas (Varade et al., 2017). Geostatistical techniques such as Inverse Distance Weighting (IDW) and Kriging provide the quantitative reliability by interpolating and modelling groundwater parameters across the area to enhance predictive accuracy. These techniques are valuable for data sparse areas, enabling generation of continuous surface from and limited point data. These approaches bridge the gap between local field observation data and regional-scale groundwater assessment.

## **3. Machine Learning Models**

The data driven approach of Machine Learning has significantly grown becoming the powerful tool to analyse complex and non-linear relationships among hydrological, geospatial and climatic variabilities. Large and heterogeneous datasets can process ML algorithms and identifies the parameters that influences groundwater occurrence, depth and quality (Lary et al., 2016,

Saha & Pal, 2025). Most widely used Random Forest (RF) model applied in delineating the groundwater potential zones offering ensemble accuracy and variable importance measures. Support Vector Machines (SVM/SVR) predicts groundwater depth and water quality index. Aquifer recharge estimation, groundwater-surface interaction, contamination study performed by Artificial Neural Networks (ANN) highlighting its flexible architecture. Recent advances such as Convolutional Neural Networks (CNN) excellent for geospatial data while Long-Short Term Memory (LSTM) effective for time series prediction contributing groundwater level fluctuation forecasting and spatio-temporal groundwater modelling (Kouadri et al., 2021).

#### **4. Integrated and Hybrid Approach**

This approach combines the conventional, geospatial analysis, geostatistical techniques and ML model to overcome the individual methodological limitations. It ensures methodological rigor by enhancing predictive performance (Subramani et al., 2025). It facilitates decision support for sustainable groundwater management and guiding adaptive resource management strategies.

#### **Research Gap and Future Directions**

Despite significant advances in groundwater studies, certain research gap remains. Spatial and temporal sparse monitoring limits the groundwater assessment. Many studies mainly rely on static datasets only. The integration of groundwater quality with geospatial and ML framework is still limited. Inconsistent weighting system in MCDA makes difficult for comparative and reproducibility of the research.

Future direction emphasizes the need for multi-disciplinary integration combining hydrology, geostatistical and artificial intelligence with robust field validation. Developing long-term monitoring network, incorporating real-time sensor data and employing deep learning models with geospatial and climatic variability parameters will enhance predictive reliability.

#### **Conclusion**

Groundwater acts as a central pillar of water security. This study aims to systematically dissect the evolution in hydrological assessment methods from field based conventional methods, geospatial revolution to advanced ML and DL architecture. This study identifies the future of this discipline lies in smarter integration of methodologies. Ultimately, amalgamation of empirical data,

spatial analysis and ML modelling offers a robust way to evolve holistic, adaptive and sustainable water resources management.

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# An Empirical Study of Environmental Protection and Clean Technologies in India

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## Abstract

Environmental protection has become one of the most significant global challenges in the twenty-first century due to rapid industrialization, population growth, and excessive exploitation of natural resources. In this context, clean technologies have emerged as an effective solution to mitigate environmental degradation while promoting sustainable economic development. Clean technologies, often referred to as green technologies, focus on reducing environmental impacts by improving resource efficiency, minimizing pollution, and promoting renewable energy solutions. India, as one of the fastest-growing economies, faces serious environmental challenges including air pollution, water scarcity, waste management issues, and climate change impacts. Therefore, the adoption and promotion of clean technologies are essential for ensuring long-term environmental sustainability. The findings highlight that environmental policies, technological innovation, and institutional support play a crucial role in promoting clean technology adoption.

**Keywords:** Environmental Protection, Clean Technologies, Green Innovation, Sustainable Development, Environmental Policy, Climate Change, Technological Innovation, Renewable Energy and Environmental Sustainability

## Introduction

Relative to most other economic issues, climate change is slow moving. Actions (e.g. carbon emissions) and consequences (e.g. related damages) can be several decades apart. Simulations of the macroeconomic impacts of climate change are thus typically estimated over relatively longtime spans. This makes the evolution of slow-moving variables, such as technological progress, unusually important. Put simply, if climate-friendly alternatives become as cheap and efficient as dirty technologies, the energy transition can be done at relatively low costs in terms of growth and inclusiveness. If on the other hand, clean

technologies remain significantly more expensive, greater and costlier policy efforts would be needed to tilt spending toward them. From a social planner's point of view, the objective should be to (i) avoid future climate-change related damages by reducing net carbon emissions, while (ii) minimizing transitional costs, including by stimulating technological progress among clean technologies. This paper focuses on how climate policies can induce innovation; an issue which has recently been object of a dynamic, though mostly theoretical, literature.

## **Review of Literature**

### **Global Perspectives on Environmental Protection and Technological Innovation**

Environmental protection has become a central issue in global policy debates due to increasing environmental degradation and climate change. Scholars have emphasized that technological innovation plays a crucial role in addressing environmental challenges while maintaining economic growth. According to Daron Acemoglu and his collaborators, technological progress is essential for transitioning from pollution-intensive production systems to cleaner and more sustainable economic structures. Their research highlights that directed technological change can significantly influence the development of environmentally friendly technologies and reduce dependence on fossil fuels.

### **Environmental Policy and Innovation**

Several studies have examined the relationship between environmental regulations and technological innovation. Theoretical frameworks suggest that environmental policies can stimulate innovation by creating incentives for firms to develop cleaner technologies. Environmental regulations such as emission standards, carbon taxes, and renewable energy subsidies encourage industries to reduce pollution and invest in environmentally friendly technologies.

### **Objective**

- To study environmental protection and clean technologies policies in India
- To investigate role of clean technologies for environmental protection
- To identify challenges for environmental protection and clean technologies in India

### **Hypothesis**

- **H1:** There is no relationship between environmental protection and clean technologies

- **H2:** There is no any challenges to implement environmental protection and clean technologies policies in India

### Research Methodology

This study explores the environmental protection and clean technologies policies in India. A survey questionnaire was designed based on literature review. Respondents were asked to indicate their attitudes to the statements using a five-point Likert scale; (1) Completely Disagree, (2) Rarely Agree, (3) Partly Agree, (4) Rather Agree, and (5) Completely Agree.

### Conceptual and Empirical Framework

The conceptual basis for the empirical estimation is a multiplicative production function of innovation in country  $i$  and time  $t$  along the lines of the one specified in Acemoglu et al. (2016).

$$\beta \quad \gamma$$

$$X_{i,t} = \theta_{i,t} (H_{i,t})^\beta (u_{i,t})^\gamma$$

... where  $u_{i,t}$  stands for the accessible stock of knowledge and  $H_{i,t}$  stands for the research effort. The equation can be re-written in a way that can be estimated with empirical count models.

$$X_{i,t} = \exp(\alpha_i + \delta_t + \beta \ln(H_{i,t}) + \gamma \ln(u_{i,t}) + \epsilon_{i,t})$$

...where  $\theta_{i,t} = \exp(\alpha_i + \delta_t)$ ,  $\alpha$  and  $\delta_t$  respectively are country- and time-fixed effects, and  $\epsilon_{i,t}$  is the residual,

The estimation relies on a conditional fixed effects Poisson model with robust standard errors.

### Data Analysis and Interpretation

To examine respondents' perceptions regarding environmental protection and the adoption of clean technologies in India, a structured questionnaire based on a five-point Likert scale was administered. The collected responses were analyzed using descriptive statistics such as frequency and percentage. The following tables present the results and interpretation of the key variables included in the study.

**Table 1**  
**Awareness of Environmental Protection Policies**

<b>Response Category</b>	<b>Frequency</b>	<b>Percentage</b>
Completely Disagree	6	5%
Rarely Agree	12	10%
Partly Agree	30	25%
Rather Agree	42	35%
Completely Agree	30	25%
<b>Total</b>	<b>120</b>	<b>100%</b>

The results indicate that 60% of respondents rather agree or completely agree that they are aware of environmental protection policies. Only 15% of respondents expressed disagreement, suggesting that awareness of environmental policies among respondents is relatively high. This reflects growing public and institutional recognition of environmental issues in India.

**Table 2**  
**Role of Clean Technologies in Environmental Protection**

<b>Response Category</b>	<b>Frequency</b>	<b>Percentage</b>
Completely Disagree	4	3.3%
Rarely Agree	10	8.3%
Partly Agree	22	18.4%
Rather Agree	46	38.3%
Completely Agree	38	31.7%
<b>Total</b>	<b>120</b>	<b>100%</b>

A significant majority (70% of respondents) believe that clean technologies play an important role in protecting the environment. Only a small proportion (11.6%) expressed disagreement. This suggests a strong perception that technological innovation is a key solution for addressing environmental challenges.

**Table 3**  
**Government Policies Encourage Clean Technology Adoption**

<b>Response Category</b>	<b>Frequency</b>	<b>Percentage</b>
Completely Disagree	8	6.7%
Rarely Agree	16	13.3%
Partly Agree	34	28.3%
Rather Agree	36	30%
Completely Agree	26	21.7%
<b>Total</b>	<b>120</b>	<b>100%</b>

Approximately 51.7% of respondents agree that government policies encourage the adoption of clean technologies. However, 20% disagree, indicating that although policy initiatives exist, there may still be challenges in policy implementation or effectiveness.

**Table 4**  
**Challenges in Implementing Clean Technologies in India**

<b>Response Category</b>	<b>Frequency</b>	<b>Percentage</b>
Completely Disagree	5	4.2%
Rarely Agree	12	10%
Partly Agree	25	20.8%
Rather Agree	44	36.7%
Completely Agree	34	28.3%
<b>Total</b>	<b>120</b>	<b>100%</b>

The findings show that 65% of respondents agree that significant challenges exist in implementing clean technologies in India. These challenges may include financial constraints, lack of infrastructure, limited technical expertise, and policy implementation barriers.

### **Findings**

The analysis of the Likert scale responses indicates that awareness of environmental protection policies among respondents is relatively high. The data show that 60% of respondents either “rather agree” or “completely agree” that they are aware of environmental protection policies, while 25% partly agree and only 15% express disagreement.

According to the survey results, approximately 70% of respondents agree or strongly agree that clean technologies play a crucial role in reducing

environmental degradation and pollution. Only about 11% of respondents disagree, indicating a strong perception that technological innovation can support environmental sustainability and reduce the negative impact of industrial activities. Around 51.7% of respondents agree that government policies encourage the adoption of clean technologies, while 28.3% partly agree and 20% express disagreement. Approximately 65% of respondents agree that there are significant barriers such as high investment costs, technological limitations, lack of infrastructure, and limited awareness.

### **Results and Discussion (Interpretation of Hypotheses)**

The empirical analysis was conducted to test the hypotheses regarding the relationship between environmental protection and clean technologies, as well as the challenges associated with their implementation in India. The findings are based on Likert scale responses collected from 120 respondents, and the interpretation is presented below.

#### **Hypothesis 1**

**H<sub>1</sub>:** There is no relationship between environmental protection and clean technologies.

The survey results indicate that 70% of respondents either “rather agree” or “completely agree” that clean technologies play a crucial role in environmental protection, while 18.4% partly agree and only 11.6% disagree with the statement. These findings demonstrate a strong positive perception of the role of clean technologies in reducing pollution, improving energy efficiency, and promoting sustainable development. The majority of respondents believe that innovations such as renewable energy systems, waste management technologies, and energy-efficient production processes significantly contribute to environmental conservation. Therefore, based on the empirical evidence, the null hypothesis (H<sub>1</sub>) is rejected, and it can be concluded that there is a significant relationship between environmental protection and clean technologies.

### **Conclusion and Policy Recommendations**

The study highlights the need for greater public awareness and education to promote environmental sustainability. Although many people are already aware, wider participation from society is necessary to encourage sustainable practices. Educational institutions, community groups, and media platforms can help spread knowledge about environmental issues and clean technologies. Financial

support is also important to motivate industries to adopt eco-friendly technologies. Incentives like subsidies, tax benefits, and low-interest loans can ease the financial burden on businesses. These measures can encourage investment in sustainable solutions. Additionally, stronger regulatory frameworks are essential for environmental protection. Clear standards and strict monitoring can ensure compliance by industries. Transparent processes can further improve accountability. Overall, combined efforts can lead to more sustainable industrial practices.

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# **An Evaluation of Dr. Bandorwala Leprosy Hospital Kondhwa (Pune): A Gender-wise Temporal Assessment of Leprosy Disease**

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## **Abstract**

Present paper is an attempt study in a case study of Dr. Bandorwala Leprosy Hospital Kondhwa (Pune) the gender-wise temporal assessment of leprosy disease was investigated. Leprosy, often known as Hansen's disease, is caused by Mycobacterium leprosy. It is an infectious sickness that persists. It mostly affects the skin and peripheral nerves and can cause severe deformity and impairment if therapy is not received. Leprosy has been severely stigmatized throughout history and culture since it was first identified in antiquity. Leprosy is a bacterial disease that can be debilitating and persistent, and it is caused by Mycobacterium leprosy e. Cases of the illness have been reported in many countries, including India. Disease incidence is highest in the poorest part of the world. Migration from endemic to no endemic leprosy areas may cause the disease to resurface. To ascertain the quantity of leprosy cases in Pune. Every year, leprosy cases that occurred in Pune City between 2010 and 2021 were compiled and analyzed, allowing researchers to observe how the disease's cases changed over time.

**Keywords:** Leprosy, Disease, Gender, Temporal, Annual.

## **Introduction**

The ancient disease leprosy is described in the literature of ancient cultures. Mycobacterium leprae is the bacterium that causes this chronic infectious disease. The disease affects the skin, peripheral nerves, eyes, and mucosa of the upper respiratory tract. Leprosy is treatable, and early intervention can prevent disability. Leprosy patients face stigma and discrimination in addition to physical abnormalities. According to the World Health Organization, there were around 173000 as of the end of 2016. These cases were mostly found in

Indonesia, Brazil, and India. Hansen's disease, commonly referred to as leprosy, disables two to three million people globally.

Bacteria such as *Mycobacterium leprae* or *Mycobacterium lipomatosus* cause the disease, which is a chronic, long-term disorder that spreads between infected people when they come into intimate contact. According to recent studies, the skin is believed to be the main channel of transmission despite being the largest organ of the integumentary system in the human body. The peripheral nervous system (PNS), vision, respiratory system, and primary organ (skin) are all impacted. Patients with peripheral nervous system (PNS) leprosy may experience sensory loss during discomfort. Numerous non-communicable diseases (NCDs) and non-infectious causes are often associated with chronic illnesses. The World Health Organization recommended preventative treatment for people who had close contact with a leprosy patient since early detection of the disease is essential for preventing leprosy.

The recommended preventive medication for adults and children over two who do not currently have leprosy or tuberculosis is a single dose of rifampicin (SDR). Precautionary and preventative treatment is linked to a 30% reduction in infections within six years and a 57% reduction in infections within two years. Leprosy has a long history; it was first discovered in antiquity in Balathal in India and Harappa in Pakistan (Robbins, G. et al., 200 BC). Robbins' discovery of skeletal evidence for leprosy in India (2000 B.C.) offers proof of older eras. The Atharva Veda and Kausika Sutra also discuss, explain, and make reference to skin conditions. Annual and sporadic examinations of disease cases were conducted. Cartographic technologies are used to visualize time data and disseminate epidemic diseases. It is very beneficial for tracking, prevention, and acquisition. Implementing appropriate management techniques to avoid illnesses may benefit from analysing the annual trends of illnesses.

### **Study Area**

Pune is situated between latitudes 18°25' and 18°37' North and longitudes 73°44' and 73°57' East. The city is situated at an average elevation of 560 meters above mean sea level in a saucer-shaped basin. The low Sahyadri hill ranges, which stretch from west to east, encircle Pune. The city is situated between 560 and 570 meters above sea level (MSL). The city of Pune is located where the Mula and Mutha, two seasonal rivers, converge. Pune's natural wealth and scenic beauty have earned it the title of "Queen of the Deccan."

**Objectives of the study**

In this study the major objectives are to identify the leprosy cases in the Bandorwala Leprosy hospital and to assess the annual temporal changes of leprosy disease in the same hospital.

**Data and Methodology**

The Dr. Bandorwala Leprosy Hospital at Kondhwa, Pune, provided the information on leprosy disorders. Expressive disease analysis using statistical software, Ms. Excel, and the creation of annual graphs of leprosy illness by gender.

**Data Analysis, Results and Discussion**

Figure No. 1 shows the temporal distribution of leprosy cases in the research area from 2010 to 2021.

Fig. No. 1 Distribution of Leprosy cases during 2010-2021 period in the study area.

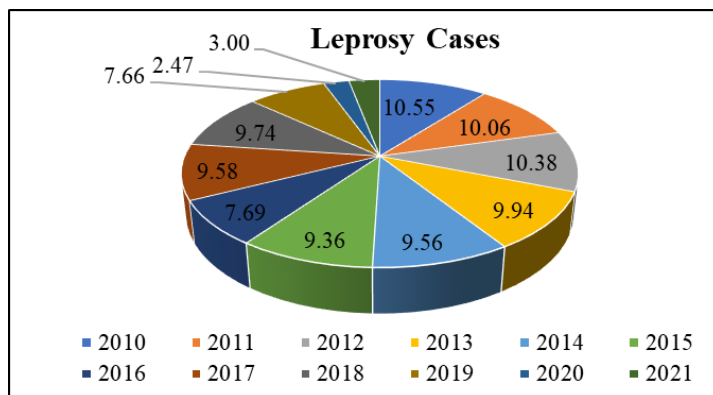
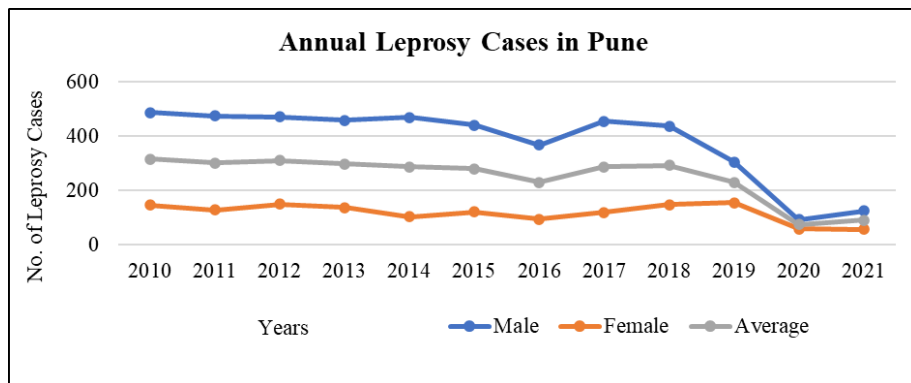


Fig. No. 2 Annual distribution of gender-wise Leprosy cases during 2010-2021 period.



The chart shows that about 5993 cases of leprosy were reported over the 12 year period from 2010 to 2021, with 10.55% of the highest number of cases occurring in 2010 and 2.47% of the lowest number occurring in 2016. Between 2010 and 2021, an average of 499 cases of leprosy were reported annually, with a declining trend in cases (fig. no. 2).

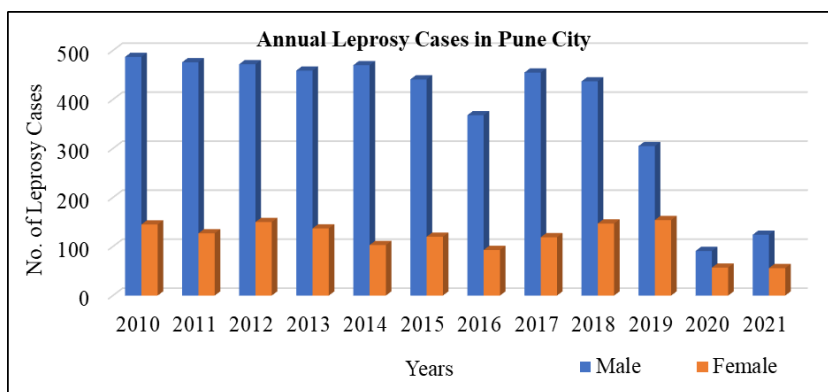
The table no. 1 shows the distribution of leprosy patients by gender throughout the 12 year period from 2010 to 2021.

Table no. 1 Gender-wise Leprosy Cases

Sr. No	Years	Male	Male %	Female	Female %	Total	Total %
1	2010	487	10.62	145	10.30	632	10.55
2	2011	476	10.38	127	9.02	603	10.06
3	2012	472	10.29	150	10.65	622	10.38
4	2013	459	10.01	137	9.73	596	9.94
5	2014	470	10.25	103	7.32	573	9.56
6	2015	441	9.62	120	8.52	561	9.36
7	2016	368	8.03	93	6.61	461	7.69
8	2017	455	9.92	119	8.45	574	9.58
9	2018	437	9.53	147	10.44	584	9.74
10	2019	305	6.65	154	10.94	459	7.66
11	2020	91	1.98	57	4.05	148	2.47
12	2021	124	2.70	56	3.98	180	3.00
		4585	100	1408	100	5993	100

(Source – Dr. Bandorwala Leprosy Hospital Kondhwa, Pune – 2022)

Fig. No. 3 Annual Leprosy cases in Pune city



The information in the table shows the proportion of boys and girls in various

years.

### **Gender Distribution over the Time**

The gender distribution during a 12-year period, from 2010 to 2021, is displayed in the table. Every year, there are variations in both the number of men and females. The percentage of men and women in the overall population for each year is shown in the male and female percentage columns. These numbers show the percentage of men and women in relation to the overall population for that specific year.

The proportion of males in the population seems to be gradually declining over time, while the proportion of females appears to be rising in tandem. This pattern points to a gradual change in the gender balance. 2010 saw the highest number of leprosy cases (632) and the highest percentage of male patients (10.62%). 2020, on the other hand, had the lowest number of leprosy cases overall (148) and the lowest percentage of males (1.98%). 2019 had the largest percentage of females (10.94%).

### **Gender Disparities**

With the exception of a few years (2014, 2015, 2016, 2019, 2020, and 2021), when the percentage of females is either significantly greater or comparable, the majority of years have a higher percentage of males than females. Every year, the degree of gender inequality varies. The number of people was notably lower in 2020 than in prior years, and the proportion of men was remarkably low at 1.98%, suggesting a significant shift in the gender distribution for that year. 2019 had the greatest percentage of female leprosy cases (10.94%), which may have been caused by fewer male cases that year.

The information could be utilized to look more closely at patterns and trends in the distribution of genders throughout time as well as to pinpoint any potential causes of the noted shifts.

### **Conclusion**

India tops the globe in newly confirmed cases of leprosy, with Brazil and Indonesia following closely behind. Leprosy was proclaimed eradicated in India in 2005, but new cases emerged as a result of changes made to the Global Leprosy Program and the National Leprosy Elimination Program (NLEP). If leprosy is not detected early, it can spread to a large number of people, and a delayed diagnosis may increase the risk of becoming disabled. In 2005,

Visakhapatnam reported about 248 cases; as of 2018 (146), the situation is basically stable. The district's increased relative humidity contributes to the persistence of leprosy.

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# **Trend Analysis of Hirda (*Terminalia Chebula*) Procurement and Its Economic Importance for Rural Communities in Junnar-Ambegaon Pune District Maharashtra**

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## **Abstract**

Forests play a crucial role in environmental sustainability and livelihood security, particularly for tribal communities dependent on non-timber forest products. The northwestern part of Pune district, located in the Sahyadri (Western Ghats) range, is characterized by hilly terrain, high rainfall, and rich forest cover. The region is predominantly inhabited by the Mahadev Koli tribal community, whose livelihood is closely linked to forest resources. Among these resources, Hirda (*Terminalia chebula*) is one of the most economically and medicinally significant forest products, widely used in Ayurveda and serving as the primary source of cash income for tribal households, especially during the summer season.

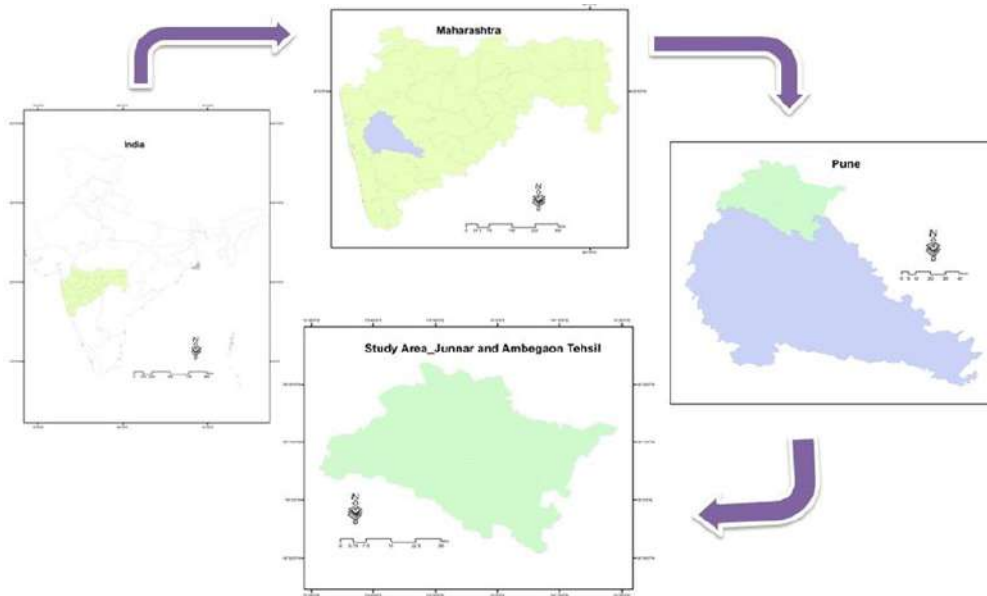
Hirda is an important non-timber forest product widely used in traditional medicine and rural trade. The present study analyzes the trend of Hirda fruit procurement by the Tribal Cooperative Marketing Society (T.C.M.S.) from 2001–2002 to 2009–2010. The study examines yearly procurement data and price variation of Hirda fruit. The findings reveal a gradual increase in procurement during the study period, indicating growing demand and improved market systems. The price analysis shows that Hirda Bal fruit recorded a maximum price of Rs. 80 per kg and a minimum price of Rs. 50 per kg. The study highlights the economic importance of Hirda for forest-dependent communities.

**Keywords:** Hirda, Non-Timber Forest Products, Forest Economy, Trend Analysis, junnar and ambegaon tahasil, Medicinal Plants

## Introduction

*Terminalia chebula*, commonly known as Hirda, is a valuable medicinal plant found in the forests of Maharashtra, particularly in the Western Ghats region. It is widely used in Ayurvedic formulations and traditional medicines. Hirda fruit is also an important non-timber forest product (NTFP) that contributes to the livelihood of tribal and rural communities. Cooperative institutions and forest development agencies often procure Hirda fruits to support forest collectors and ensure fair market prices. Understanding the trends of Hirda procurement helps in assessing its economic significance and sustainable utilization. The study highlights that Hirda production remains the most significant source of seasonal income for tribal communities. However, the discontinuation of procurement by the Adivasi Vikas Mahamandal since 2015, dependence on private traders, price exploitation, storage-related weight loss, and climate variability have adversely affected tribal livelihoods. The findings emphasize the need for policy intervention, institutional support, and sustainable harvesting strategies. Integrating geospatial analysis with socio-economic assessment provides a scientific basis for improving tribal livelihoods, ensuring fair pricing, and promoting sustainable forest-based economic development in northwestern Pune district.

## Study Area



The study focuses on forest regions of Junnar and Ambegaon tehsil in Pune district where Hirda trees are commonly found. The study area has diverse

forest ecosystems, particularly in the Western Ghats and central forest regions. The tropical climate and suitable soil conditions support the growth of various medicinal plants, including Hirda. Forest-dependent communities in these regions collect Hirda fruits during the harvesting season and sell them through cooperative marketing networks.

The present study focuses on the regions of Junnar and Ambegaon situated in the Pune district of Maharashtra, India, geographically positioned at approximately 19.2057° N latitude and 73.8694° E longitude for Junnar, and 19.1138° N latitude and 73.8500° E longitude for Ambegaon.

### **Objectives of the Study**

- To examine the trend of Hirda fruit procurement from 2001–2010.
- To analyze the price variation of Hirda fruit in the market.
- To understand the economic importance of Hirda collection for rural communities.

### **Data and Methodology**

The present study is based on secondary data obtained from procurement records of T.C.M.S. for the period 2001–2002 to 2009–2010.

- Methods Used
- Tabular analysis
- Trend analysis

### **Graphical Representation**

The total quantity of Hirda fruit purchased was analyzed to understand changes in procurement over time.

The north-western part of the Junnar–Ambegaon tahsil in Pune district is largely inhabited by tribal populations. Hirda collection and its subsequent sale to local vendors constitute one of the primary income-generating activities for the tribal communities in the area.

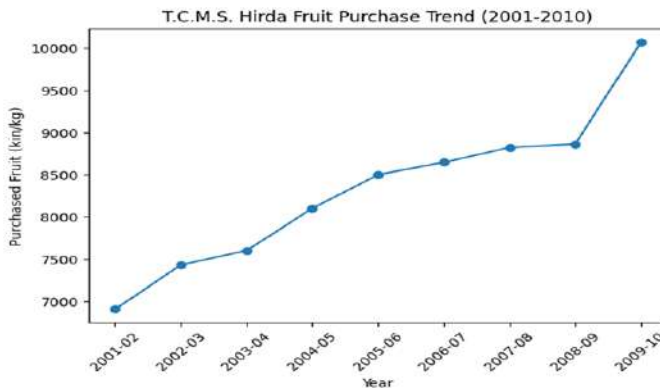
This forest sector is the main source of medicinal plants and the income of the sources of these medicinal plants. 'Hirida' is the one of the most medicinal products which is produced in Hilly area. The hilly area through the provides production of 'Hirida' fruit, that production helps the employability to the Hilly population. The employability is good for the economic development of rural areas.

**Trends of Hirda Production**

Sr. No.	Year	Purchased fruit by T.C.M.S. (Total fruit in kin /kg)
1	2001-2002	6907.30
2	2002-2003	7431.20
3	2003-2004	7601.70
4	2004-2005	8101.70
5	2005-2006	8500.95
6	2006-2007	8646.40
7	2007-2008	8822.80
8	2008-2009	8863.10
9	2009-2010	10070.64
	Total	74945.79

(Reference - Annual Report of Year 2001toYear 2010, T.C.M.S. of Junnar)

The above table shows that total 74945.79 kin/kg 'Hirda fruit' was collected / purchased by T.C.M.S. of Junnar in the last 10 years. The data shows a steady increase in Hirda fruit procurement during the study period. The lowest procurement was recorded in 2001–2002, while the highest procurement was observed in 2009–2010.



**Growth Rate Analysis**

The procurement data indicates a consistently positive growth trend, with no

instances of decline over the study period.

- The average annual growth rate is approximately 4.90%, indicating steady expansion.
- The Compound Annual Growth Rate (CAGR) is calculated as:

$$\text{CAGR} = \left( \frac{10070.64}{6907.30} \right)^{\frac{1}{9}} - 1 \approx 4.2\%$$

This reflects a stable long-term growth pattern, slightly smoothing year-to-year fluctuations. The highest growth occurs between 2008–2009 and 2009–2010, indicating a significant improvement in procurement during the final phase.

### **Trend Line and Regression Analysis**

A linear regression model is fitted to examine the long-term trend:

$$Y=395X+6907$$

Where

Y= Hirda procurement (kin/kg)

X= Time (year index)

The slope (395) indicates that procurement increased by approximately 395 kin/kg per year.

The positive slope confirms a strong upward trend.

The coefficient of determination ( $R^2$ ) is approximately:

$$R^2 \approx 0.97$$

This indicates that 97% of the variation in procurement is explained by time, showing a very strong model fit and consistent growth pattern. The absence of negative growth highlights a stable and well-functioning procurement system.

1. The steady increase reflects sustainable utilization of forest resources, particularly Hirda.
2. The high  $R^2$  value confirms that time is a significant factor influencing procurement trends.
3. The sharp rise in the final year suggests possible policy support, improved market linkages, or increased production efficiency.

4. The moderate CAGR (~4.2%) indicates balanced growth without over-exploitation, which is crucial for ecological sustainability.

The above statistical analysis effectively fulfills the study by clearly demonstrating the temporal trend and growth pattern of Hirda fruit procurement during the period 2001–2010.

### **Price Variation of Hirda Fruit**

This time the market price of Hirda fruit varies depending on its type, quality and size.

- Maximum price of Hirda Bal fruit: Rs. 80 per kg
- Minimum price of Hirda fruit: Rs. 50 per kg

Higher prices are generally associated with better fruit quality and larger size.

### **Discussion**

The analysis indicates that Hirda procurement has increased gradually over the years. This suggests that Hirda has gained importance as a commercial forest product. However, fluctuations in price may influence the income of collectors. Therefore, strengthening cooperative marketing systems and ensuring sustainable harvesting practices are necessary for long-term benefits. The study reveals that Hirda fruit procurement has increased steadily during the study period. This indicates the growing commercial importance of medicinal forest products. Hirda collection plays an important role in supporting the livelihoods of tribal and rural communities. Income generated from forest products contributes to household economies, particularly in forest-dominated regions. However, challenges such as price fluctuations, market access, and unsustainable harvesting practices may affect the long-term availability of Hirda resources. Strengthening cooperative marketing systems and promoting sustainable harvesting techniques can help address these issues.

### **Conclusion**

The study shows a clear increasing trend in Hirda fruit procurement from 2001–2010. The price variation between Rs. 50 and Rs. 80 per kg reflects the influence of fruit quality and market demand. Proper management and marketing strategies can enhance the economic benefits of Hirda collection for forest communities. The present study analyzed the trend of Hirda fruit procurement and price variation over a nine-year period. The findings show a gradual increase in Hirda procurement, reflecting the rising demand for medicinal plant products. The price analysis indicates that Hirda fruit prices

range between Rs. 50 and Rs. 80 per kilogram depending on quality and market conditions. The study highlights the economic importance of Hirda as a non-timber forest product and emphasizes the need for sustainable resource management and improved marketing systems to ensure long-term benefits for forest communities.

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# Energy Storage Systems: Technologies, Applications, and Future Prospects

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## Abstract

Energy storage systems (ESS) play a pivotal role in the modern transition toward sustainable, reliable, and resilient power systems. As renewable energy generation—such as solar and wind—grows globally, so does the need for efficient energy storage to balance supply and demand, provide grid stability, and support decarbonisation strategies. This paper reviews the principles, technologies, advantages, and challenges of energy storage systems. It also discusses technical, economic, and environmental considerations, explores ongoing research and development, and highlights future trends and recommendations for advancing ESS deployment worldwide.

**Keywords:** Energy storage systems (ESS), Renewable energy, Global energy, Types of ESS, Mechanical Energy Storage, Air Energy Storage.

## Introduction

The global energy landscape is undergoing a dramatic transformation. With increasing environmental concerns and commitments to reduce carbon emissions, renewable energy technologies are being adopted at unprecedented rates. However, renewable sources like wind and solar are intermittent, meaning they cannot always produce electricity when demand is high. Energy storage systems (ESS) address this challenge by storing excess electricity when generation exceeds demand and releasing it when needed.

This research paper examines the current state of ESS, explores key technologies, evaluates their benefits and limitations, and outlines future directions for research and deployment.

## Objectives

The main objective of this research is to study and analyze Energy Storage Systems (ESS) in terms of technology, performance, applications, and future

potential. The specific objectives are:

- To examine the fundamental principles and classifications of energy storage systems.
- To analyze different types of energy storage technologies such as mechanical, electrochemical, thermal, and chemical storage systems.
- To study the role of energy storage systems in renewable energy integration and grid stability.

**Research Hypotheses:** Energy storage systems significantly improve grid stability and reliability in power systems with high renewable energy penetration.

### **Importance of Energy Storage Systems**

Energy storage is vital for:

- **Grid Stability and Reliability:** ESS can absorb and supply energy quickly to balance fluctuations in electricity generation and demand.
- **Renewable Integration:** By storing surplus energy from renewable sources, ESS reduces curtailment and smoothes variable generation profiles.
- **Peak Shaving and Load Levelling:** ESS can be charged during low-demand periods and discharged during peak demand, reducing stress on grids.
- **Backup Power Supply:** In events of outages, ESS can provide emergency power for homes, industries, and critical infrastructure.
- **Economic Benefits:** ESS can reduce electricity costs, defer infrastructure upgrades, and provide ancillary services like frequency regulation.

### **Types of Energy Storage Systems**

Energy storage technologies vary widely in terms of scale, performance, and application. They can be broadly classified into mechanical, electrochemical, thermal, and chemical systems.

#### **Mechanical Energy Storage**

##### **Pumped Hydro Storage (PHS)**

**Principle:** Water is pumped from a lower reservoir to a higher reservoir during periods of surplus energy and released back through turbines to generate electricity when needed.

##### **Advantages**

- High efficiency (70–85%)

- Long life (50+ years)
- Large energy capacity (hundreds of megawatts to gigawatts)

### **Challenges**

- Requires suitable topography
- High upfront construction costs
- Environmental impacts on aquatic ecosystems

Pumped hydro is the most widely deployed form of energy storage, representing more than 90% of current installed capacity globally.

### **Compressed Air Energy Storage (CAES)**

**Principle:** Air is compressed and stored under pressure in underground caverns or tanks during off-peak times and released to drive turbines during peak demand.

### **Advantages**

- Scalable to large capacities
- Potentially lower costs than batteries

### **Challenges**

- Lower round-trip efficiency (40–70%)
- Requires suitable geological formations
- Heat management during compression and expansion

CAES plants often incorporate thermal storage to improve efficiency, capturing heat generated during compression for later use.

### **Flywheel Energy Storage**

**Principle:** A rotor spins at high speeds to store kinetic energy. Energy is drawn by slowing the rotor.

### **Advantages**

- High power density
- Fast response times
- Long cycle life (millions of cycles)

### **Challenges**

- High cost per unit of energy stored
- Limited energy storage capacity
- Mechanical friction losses

Flywheels are commonly used for short-duration storage and grid frequency

regulation.

## **Electrochemical Energy Storage**

### **Lithium-Ion Batteries**

**Principle:** Chemical reactions in lithium-ion cells facilitate the flow of ions between electrodes to store and release energy.

#### **Advantages**

- High energy and power density
- Fast response time
- Modular and scalable

#### **Challenges**

- High-cost relative to traditional storage
- Safety concerns (thermal runaway)
- Resource limitations (lithium, cobalt)

Lithium-ion batteries are widely used in electric vehicles (EVs), consumer electronics, and utility-scale storage.

### **Flow Batteries**

**Principle:** Electrolyte liquids containing electroactive materials flow through a cell stack to store and discharge energy.

#### **Advantages**

- Long cycle life
- Decoupled energy and power rating (scalable)
- Minimal degradation

#### **Challenges**

- Lower energy density than lithium-ion
- Higher upfront costs
- Large footprint

Flow batteries are particularly suited for large-scale, long-duration storage applications.

### **Other Battery Technologies**

Other emerging battery types include sodium-ion, solid-state, zinc-air, and metal-sulfur systems. These aim to improve safety, reduce costs, and increase energy capacity.

## **Thermal Energy Storage**

**Principle:** Heat or cold is stored for later use in electricity generation or thermal applications.

### **Examples**

- **Molten Salt Storage:** Used in concentrated solar power (CSP) plants to retain heat for power generation after sunset.
- **Phase-Change Materials (Pcms):** Store energy through melting and solidification.
- **Ice Storage:** Used for cooling buildings during peak demand periods.

### **Advantages**

- Can address heating and cooling needs directly
- Cost-effective in specific applications

### **Challenges**

- Lower energy storage density
- Often site-specific applications

## **Chemical Energy Storage**

### **Hydrogen Storage**

**Principle:** Electricity is used to split water into hydrogen and oxygen through electrolysis. Hydrogen is stored and later converted back to electricity using fuel cells or combustion.

### **Advantages**

- High energy density by weight
- Suitable for long-duration storage
- Supports multiple energy sectors (transport, industry)

### **Challenges**

- Low round-trip efficiency (30–50%)
- High cost of electrolysis and storage
- Requires infrastructure development

Hydrogen is considered a key component in achieving deep decarbonization.

### **Key Performance Metrics**

When comparing energy storage technologies, several performance metrics are important:

- **Energy Density:** Amount of energy stored per unit mass or volume.
  - **Power Density:** Rate at which energy can be delivered.
  - **Round-Trip Efficiency:** Ratio of energy output to input.
  - **Cycle Life:** Number of charge/discharge cycles before significant degradation.
  - **Response Time:** How quickly the system can respond to demand.
  - **Cost:** Includes capital cost (\$/kWh), operating cost, and lifecycle cost.
- Each technology must be evaluated based on desired application requirements.

### **Applications of Energy Storage Systems**

- **Grid Support and Stabilization:** ESS helps maintain grid balance by providing frequency regulation, voltage support, and black start capabilities.
- **Renewable Energy Integration:** ESS reduces curtailment of wind and solar power by storing excess generation and supplying it during low generation periods.
- **Peak Shaving and Load Shifting:** Large industrial and residential consumers use ESS to reduce peak demand charges and optimize electricity use.
- **Backup and Emergency Power:** Critical facilities such as hospitals, data centres, and telecom networks use Energy Storage Systems to ensure continuous operation during outages.
- **Transportation and Electrification:** Electric vehicles (EVs) depend on battery storage. Vehicle-to-grid (V2G) technologies also allow EVs to support grid operations.

### **Economic and Environmental Considerations**

#### **Cost Trends**

The cost of energy storage, particularly lithium-ion batteries, has declined significantly over the past decade due to manufacturing scale and technological improvements. Continued cost reduction is necessary to accelerate adoption.

#### **Environmental Impacts**

Environmental considerations include:

- Mining impacts (lithium, cobalt)
- End-of-life disposal and recycling
- Land and ecosystem disruption for large projects (e.g., pumped hydro)

Developing sustainable supply chains and recycling systems is an active area of research.

## **Challenges and Limitations**

Despite significant progress, several challenges remain:

- High upfront capital costs
- Safety concerns in high-energy batteries
- Limited lifespan and degradation
- Regulatory and policy barriers
- Integration complexities with existing infrastructure

Addressing these challenges requires technical innovation, policy support, and investment.

## **Recent Advances and Research Directions**

Significant research is ongoing to improve ESS performance and reduce costs:

- Solid-State Batteries: Offering enhanced safety and higher energy density.
- Advanced Flow Battery Chemistries: Using abundant and low-cost materials.
- AI-Enabled Energy Management: Optimizing battery charging and dispatch.
- Hybrid Storage Systems: Combining different technologies to balance fast response and long-duration needs.
- Recycling Technologies: Improving recovery of valuable materials.

Collaborations between academia, industry, and governments are essential to accelerate innovation.

## **Future Prospects**

The future of energy storage is promising. Key trends include:

- Growth in hybrid energy systems
- Policy reforms supporting storage markets
- Expansion of long-duration storage solutions
- Decentralized storage at household and community levels
- Global collaboration on standards and recycling infrastructure

With continued innovation and supportive policies, ESS will be central to energy transition goals.

## **Conclusion**

Energy storage systems are foundational to building resilient, efficient, and sustainable energy systems. A diverse mix of technologies—from batteries to pumped hydro and emerging solutions like hydrogen—provides flexibility across different applications. While challenges related to cost, safety, and environmental impact remain, ongoing research and market growth are driving

rapid improvements.

To fully realize the potential of ESS, integrated approaches involving technological innovation, economic incentives, regulatory frameworks, and public understanding are essential. As the world strives toward net-zero emissions, energy storage will play a crucial role in enabling reliable and clean energy futures.

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# Application of Remote Sensing and GIS in River Basin Analysis and Management

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## Abstract

River basins are important hydrological units that control the flow of water, sediment transport, and ecological processes within a landscape. Effective river basin management is essential for sustainable water resource development, environmental conservation, and disaster mitigation. Remote Sensing (RS) and Geographic Information Systems (GIS) have emerged as powerful tools for analyzing river basin characteristics and supporting watershed management. This study highlights the applications of RS and GIS in river basin analysis including watershed delineation, morphometric analysis, land use and land cover mapping, flood risk assessment, and groundwater potential mapping. Satellite imagery and spatial data analysis provide accurate and timely information about river basin dynamics. The integration of RS and GIS techniques significantly improves decision-making processes in water resource management and environmental planning.

**Keywords:** Remote sensing, GIS, river basin analysis, watershed management, morphometric analysis, hydrology.

## Introduction

River basins play a vital role in sustaining ecosystems and supporting human activities such as agriculture, water supply, and industrial development. However, increasing population pressure, deforestation, urban expansion, and climate variability have led to significant changes in river basin environments. Traditional methods of hydrological analysis were based on field surveys and topographic maps. Although these methods provide valuable information, they are often time-consuming and limited in spatial coverage. The advancement of geospatial technologies has transformed the way river basins are studied.

Remote sensing provides satellite-based observations of the Earth's surface, enabling continuous monitoring of environmental changes. GIS allows the

storage, processing, and analysis of spatial data to understand relationships between different geographic features. The integration of Remote Sensing and GIS has become an effective approach for river basin analysis. These technologies help researchers map drainage networks, analyze watershed characteristics, monitor land use changes, and assess environmental impacts.

### **Concept of River Basin**

A river basin is defined as the area of land drained by a river and its tributaries. It forms a natural hydrological unit where all precipitation eventually flows into a common outlet such as a river, lake, or ocean. River basins consist of several components including:

- **Watersheds and Sub-Watersheds:** A watershed is the area that drains water into a main river, while sub-watersheds are smaller divisions within the basin. They help in managing water resources and planning conservation measures.
- **Drainage Networks:** Drainage networks consist of the main river and its tributaries that carry water through the basin. They control the movement of runoff and influence the basin's hydrological behavior.
- **Soil and Geological Formations:** Soil type and underlying rock structures affect infiltration, groundwater recharge, and erosion processes within the river basin.
- **Vegetation and Land Use Patterns:** Vegetation cover and human land use activities such as agriculture and settlements influence water runoff, soil erosion, and environmental stability.
- **Hydrological Processes:** These include rainfall, infiltration, surface runoff, evaporation, and groundwater flow, which control the movement and distribution of water in the basin.

Understanding all these components is important for sustainable river basin management and environmental planning.

### **Remote Sensing and GIS in River Basin Studies**

- **Remote Sensing**

Remote sensing refers to the acquisition of information about Earth's surface without direct contact. Satellite sensors capture data in different spectral bands that can be used to analyze land surface features.

Commonly used satellite data sources include the Landsat Program and Sentinel-2 missions, which provide multispectral images useful for mapping water bodies, vegetation, and land cover changes.

Remote sensing helps in monitoring river basin dynamics such as vegetation cover, surface water distribution, and environmental degradation.

- **Geographic Information System (GIS)**

GIS is a computer-based system designed for storing, managing, and analyzing geographic data. It integrates different types of spatial data layers such as elevation, land use, soil type, and drainage networks.

Using GIS tools, researchers can perform spatial analysis to understand relationships between environmental factors within a river basin.

### **Data and Methodology**

#### **Data Sources**

The analysis of river basins using RS and GIS typically requires the following datasets:

*Table No.1: Data Sources of River Basin Analysis*

<b>Data</b>	<b>Source</b>
Satellite imagery	Landsat / Sentinel
Elevation data	Digital Elevation Model (DEM)
Topographic maps	Survey of India
Rainfall data	Meteorological stations
Soil maps	Agricultural departments

#### **Watershed Delineation**

Watershed boundaries are delineated using DEM data in GIS software. Hydrological tools such as flow direction and flow accumulation are used to extract drainage networks.

#### **Morphometric Analysis**

Morphometric analysis involves quantitative measurement of river basin characteristics. It is useful for understanding basin geometry, drainage patterns, and hydrological behaviour.

Morphometric parameters are classified into three categories:

**Table No. 2. Morphometric parameters of River Basin**

Sr. Name	Parameters	Formula	
<b>A</b>	<b>Linear Parameters</b>	Stream order	Hierarchical ranking
		Stream Length	Total length of streams
		Bifurcation Ratio	$R_b = N_u / N_{u+1}$
<b>B</b>	<b>Areal Parameters</b>	Drainage Density	$D_d = \sum L_u / A$
		Basin Area	A (Basin Area)
		Form Factor	$R_f = A / L_b^2$
<b>C</b>	<b>Relief Parameters</b>	Basin Relief	$B_h = H - h$
		Relief Ratio	$R_h = B_h / L_b$
		Ruggedness Number	$R_n = B_h * D_d$

### Linear Parameters

Linear parameters describe the stream network characteristics of a river basin.

- **Stream Order:** It represents the hierarchical classification of streams. The smallest tributaries are first-order streams, and when two streams of the same order join, the order increases.
- **Stream Length:** It refers to the total length of streams in each order within a basin. It indicates the size and development of the drainage system.
- **Bifurcation Ratio:** It is the ratio between the number of streams of one order to the number of streams of the next higher order. It indicates the degree of branching in a drainage network.

### Areal Parameters

Areal parameters describe the two-dimensional characteristics of a river basin area.

- **Drainage Density:** It is the total length of streams divided by the basin area. It reflects how closely spaced the streams are within a basin.
- **Basin Area:** It is the total area drained by a river and its tributaries. It influences runoff and discharge characteristics.
- **Form Factor:** It is the ratio of basin area to the square of basin length. It indicates the shape of the basin and affects flood potential.

### Relief Parameters

Relief parameters represent the elevation and slope characteristics of the basin.

- **Basin Relief:** It is the difference between the highest and lowest elevation points in the basin.
- **Relief Ratio:** It is the ratio of basin relief to basin length, indicating the steepness of the terrain.
- **Ruggedness Number:** It is the product of basin relief and drainage density, showing the degree of terrain roughness and erosion susceptibility.

These parameters help identify erosion susceptibility and watershed development priorities.

### **Applications of Remote Sensing and GIS in River Basin Analysis**

- **Watershed Delineation**

GIS-based hydrological analysis allows accurate delineation of watershed boundaries and sub-watersheds. This helps in planning water resource development and soil conservation measures.

- **Land Use and Land Cover Mapping**

Satellite imagery is widely used to classify land use categories such as agriculture, forest, settlements, water bodies, and barren land. LULC analysis helps identify environmental changes within river basins.

- **Flood Risk Assessment**

Flood risk mapping is an important application of RS and GIS. Elevation models and hydrological data help identify flood-prone areas and simulate flood scenarios.

- **Soil Erosion Assessment**

Soil erosion is a major environmental problem in river basins. GIS-based models such as the Universal Soil Loss Equation are used to estimate soil loss based on rainfall, slope, soil type, and land cover.

- **Groundwater Potential Mapping**

Groundwater potential zones can be identified by integrating geological, geomorphological, slope, and drainage density layers in GIS.

- **Environmental Monitoring**

Remote sensing allows continuous monitoring of environmental conditions such as vegetation cover, water bodies, and land degradation.

### **Advantages of Remote Sensing and GIS**

The integration of RS and GIS provides several advantages in river basin

studies:

- Large-scale spatial coverage
- Ability to monitor changes over time
- Accurate mapping of drainage networks
- Efficient analysis of environmental parameters
- Support for decision-making in watershed management

These technologies are cost-effective compared to traditional field-based methods.

### **Limitations**

Despite their benefits, RS and GIS techniques also have some limitations:

- Cloud cover may affect satellite imagery
- Data processing requires technical expertise
- Ground verification is necessary for accurate results
- High-resolution data may be expensive

### **Future Scope**

The future of river basin studies will involve advanced geospatial technologies such as:

- Machine learning-based land cover classification
- Real-time satellite monitoring
- Integration of drone data with GIS
- Climate change modeling in hydrological studies

These technologies will improve the accuracy and efficiency of river basin management.

### **Conclusion**

Remote sensing and GIS have revolutionized river basin analysis by providing powerful tools for spatial data collection, analysis, and visualization. These technologies enable accurate mapping of watershed boundaries, drainage networks, and land use patterns. They also support flood risk assessment, soil erosion analysis, and groundwater potential mapping.

The integration of RS and GIS plays a crucial role in sustainable river basin management and environmental planning. Future research should focus on integrating advanced geospatial technologies to improve hydrological modeling and water resource management.

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# The Study of Rural Settlements Name Related with Natural and Human Aspects in Daund Tahsil, Pune District

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## Abstract

Rural settlements form an essential component of India and the world, representing the fundamental unit of human habitation. Each rural settlement possesses a distinct name, reflecting its identity and socio-cultural background. In Maharashtra, saints like Sant Tukaram and Samarth Ramdas significantly shaped the socio-cultural framework. Ramdas emphasized unity through the philosophy of “Maratha Tituka Melawawa” (unity among Marathas) and “Maharashtra Dharma”, which influenced regional identity and cultural expressions, including place names.

Place names, therefore, hold great social and geographical significance. Daund Tahsil, located on the Deccan Plateau of Maharashtra, is geographically and historically dynamic. Its diverse landscape is reflected in the naming of rural settlements, which are influenced by both physical and cultural factors. The study reveals that rural settlement names are closely associated with natural features such as flora, fauna, topography, and water bodies, as well as human elements like religion, caste, historical events, and personalities. While physical factors play a dominant role, cultural factors also significantly contribute to naming patterns.

**Keywords:** Rural settlements, place names, natural factors, cultural factors, Daund Tahsil, Maharashtra.

## Introduction

Every rural settlement has a name, and the study of these names provides valuable insights into the origin, development, and characteristics of villages. Place names are closely related to the physical and socio-cultural environment of a region and serve as an important source of geographical information. As Mandal (1978) observed, place names reflect identifiable relationships with environmental and cultural characteristics.

The study of rural place names helps reconstruct past geographical conditions and provides evidence of historical, social, and cultural transformations. These names preserve information about earlier landscapes, vegetation, occupations, and community structures. Scholars such as S. M. Singh (1962) and S. S. Padhye (1967) have contributed significantly to the study of rural settlement names in India.

In recent times, the development of rural settlement systems has become a crucial aspect of land-use planning. Understanding place names based on natural and human factors offers a scientific approach to analyzing changes in settlement patterns. This study focuses on Daund Tahsil and examines how physical and cultural elements have influenced rural settlement names.

### **Study Area**

Daund Tahsil is located in western Maharashtra within Pune District. It lies between 18°18' to 18°40' North latitudes and 74°06' to 74°50' East longitudes. The total area of the tahsil is 1288.04 sq. km., and it is one of the 13 tahsils in Pune district.

The region includes 102 villages and one urban center (Daund town), divided into six revenue circles: Rahu, Yavat, Kedgaon, Patas, Daund, and Ravangaon. The elevation ranges from 500 to 600 meters above mean sea level. The area is drained by the Bhima River and its tributaries, including Mula-Mutha. Several lakes such as Warvand and Kasurdi are also present.

Climatically, the region falls in a semi-arid zone and experiences low and irregular rainfall, being located in the rain shadow area. The soil is predominantly black cotton soil, suitable for crops like sugarcane, bajra, jowar, onion, and groundnut.

According to the 2011 Census, the population of Daund Tahsil is 382,535, with a density of 297 persons per sq. km. Irrigated land covers 74,463 hectares (58.05%). The region has well-developed transport and communication facilities, including Daund railway junction, Pune-Solapur National Highway, and other state roads. Kurkumbh serves as an important industrial area.

### **Objectives**

- To collect and analyze rural settlement place names related to natural and human factors in Daund Tahsil.
- To study the revenue circle-wise distribution of these place names.

## Materials and Methods

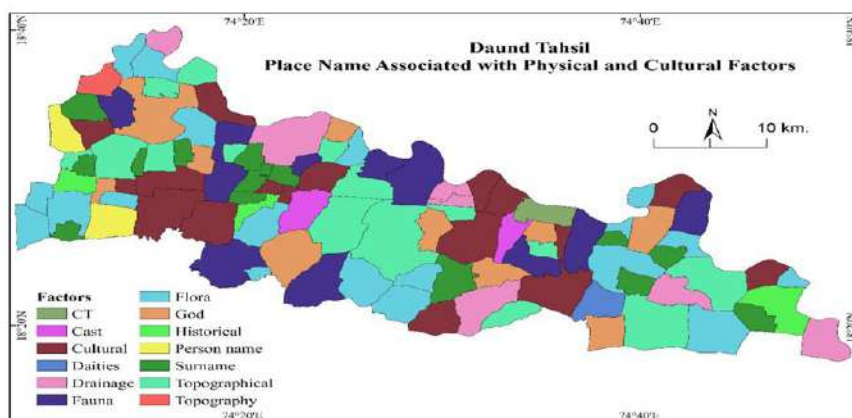
The study is based on secondary data collected from the Census of India (2011) and District Census Handbooks (1991, 2001, 2011). Rural settlement names were categorized into six major groups based on natural and human factors:

- **Natural Factors:** Flora, fauna, water bodies, topography
- **Human Factors:** Gods/deities, caste/religion, personal names/surnames, historical/cultural elements

The data was analyzed across six revenue circles: Rahu, Yavat, Kedgaon, Patas, Daund, and Ravangaon. Statistical methods were used to calculate frequencies and percentages.

*The Rural Settlements Names Related with Natural and Human features*

Sr No	Circle Name	Natural Factors				Human Factors				Total Villages
		Flora	Fauna	Water Bodies	Topography	Gods / Deities	Cast /Religion	Person /Surname	Cultural / Historic	
1	Rahu	03	02	01	04	02	-	03	02	17
2	Yawat	06	03	-	02	01	01	04	04	21
3	Kedgaon	01	02	01	01	02	01	03	05	16
4	Patas	03	02	03	04	02	-	01	01	16
5	Daund	03	03	-	01	02	01	02	05	17
6	Ravangaon	03	-	02	03	02	-	02	03	15
<b>Total Village</b>		<b>19</b>	<b>12</b>	<b>07</b>	<b>15</b>	<b>11</b>	<b>03</b>	<b>15</b>	<b>20</b>	<b>102</b>
<b>Percentage %</b>		<b>18.62</b>	<b>11.76</b>	<b>6.86</b>	<b>14.70</b>	<b>10.78</b>	<b>2.94</b>	<b>14.70</b>	<b>19.60</b>	<b>100%</b>
		<b>51.96%</b>				<b>48.04</b>				<b>100%</b>



## **Results and Discussion**

The analysis shows that rural settlement names in Daund Tahsil are strongly influenced by both natural and cultural features.

### **Place Names Related to Natural Factors**

Natural factors account for 53 villages (51.96%), indicating their dominant role.

#### **1. Flora (18.62%)**

Many villages are named after vegetation, reflecting the region's historical forest cover. Examples include Takali, Pimpalgaon, Boribel, Hingni, and Chincholi. Yavat circle has the highest number of such names, while Kedgaon has the lowest.

#### **2. Fauna (11.76%)**

Some villages derive names from animals and related elements, such as Dahitane, Padvi, and Hatwalan. Yavat and Daund circles show higher occurrences, while Ravangaon has none.

#### **3. Water Bodies (6.86%)**

Names like Kasurdi, Pargaon, and Khanote indicate proximity to rivers, streams, or lakes. Patas circle has the highest number of such names.

#### **4. Topography (14.70%)**

Several villages reflect landforms such as hills, plateaus, and slopes. Examples include Malthan, Malwadi, and Kadethanwadi. These names indicate settlement location in relation to terrain features.

Overall, natural factors such as vegetation, landforms, and hydrology significantly influence settlement naming, highlighting the close relationship between humans and the environment.

### **Place Names Related to Human (Cultural) Factors**

Human factors account for 49 villages (48.04%), demonstrating their substantial influence.

#### **1. Gods and Deities (10.78%)**

Many villages are named after religious elements, such as Deulgaon, Lingali, and Nandadevi. These names reflect strong religious beliefs and practices.

#### **2. Caste and Religion (2.94%)**

Names like Gopalwadi and Boripardhi indicate caste or community dominance in certain villages.

#### **3. Personal Names and Surnames (14.70%)**

Some villages are named after prominent individuals or families, reflecting historical ownership or leadership.

#### **4. Historical and Cultural Factors (19.60%)**

This category has the highest share among cultural factors. It includes names linked to historical events, traditions, and settlement processes, indicating the region's cultural evolution.

Cultural factors reveal the social structure, religious traditions, and historical development of the region. They help in understanding settlement history and cultural diffusion.

#### **Conclusion**

The study highlights that rural settlement names in Daund Tahsil are influenced by both natural and human factors. Natural factors contribute 51.96%, while cultural factors account for 48.04% of the total place names.

Among natural factors, flora (18.62%) and topography (14.70%) play a major role, followed by fauna and water bodies. Among cultural factors, historical and cultural elements (19.60%) and personal names (14.70%) are most significant.

This indicates that environmental features such as vegetation, landforms, and water resources have strongly influenced settlement naming. At the same time, cultural aspects like religion, social structure, and historical developments also play an important role.

Thus, place names serve as valuable indicators of both physical geography and cultural heritage. They provide insights into past environments, settlement processes, and socio-cultural evolution. The study is useful for understanding regional geography and can support further research in cultural and historical geography.

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# AI in Climate Studies and Disaster Management

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## Abstract

The increasing frequency and intensity of natural disasters, driven by climate change, rapid urbanization, and human activities, have underscored the urgent need for more effective disaster management systems. According to the Disaster Management Act, 2005 (India), disaster management is a continuous procedure that includes preparedness, response, recovery, and mitigation. Artificial Intelligence (AI) and Machine Learning (ML) are significantly enhancing climate disaster management by introducing innovative approaches for forecasting, risk reduction, and emergency response. By processing large and complex datasets from satellite imagery, weather monitoring systems, and online platforms, these technologies improve decision-making and operational efficiency. As natural disasters result in widespread destruction and considerable social and economic impacts, AI and ML are essential for strengthening preparedness, minimizing losses, and building climate resilience. It is essential to comprehend the dynamics of flood and landslide prediction in existing and nearby places in order to develop and enhance efficient prediction models, conservation strategies, and management approaches. Although predicting landslides is a challenging task, the damage and loss of life caused by landslides can be significantly reduced by developing landslide susceptibility maps using artificial intelligence techniques. The primary objective of this study is to evaluate and compare landslide susceptibility mapping (LSM) in the mountainous regions of western India by applying machine learning models such as Random Forest (RF), along with disaster risk management approaches, Geographic Information Systems (GIS), and remote sensing techniques.

**Keywords:** Artificial Intelligence (AI), Disaster Management, Climate Change, Machine Learning, GIS, Random Forest, Remote Sensing, mitigation, preparedness, response, recovery.

## **Introduction**

Climate change is widely acknowledged as a pressing global challenge amplifying the occurrence and intensity of natural hazards, including droughts, floods, and landslides. These disasters are becoming more frequent and destructive, leading to significant impacts on communities, economic systems, and natural environments. The United Nations Office for Disaster Risk Reduction highlights the critical role of hazard modeling in analyzing the spatial and temporal patterns of such events---such as their distribution, magnitude, and likelihood---to support informed risk reduction and management practices (2019). Recent reports from the World Meteorological Organization indicate a sharp rise in economic damages linked to climate-related disasters, with average global losses surpassing \$200 million per day, along with considerable annual loss of life (2023). Natural hazards have benefited greatly from the use of conventional hazard modelling techniques, such as statistical and physical methodologies. However, according to Gariano and Guzzetti (2016), these approaches are limited in their ability to handle the complexity of modern climate systems because they frequently struggle to process the enormous, dynamic datasets produced by advanced observation technology. Climate change is an urgent global challenge that influences nearly every dimension of human life and livelihoods. As climate-related risks intensify, there is an increasing need for proactive strategies focused on adaptation and mitigation.

Urbanisation and global climate change have contributed to the sharp rise in natural disasters in recent decades. Under India's Disaster Management Act, a "disaster" is defined as a sudden and severe event, whether man-made or natural, that results in significant human casualties, widespread destruction of infrastructure, or environmental harm---triggered by earthquakes, landslides, floods, tsunamis, industrial accidents, or human negligence. Such an occurrence is referred to as a disaster when it grows too large for a community to manage independently. Disaster management is a continuous and coordinated process encompassing preparedness before a disaster, effective response during, and recovery and rehabilitation after.

The four phases of disaster management are: Mitigation (reducing risk through building codes, flood plain management, and public education); Preparedness (planning, training, emergency drills, and warning systems); Response (immediate actions such as search and rescue, emergency medical assistance, and firefighting); and Recovery (rebuilding infrastructure and providing long-term support for affected communities).

Artificial Intelligence (AI) is widely acknowledged as a transformative technology capable of enhancing every stage of the disaster management cycle. AI is a branch of computer science enabling machines to simulate human-like intelligence---learning, reasoning, problem-solving, perception, and decision-making. AI plays a vital role in enhancing early warning systems, accelerating emergency responses, assisting rescue efforts, and improving damage assessments. Its algorithms examine vast amounts of data from sensors and satellites to identify early warning indicators of severe events like floods, cyclones, and landslides, enabling authorities to issue earlier warnings and prepare for evacuations. AI is extensively used in India to combat flood and landslide hazards through early warning systems, real-time tracking, and predictive modeling.

### **AI and ML in Mitigation**

AI is transforming disaster preparedness by enabling communities to plan more effectively and reduce long-term impacts. Unlike traditional disaster risk assessments---which relied on historical records, manual surveys, fixed zoning regulations, GIS-based maps, and expert judgment---AI-driven systems are dynamic and predictive. Conventional approaches often lacked real-time data integration, making them slow and less responsive to rapidly evolving hazards. In contrast, AI integrates machine learning, geospatial analytics, and satellite observations to detect emerging patterns and predict potential threats in advance.

Landslide susceptibility refers to the probability of landslides occurring in a particular geographic area (van Westen et al., 2006; Guzzetti et al., 2006). The use of landslide prediction models can help reduce potential damages (Pradhan and Lee, 2010). Over the past two decades, advances in processing power, Remote Sensing (RS), and Geographic Information Systems (GIS) have significantly improved the preparation of landslide susceptibility maps (Achour and Pourghasemi, 2020). These technological developments have greatly enhanced landslide research and applications (Lee, 2019; Shano et al., 2020; Patil et al., 2020; Pradhan et al., 2020, 2021; Coco et al., 2021; Hodasova and Bednarik, 2021). Such mapping plays a critical role in minimizing infrastructure damage and reducing loss of life. Consequently, landslide susceptibility mapping has become a foundational step in hazard assessment, risk evaluation, and mitigation planning. In India, most landslide vulnerability maps have traditionally focused on major transportation corridors and selected high-risk states. However, effective landslide risk management requires susceptibility

mapping at multiple spatial scales (Persichillo et al., 2016). Comprehensive mapping supports strategic risk reduction planning, the development of monitoring and early warning systems, and the formulation of sustainable land-use policies.

India is increasingly utilizing AI to generate detailed flood and landslide risk maps that guide safer urban development. Landslide susceptibility maps have been developed from district to national scales using machine learning models trained on terrain, rainfall, geological, and satellite datasets. The country is now moving toward ultra-high-resolution mapping (0.001° resolution) and applying advanced Deep Learning (DL) and ML techniques in seven regions, including Sikkim and Wayanad, significantly enhancing road alignment planning, zoning accuracy, and strategic placement of relief and emergency infrastructure.

### **Risk Reduction with AI and ML**

Existing landslide-prone areas experience single or multiple types of landslides simultaneously, making it essential to identify sub-events and the methodologies needed to capture their distinct signals in a timely manner. An effective Landslide Early Warning System (LEWS) must accurately capture, in real-time, the distinct signals generated during pre-event conditions, the initiation of the failure mechanism, and post-event scenarios, delivering effective and location-specific warnings to at-risk and vulnerable communities. This necessitates that the LEWS be capable of capturing the sub-events of multiple landslide types to provide targeted, location-specific warnings. To achieve this, new geographical areas are being explored for the deployment of landslide early warning systems through the application of geospatial technology and Web-GIS, utilizing precipitation measurement as a key indicator for regional-level warning (Ahmed et al. 2020; Hidayat et al. 2019). Furthermore, multi-domain solutions such as IoT-based landslide early warning systems, social media analytics, and community engagement are being integrated to develop comprehensive approaches for landslide risk reduction and resilience building.

### **Conclusion**

The landslide inventory may limit the model's ability to identify recent patterns or long-term trends resulting from haphazard roadway construction and infrastructure development, highlighting the importance of incorporating dynamic factors---such as ongoing land-use changes---into future models. The Landslide Susceptibility Maps (LSMs) generated through this study can be used

alongside other land monitoring systems to mitigate landslide risks in highly vulnerable areas. Building on these findings, the study identifies requirements for landslide risk reduction and establishes a comprehensive landslide risk management framework. IoT-based solutions have been proposed as a practical intervention strategy, with the IoT system deployed across the North Eastern Himalayas and the Western Ghats, drawing upon a decade of hands-on experience in building an end-to-end system for landslide disaster risk reduction.

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# Spatial Evaluation of Agricultural Risk and Resilience in Chalisingaon Taluka, Jalgaon District, Maharashtra

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## Abstract

Agricultural systems in semi-arid regions face increasing pressures from climate variability and socio-economic challenges, which together determine risk and resilience. This study examines agricultural risk and resilience in Chalisingaon taluka of Jalgaon district, Maharashtra, by integrating climate and socio-economic indicators within a Geographic Information System (GIS) framework. Key factors—including rainfall variability, temperature trends, soil characteristics, irrigation availability, landholding sizes, and literacy rates—were analyzed to map spatial variations in vulnerability and adaptive capacity. The findings indicate that rainfed areas with limited resources are most at risk, whereas regions with adequate irrigation and better socio-economic conditions exhibit greater resilience. The study underscores the importance of combining environmental and socio-economic dimensions to inform climate-resilient agricultural strategies and targeted interventions.

**Keywords:** Agricultural risk, Resilience, GIS, Climate variability, Socio-economic factors, Chalisingaon, Jalgaon, Maharashtra

## Introduction

Agriculture remains the mainstay of livelihoods in India, particularly in semi-arid zones where climate variability poses significant challenges. Increasing fluctuations in rainfall, rising temperatures, and recurrent droughts have adversely affected crop productivity, threatening food security and rural income. Socio-economic constraints, such as small landholdings, insufficient irrigation infrastructure, and low literacy, limit farmers' adaptive capacity and influence resilience.

Chalisingaon taluka, located in the northern part of Jalgaon district within the Khandesh region of Maharashtra, is predominantly semi-arid and heavily reliant on rainfed agriculture. The main crops include cotton, jowar, bajra, pulses, and

sugarcane in irrigated pockets. The combination of climatic stress and socio-economic constraints makes a spatial assessment of agricultural risk and resilience vital for planning adaptive measures.

Geospatial techniques, particularly GIS, provide a robust framework to analyze spatial variations in risk and resilience. By integrating climate, environmental, and socio-economic datasets, GIS allows the identification of high-risk areas and regions of stronger resilience, aiding evidence-based policy decisions. This study provides a descriptive spatial assessment of agricultural risk and resilience in Chalisgaon taluka to support climate-resilient agricultural planning.

### **Study Area**

Chalisgaon taluka is situated in northern Jalgaon district, Maharashtra, between 20.4°N–20.9°N latitude and 75.4°E–75.8°E longitude, covering approximately 1,400 km<sup>2</sup>. The taluka lies in the semi-arid zone of Khandesh, characterized by flat plains interspersed with low hills and gentle slopes. The predominant soils are black cotton soils (regur) and alluvial deposits along river valleys.

The region experiences a semi-arid climate, with annual rainfall ranging from 650 to 900 mm, mostly during the southwest monsoon. Temperatures vary from 10°C in winter to 45°C in peak summer, leading to heat stress and high evapotranspiration. Agriculture is the primary livelihood, with key crops including cotton, jowar, bajra, pulses, and sugarcane. Irrigation is limited and depends primarily on wells, borewells, and a few canal systems.

### **Data and Methodology**

#### **Data Sources**

Secondary data were obtained from:

- Rainfall and temperature records from the India Meteorological Department (IMD)
- Soil and land resource data from NBSS&LUP
- Land Use/Land Cover (LULC) derived from Landsat 8 imagery
- Digital Elevation Model (DEM) for topographical analysis
- Socio-economic data, including landholding size, literacy, irrigation coverage, and infrastructure from Census 2011 and district reports

#### **Indicator Framework**

Indicators were classified into three dimensions:

- **Exposure (Climate Factors):** Rainfall irregularity, temperature extremes, drought incidence

- **Sensitivity (Environmental Factors):** Soil fertility, slope, and land use patterns
- **Adaptive Capacity (Socio-Economic Factors):** Irrigation access, landholding size, literacy, market connectivity, and infrastructure

### **Analytical Approach**

All spatial datasets were processed using ArcGIS 10.8. Data layers were normalized to a common scale to ensure comparability. Descriptive spatial analysis was conducted for each indicator.

A Composite Risk and Resilience Index (CRRI) was calculated using a weighted overlay method:

$$\text{CRRI} = \text{Exposure} + \text{Sensitivity} - \text{Adaptive Capacity}$$

Based on CRRI values, areas were classified into:

- Very High Risk / Low Resilience
- High Risk / Moderate Resilience
- Moderate Risk / Moderate Resilience
- Low Risk / High Resilience

## **Results and Discussion**

### **1. Climate Exposure**

Rainfall and temperature analyses revealed substantial variability across Chalisgaon taluka. Rainfed regions with erratic monsoon rainfall exhibited high exposure to droughts, while irrigated areas experienced lower climatic stress. Rising temperatures have increased evapotranspiration, adding additional pressure on crop productivity.

### **2. Environmental Sensitivity**

Sensitivity varied according to soil depth, fertility, and terrain. Plateau and rocky areas were more susceptible to water stress, whereas alluvial plains were less sensitive. Areas dominated by monocropping, particularly cotton and jowar, were highly sensitive, while diversified cropping systems enhanced resilience.

### **3. Socio-Economic Adaptive Capacity**

Socio-economic conditions significantly influenced resilience. Small and marginal farmers with limited irrigation and low literacy showed reduced adaptive capacity. Areas with better irrigation, higher literacy rates, and

improved infrastructure exhibited stronger adaptive capacity, supporting greater agricultural resilience.

#### **4. Spatial Patterns of Risk and Resilience**

Integration of climate, environmental, and socio-economic indicators highlighted spatial heterogeneity:

- **Very High Risk / Low Resilience:** Rainfed areas with poor soils and limited socio-economic capacity
- **High Risk / Moderate Resilience:** Areas with partial irrigation and moderate socio-economic conditions
- **Moderate Risk / Moderate Resilience:** Villages with some irrigation and literacy advantages
- **Low Risk / High Resilience:** Well-irrigated zones with diversified crops and strong infrastructure

These patterns indicate that both risk and resilience are spatially uneven and determined by the interplay of environmental and socio-economic factors.

#### **Discussion**

The study demonstrates that climate exposure is a key determinant of agricultural risk, while socio-economic factors strongly influence resilience. Targeted interventions—such as improving irrigation, promoting drought-tolerant crops, and enhancing literacy and infrastructure—can reduce risk and strengthen resilience. GIS-based spatial analysis provides an effective tool for identifying priority areas for policy and planning.

#### **Policy Implications and Recommendations**

- **Water Management:** Implement micro-irrigation systems, farm ponds, check dams, and watershed development.
- **Crop Adaptation:** Encourage crop diversification with drought-resistant and short-duration varieties.
- **Socio-Economic Development:** Improve literacy, provide climate-smart agriculture training, and strengthen market access through Farmer Producer Organizations (FPOs).
- **Infrastructure Improvement:** Enhance rural roads, storage facilities, and access to credit and crop insurance to boost resilience.

## **Conclusion**

This study provides a comprehensive spatial assessment of agricultural risk and resilience in Chalisgaon taluka by integrating climate, environmental, and socio-economic indicators using GIS. Rainfed and socio-economically weaker areas are at high risk with low resilience, while irrigated and infrastructure-rich areas exhibit greater resilience.

The findings highlight the importance of incorporating both environmental and socio-economic dimensions in planning adaptive strategies. Geospatial analysis enables evidence-based decision-making, guiding interventions to enhance agricultural resilience in semi-arid regions. Future studies should consider higher-resolution spatial data and dynamic climate projections for more precise assessments.

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# A Geographical Study of Agricultural Productivity in Pune District (Maharashtra)

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## Abstract

Agricultural productivity is an important indicator of the efficiency and sustainability of farming systems. This study presents a descriptive overview of agricultural productivity in Pune District, a region characterized by varied agro-climatic conditions. The district comprises both irrigated plains and rainfed hilly areas, leading to considerable differences in crop yields and farming practices. The study analyzes major crops, regional variations in productivity, and key factors influencing agricultural output. The results indicate that irrigation availability, soil quality, and technological adoption significantly influence productivity levels, while climatic variability and water scarcity pose major challenges. The study underscores the importance of sustainable agricultural practices to enhance productivity and ensure long-term food security.

## Introduction

Agriculture is a fundamental sector of the Indian economy, providing employment and livelihood to a large segment of the population. Agricultural productivity, defined as output per unit area, plays a crucial role in determining farmers' economic conditions and rural development. In regions such as Pune District, agricultural practices are shaped by both natural and human factors. The district exhibits a combination of traditional and modern farming systems, making it an ideal case for studying productivity patterns. Variations in rainfall, soil characteristics, and irrigation facilities contribute to differences in agricultural performance across different parts of the district. This study aims to provide a descriptive analysis of agricultural productivity in Pune district and to examine the factors influencing it.

## Study Area

Pune District is situated in the western part of Maharashtra and is recognized as an important agricultural region. The district features diverse physical

characteristics, including the Western Ghats in the western part and fertile plains in the eastern region.

### **Key Features:**

- **Climate:** Tropical monsoon with moderate rainfall
- **Topography:** Hilly terrain in the west and plains in the east
- **Soil Types:** Black soil, red soil, and lateritic soil
- **Water Resources:** Rivers such as Mula, Mutha, and Bhima

Agriculture is widely practiced throughout the district, with cropping patterns varying based on water availability and soil conditions.

### **Agricultural Scenario**

Agriculture in Pune district is diverse, encompassing both subsistence and commercial farming. Farmers cultivate a wide range of crops depending on environmental and economic conditions.

Major Crops:

- **Food Crops:** Jowar, bajra, rice, and wheat
- **Cash Crops:** Sugarcane and maize
- **Horticulture Crops:** Grapes, pomegranate, and vegetables

The eastern region, which benefits from better irrigation facilities, is known for high-value crops such as sugarcane and horticulture. In contrast, the western hilly areas depend mainly on rainfall and exhibit lower agricultural output.

### **Agricultural Productivity Pattern**

Agricultural productivity in Pune district shows distinct spatial variations and can be categorized into three levels:

#### **High Productivity Regions**

Areas such as Baramati, Indapur, and Daund demonstrate high levels of productivity due to:

- Availability of canal and well irrigation
- Fertile soil conditions
- Adoption of modern agricultural practices
- Farmers in these regions achieve higher yields and improved income levels.

#### **Medium Productivity Regions**

Talukas like Shirur, Khed, and Ambegaon fall into the medium productivity category. These areas are characterized by:

- Moderate irrigation facilities

- Average rainfall
- Mixed cropping systems

Productivity in these regions is moderate and influenced by seasonal variations.

### **Low Productivity Regions**

Regions such as Junnar, Velhe, and Mulshi have comparatively low productivity due to:

- Limited irrigation facilities
- Heavy dependence on rainfall
- Less favorable soil conditions in some areas

Farmers in these areas often face challenges in achieving consistent agricultural output.

### **Factors Influencing Agricultural Productivity**

Several factors contribute to the variation in agricultural productivity across Pune district.

- **Irrigation:** Irrigation is a key determinant of productivity. Areas with reliable irrigation systems exhibit higher yields compared to rainfed regions.
- **Soil Fertility:** Soil quality significantly affects crop growth. The black cotton soils found in eastern Pune are highly fertile and suitable for crops such as sugarcane and wheat.
- **Rainfall:** Variability in rainfall has a direct impact on crop production, especially in rainfed areas. Irregular rainfall patterns can lead to crop failure.
- **Technology:** The adoption of improved seeds, fertilizers, mechanization, and modern irrigation techniques enhances productivity. Farmers using advanced technologies generally achieve better results.
- **Cropping Pattern:** The choice of crops also affects productivity. The shift towards cash crops and horticulture has increased productivity in certain regions.
- **Socio-Economic Conditions:** Factors such as landholding size, farmer education, access to credit, and market availability influence the adoption of improved agricultural practices and overall productivity.

### **Challenges in Agricultural Productivity**

Despite favorable conditions in certain areas, several challenges affect agricultural productivity in Pune district:

- Water scarcity in drought-prone regions
- Declining soil fertility due to excessive chemical use

- Reduction of agricultural land due to urban expansion
- Climate change and unpredictable weather conditions
- High cost of agricultural inputs

These challenges create instability in agricultural production and affect farmers' livelihoods.

### **Discussion**

The analysis reveals that agricultural productivity in Pune district is unevenly distributed. Irrigated regions in the eastern part of the district show higher productivity, while rainfed and hilly areas in the west lag behind.

The study highlights the importance of irrigation development, soil management, and technological adoption in improving productivity. It also emphasizes the need for balanced regional development to minimize disparities.

### **Conclusion**

Agricultural productivity in Pune District is shaped by a combination of environmental and socio-economic factors. While some regions have achieved high productivity through irrigation and modern practices, others continue to face limitations due to natural constraints.

Enhancing irrigation facilities, promoting sustainable agricultural practices, and increasing awareness among farmers can significantly improve productivity and ensure long-term agricultural sustainability.

### **Suggestions**

- Expand irrigation facilities in rainfed areas
- Promote organic and sustainable farming methods
- Encourage crop diversification
- Improve soil health management
- Provide training and financial assistance to farmers
- Strengthen agricultural marketing infrastructure

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# A Geographical Study of Population Growth in Nashik District

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## Abstract

The present paper, based on the secondary data, intends to measure the population growth. The growth of population in 1991-2001 was higher (+29.52%) than what it was in 2001-11 (22.44%). Nashik tahsil being headquarters as well as a very fascinating tourist place, have shown very high population growth (55.59%) in 1991-2001 but in 2001-2011 it has down up to 33.29% in Nashik tahsil.

**Keywords:** Population growth, Geographical analysis, Human Resources.

## Introduction

HRD (Human Resources Development) is continues progressive and human resource accounting is a new concept, developed by Lew and Schwarty in 1971. In human resources development it is necessary to refer to quantitative as well as qualitative things. The concept of human resources has been studied by different scientists in different fields or in different direction as well as is taken differently in different senses. At the same time HRD has studied in different knowledge in different subjects. The word 'Demography' has come from the Greek word, 'Demos' means to people or population and 'Graphein' means study or describe [5, 6]. Prof Nadlar was the first to deliver a comprehensive concept of the human resources development program. He subdivided the human resources development program into two types. In the first program on available human resources and the second program on potential human resources for future use. The first program is the optimal use of productive human resources and the use of non-productive human resources. The second program, their human resources development is a continuous process it ends only at the death of a person. The study and analysis of population and human resources is considered importance from the social point of view and in the interest of the nation or any region. [31]. The study of human resources and

population is considered importance as population components and HRD components is importance for economic and social development of any nation or region. The mainly include population growth rate, literacy, population density, sex ratio, etc elements are viewed from a positive point of view. The Pathardi tehsil is a completely drought-prone and hilly area due to which it appears to have affected the geographical condition on human resources. For all these reasons the Pathardi tehsil is selected for the study. The population and human resource factors were studied according to geographical area and situation in any region. The HRD elements not only active resources but also play an importance role in developments for any region. The population characteristics for the study of human resources development in any area. There for the main objective of this research is to study human development therefore demographic factors are considered in the study area.

### **Study Area**

Nasik is the third largest district of Maharashtra having a total geographical area of 15530 sq. km. This district consists of 15 tehsils, 1919 villages and 25 towns as per the census of 2011. It lies between 19° 35' 18" to 20° 53' 07" North latitude and 73° 16' 07" to 74° 56' 22" East latitudes. Physiographically, Nasik district comprises of a part of a Deccan Plateau, one of the oldest originated blocks of the earth surface. The climate of the district is generally dry except during the south-west monsoon season. The average annual rainfall for the district as a whole is 1035.5mm.

### **Aims and Objectives**

- To study the population growth in Nashik district.
- To study of population growth rate in Nashik district

### **Methodology**

The present study is based on the secondary data, obtained from district census handbook of Nashik. The population data taken from Indian censuses book during 1991-2011. As well as the using population growth rate formula and used cartography methods for population growth and growth rate.

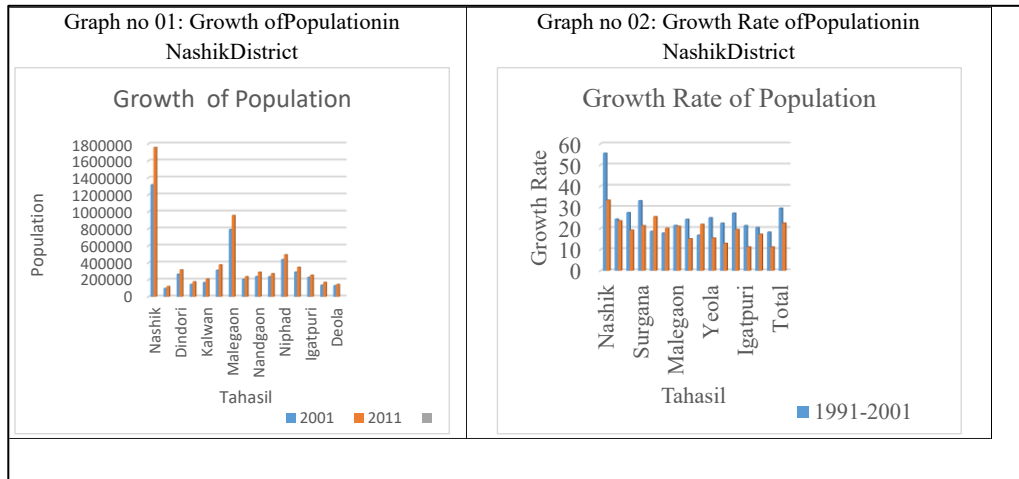
### **Result**

Tahsil-wise Decadal Growth of Population in Nashik District: In the last decade of 1991-2001, the population growth rate ranged from a maximum of 55.49 per cent in Nashik tahasil to a lowest of 16.75 per cent in Nandgaon tahsil of Nashik district with average of 29.52 per cent. The high growth rate is noticed

in Nashik (55.49%), Suragana (33.03%), Dindori (27.40%), Sinnar (27.19%) and Yeola (25.00%). These tahasil are identified with very high population growth rates i.e. 25 percent and above and recorded their population growth rate close to the district average (29.52%) Table 1 further reveals that tahsils viz. Peth, Chandwad, Niphad, Malegaon, Igatpuri and Trimbakthe district of medium population growth that varies from 20 to 25 per cent during the 1901-2001. Kalwan (18.57%), Deola (18.18%) and Satana (17.74%) tahsils have recorded their population growth rate below 20 percent In 2001-11, it is very astonishing to note that Nashik (33.29%) tahsil has recorded highest positive population growth rate. Nashik city is a one of the best tourist center in the district as well as in the state. So tourism industry is quite developed and it has a conducive atmosphere so people migrate towards this tahsil. In all there are as many as two tahsils Viz. Kalwan (25.52%), and Peth (23.54%) which are identified with high population growth rate near to district population growth rate in 2011. Other than tahsils like Nandgaon, Surgana, Malegaon, Satana, Sinnar, Dindori, Trimbak, Yeola and Chandwad have recorded their population growth below the district average and the rest of 3 tahsils viz. Niphad, Igatpuri and Deola have shown their growth rate is less than 15 in 2011.

**Table1: Growth Rate of Population in Nashik District (1991-2011)**

Sr. No	Tahasil	1991	2001	2011	1991-2001	2001-2011
		Population	Population	Population	Growth Rate	Growth Rate
1	Nashik	847000	1317000	1755491	+55.49	+33.29
2	Peth	78000	97000	119838	+24.36	+23.54
3	Dindori	208000	265000	315709	+27.40	+19.13
4	Surgana	109000	145000	175816	+33.03	+21.25
5	Kalwan	140000	166000	208362	+18.57	+25.52
6	Satana	265000	312000	374435	+17.74	+20.01
7	Malegaon	651000	790000	955594	+21.35	+20.96
8	Chandwad	165000	205000	235849	+24.24	+15.05
9	Nandgaon	203000	237000	288848	+16.75	+21.88
10	Yeola	188000	235000	271146	+25.00	+15.38
11	Niphad	357000	437000	493251	+22.41	+12.87
12	Sinner	288000	290000	346390	+27.19	+19.44
13	Igatpuri	188000	228000	253513	+21.28	+11.19
14	Trimbak	113000	136000	168423	+20.35	+17.22
15	Deola	110000	130000	144522	+18.18	+11.17
	Total	3851000	4988000	6107187	+29.52	+22.44



## Conclusion

The fact that population is a resource depends on its nature, in short if you geographically the population is a resource asset that includes many factors. Such as the literacy, sex ratio, population density, population growth rate, Population engaged in actual occupation Structure etc. In short, there are two types of human resources, one quantitative and the other qualitative. Numerical resource wealth Population distribution, Population growth, Population density, these factors are included. At the same time, the qualitative population includes the literacy, knowledge, skill, Age group etc. Also, these human resources are affected by various factors such as natural, cultural, socio-economic and political. These factors have a positive or negative effect on human resources.

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# Potential of Solar Energy Integration for Sustainable Small Scale Industry Operations in Ahilyanagar District

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## Abstract

This paper analyzes the opportunities for integrating solar energy into small-scale industries in Ahilyanagar District, Maharashtra, within India's broader renewable energy transition (MNRE; IEA). Solar energy is widely recognized as a clean and sustainable alternative to fossil fuel-based electricity due to its environmental, economic, and energy security benefits (Bhattacharyya; REN21). Maharashtra receives high solar radiation (4–7 kWh/m<sup>2</sup>/day), making regions like Ahilyanagar suitable for decentralized solar systems (Chandel et al.; Gautam). Despite rapid growth under the National Solar Mission, MSMEs show low adoption due to financial, awareness, and technical barriers (Government of India; Painuly). Rising electricity tariffs and unreliable supply further increase operational costs and reduce competitiveness (TERI; Singh et al.). The study highlights the need for targeted financial incentives, supportive policies, and awareness initiatives to accelerate solar adoption in small industrial clusters (NITI Aayog; World Bank).

**Keywords:** Solar energy; small-scale industries; sustainability; renewable energy integration; Ahilyanagar District; Maharashtra; MSMEs.

## Introduction

In the 21st century, energy security, environmental sustainability, and climate resilience have become central to India's development agenda amid rising energy demand and global climate commitments (Government of India, Economic Survey 2023–24). The transition to renewable energy is essential to reduce dependence on imported fossil fuels and lower greenhouse gas emissions (IEA, India Energy Outlook 2023). Among renewables, solar energy stands out due to its abundance, scalability, and declining costs (REN21, Global Status Report 2023). India's tropical location provides strong solar potential, with

Maharashtra receiving 4–7 kWh/m<sup>2</sup>/day of solar radiation and ample sunshine hours (Chandel et al.).

In districts like Ahilyanagar, characterized by agro-based and small-scale industries, rising electricity tariffs, unreliable supply, and increasing production costs pose major challenges (Singh et al.). Many industries rely on grid electricity and diesel generators, leading to higher costs and environmental impacts (Bhushan et al.). Integrating rooftop or captive solar PV systems can significantly reduce energy expenses and carbon emissions (Pandey et al.). This aligns with India's target of achieving 500 GW of non-fossil fuel capacity by 2030, supporting decentralized solar adoption among MSMEs (NITI Aayog).

### **Study Area**

Maharashtra, particularly Ahilyanagar District, has a largely agrarian and semi-urban economy with small-scale industries such as agro-processing, engineering, dairy, and food production that are energy-intensive (Gautam). Located on the Deccan Plateau, the district receives high solar radiation—around 5 kWh/m<sup>2</sup>/day—making it well-suited for solar photovoltaic (PV) development in both rural and industrial sectors.

In recent years, renewable energy initiatives have grown in Ahilyanagar to meet rising energy demand and reduce dependence on grid electricity and fossil fuels. For instance, Bhageria Industries Limited has developed a 9.50 MW solar power project in Akole taluka, with part of the energy used for captive consumption and the remainder supplied to the MSEDCL grid. Such projects support clean energy supply, particularly benefiting irrigation and agriculture, which are key to the district's economy.

### **Research Methodology**

#### **Research Design**

The research approach is a qualitative research design, which fully relies on the secondary sources to examine the possibilities of integrating solar energy into small-scale industries of Ahilyanagar District. The study design underlines a systematic review, scholarly books, government policy reports, renewable energy mission, industry surveys, and feasibility analysis concerning solar adoption in the MSMEs. The publications of the Ministry of New and Renewable Energy (MNRE), NITI Aayog reports, TERI studies, and international agencies like IEA and REN21 were relevant and included in the list of sources of the necessary data. The second research method allows a thorough investigation of the policy trends, the technology feasibility, the

financial limitations, and the sustainability inferences without doing direct field surveys.

### **Data Collection**

Secondary data were used to ensure reliability and academic validity. Information was collected from online academic databases on renewable energy and MSME sustainability. Reports from organizations such as TERI, NITI Aayog, and the International Energy Agency were reviewed to understand energy trends. Official statistics and policy updates were sourced from MNRE and MEDA. Additionally, feasibility studies, industry surveys, and solar market reports were analyzed to study adoption patterns in small-scale and rural sectors.

### **Results and Discussion**

#### **Solar Energy Potential in Ahilyanagar and Maharashtra**

The state government policies and incentives have seen it become one of the most active solar markets in India, and the state has seen high growth in installed capacity of solar energy over the last few years; as of July 2024, the state had over 7.15 GW of cumulative solar energy capacity, including ground-mounted, rooftop, and off-grid solar systems, making it one of the leaders in terms of solar deployment in the industry.

**Table 1: Solar Potential Indicators (Ahilyanagar Area)**

<b>Indicator</b>	<b>Approx. Value</b>	<b>Source</b>
Annual solar insolation	~5 kWh/m <sup>2</sup> /day	IRJET study
Sunshine hours per year	2300–3200 h	Clean Energy research
Rooftop capacity potential	High (≥2 kW per unit)	State solar data

Table 1 indicates that Ahilyanagar District has a massive solar energy potential due to the major climatic indicators reported by Gautam (2020). Annual solar insolation of about 5 kWh/m<sup>2</sup>/day shows that the district enjoys a lot of solar radiation that is sufficient to support effective generation of photovoltaic (PV) power the whole year round. The potential of solar energy in the area with 2300-3200 hours of sunshine each year also makes the rooftop and ground-mounted solar systems even more feasible with the guarantee of stable power production and enhanced ROI. Also, there is a high potential capacity of the rooftop (2 kW/unit), which can support that small scale industrial units should

successfully install decentralized solar systems to supplement grid electricity usage. In general, this table validates the technical suitability of Ahilyanagar to be integrated into sustainable solar energy.

### **Advantages of Solar Integration**

Solar PV systems can significantly benefit MSMEs by reducing electricity costs through onsite power generation, lowering dependence on grid energy, and improving cost predictability (Ghosh and Palit). They also help reduce greenhouse gas emissions by replacing conventional energy use, supporting climate mitigation goals. Overall, solar integration lowers operational costs, enhances resilience, promotes environmentally sustainable practices, and serves as a strategic tool for sustainable industrial development in energy-intensive regions like Ahilyanagar District.

### **Barriers to Adoption**

#### **High Upfront Capital Costs and Limited Financing Options**

A major barrier to solar adoption among MSMEs is the high upfront cost of purchasing and installing solar PV systems (Painuly). Despite declining technology costs, expenses for panels, inverters, and other components remain significant for resource-constrained enterprises (Bhushan et al.). Additionally, limited awareness of financial incentives such as subsidies, tax benefits, and renewable energy loans further restricts adoption (MNRE Annual Report 2023–24). These financial constraints collectively slow down solar adoption, even in regions with high potential like Ahilyanagar District.

#### **Lack of Awareness About Technology Benefits and Policies**

A key non-financial barrier to solar adoption among MSMEs is the lack of awareness about its technical, economic, and environmental benefits (Kumar et al.; Sharma et al.). Many entrepreneurs do not understand how solar PV systems work, their long-term savings, or their role in reducing emissions. Limited knowledge of government schemes, net-metering, and tax incentives further restricts adoption. As a result, MSMEs often view solar energy as complex or risky and continue using conventional sources (Palit and Chaurey). Additionally, inadequate technical expertise among local advisors creates an information gap (TERI Report). Hence, awareness and outreach programs are essential to encourage adoption.

#### **Technical Expertise Gaps for Installation and Maintenance**

A persistent challenge in solar adoption among MSMEs is the lack of local

technical expertise in system design, installation, and maintenance (Painuly). Even in areas with financial incentives and awareness, small industries—especially in semi-urban and rural regions like Ahilyanagar—struggle to find qualified installers and service providers (Palit and Chaurey). This can lead to improper system sizing, poor installation, and reduced performance, weakening trust in solar investments (Ghosh and Palit). Limited access to maintenance services further raises concerns about long-term reliability (Sharma et al.). As a result, many MSMEs hesitate to adopt solar solutions (Kumar et al.). Strengthening technical training, certification programs, and local service networks is essential to overcome this barrier.

### **Grid-Connectivity and Regulatory Issues for Net Metering and Feed-In Tariffs**

A major barrier to solar adoption is complex grid interconnection rules and inconsistent net-metering and feed-in tariff policies, which affect the financial viability of solar investments (Bhushan et al.). Although net-metering allows MSMEs to sell excess power, policies vary across states and involve lengthy, bureaucratic approval processes (MNRE Annual Report 2023–24). Utilities may also impose technical restrictions and additional charges, reducing economic benefits (IEA, India Energy Outlook 2023). Frequent policy changes create uncertainty, making it difficult for MSMEs to predict returns (NITI Aayog). Additionally, outdated grid infrastructure and capacity limitations hinder solar integration in some areas (REN21, Global Status Report 2023). Streamlining regulations, ensuring policy stability, and modernizing grid systems are essential to accelerate solar adoption.

### **Conclusion**

The integration of solar energy in small-scale industries in Ahilyanagar District is crucial for sustainable industrial development. The region's high solar potential makes photovoltaic adoption technically feasible. By shifting to decentralized solar systems, MSMEs can reduce energy costs, improve profitability, and ensure long-term financial stability. Solar adoption also supports environmental sustainability by lowering greenhouse gas emissions and reducing dependence on fossil fuels, aligning with India's renewable energy goals and Maharashtra's supportive policies. However, challenges such as high initial costs, limited access to finance, lack of technical knowledge, and regulatory issues must be addressed. Targeted policy support, awareness programs, skill development, and accessible green financing are essential to

accelerate adoption. Overall, solar integration can enhance energy security, environmental performance, and sustainable industrial growth in Ahilyanagar.

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# Geospatial Innovations for Climate Change Adaptation and Sustainable Development

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## Abstract

Climate change has emerged as a major global concern, affecting environmental systems, economic stability, and human well-being. Rising temperatures, unpredictable rainfall patterns, and the increasing occurrence of extreme climatic events have intensified the demand for effective adaptation strategies. Geospatial innovations—such as Geographic Information Systems (GIS), remote sensing, spatial analysis, and related technologies—have become essential tools in addressing climate-related challenges and advancing sustainability.

This study explores the significance of geospatial technologies in climate change adaptation and sustainable development. It highlights their role in environmental monitoring, disaster risk reduction, natural resource management, and policy planning. The findings indicate that the integration of geospatial tools into planning processes improves resilience and promotes sustainable resource utilization. However, issues such as limited technical capacity, restricted data access, and high implementation costs continue to hinder their widespread use. The study emphasizes the importance of strengthening institutional support, enhancing technical skills, and promoting innovation to fully utilize these technologies.

**Keywords:** Climate Change, GIS, Remote Sensing, Adaptation, Sustainability, Geospatial Systems

## Introduction

Climate change represents one of the most critical challenges of the modern era, influencing natural ecosystems, economic activities, and social systems worldwide. Increasing global temperatures, altered precipitation patterns, and more frequent extreme weather events have created serious environmental and developmental concerns.

Adaptation to climate change involves modifying natural and human systems to reduce adverse impacts and improve resilience. At the same time, sustainable development focuses on fulfilling current needs without compromising the ability of future generations to meet their own requirements.

In this context, geospatial innovations have gained importance as effective tools for analyzing and managing climate-related issues. Technologies such as GIS, remote sensing, and spatial analytics enable accurate observation, evaluation, and planning, thereby supporting climate adaptation and sustainability efforts.

### **Concept of Geospatial Innovation**

Geospatial innovation refers to the application of advanced spatial technologies and analytical techniques to gather, process, and interpret geographic data. These tools help in identifying spatial patterns and relationships related to environmental and socio-economic phenomena.

Key components of geospatial innovation include:

- Geographic Information Systems (GIS)
- Remote sensing technologies
- Global Positioning Systems (GPS)
- Spatial modeling and data analysis

These technologies provide reliable and real-time data, which is crucial for informed decision-making in climate adaptation and sustainable development.

### **Role of Geospatial Innovations in Climate Change Adaptation**

Geospatial technologies such as Geographic Information Systems (GIS), remote sensing, and satellite-based monitoring have become essential tools for understanding and addressing the impacts of climate change. These innovations provide accurate, real-time, and spatially detailed information that supports effective planning, decision-making, and sustainable development.

- **Climate Monitoring and Evaluation**

Geospatial technologies play a crucial role in monitoring key climate variables such as temperature, rainfall, and vegetation dynamics. Through satellite imagery and remote sensing, continuous and reliable data on environmental changes can be obtained. These tools help in identifying land use and land cover changes, tracking deforestation and land degradation, and assessing phenomena such as glacier retreat and sea-level rise. Such information is vital for policymakers and researchers to understand the scale, trends, and consequences of climate change, thereby supporting informed policy formulation.

- **Disaster Risk Reduction**

With the increasing frequency and intensity of natural disasters due to climate change, geospatial tools have become indispensable for disaster management. GIS-based flood hazard mapping helps identify flood-prone areas, while satellite-based early warning systems provide timely alerts. These technologies also assist in identifying vulnerable and high-risk zones, enabling better preparedness and mitigation strategies. As a result, they contribute significantly to reducing disaster risks and improving response and recovery efforts.

- **Water Resource Management**

Climate variability has placed considerable stress on water resources, making efficient management essential. Geospatial technologies support the mapping of groundwater potential zones, monitoring of rivers, lakes, and reservoirs, and planning of irrigation systems. These tools enable better assessment and allocation of water resources, ensuring sustainable and efficient utilization, especially in water-scarce regions.

- **Agricultural Adaptation**

Agriculture, being highly sensitive to climate variability, benefits greatly from geospatial innovations. These technologies assist in analyzing crop suitability based on soil and climatic conditions, preparing soil fertility maps, and providing weather forecasts and advisory services. By offering location-specific information, geospatial tools help farmers make informed decisions, improve productivity, and reduce risks associated with climate uncertainty.

- **Urban Planning and Infrastructure Development**

Urban areas are increasingly vulnerable to climate-related risks such as flooding, heatwaves, and environmental degradation. Geospatial technologies aid in land use zoning, analysis of urban heat island effects, and infrastructure planning. These applications help in designing resilient and sustainable urban systems, improving the capacity of cities to cope with climate challenges.

### **Geospatial Innovations for Sustainability**

Geospatial technologies also play a key role in promoting environmental sustainability and efficient resource management.

- **Environmental Protection:** These technologies are widely used for conserving natural ecosystems and biodiversity. They assist in mapping forest resources and wildlife habitats, monitoring environmental degradation, and supporting conservation strategies. Such applications are

essential for maintaining ecological balance and protecting natural resources.

- **Natural Resource Management:** Sustainable development depends on the efficient use of natural resources. Geospatial tools facilitate land resource assessment, identification of mineral and energy resources, and sustainable land use planning. These approaches help minimize environmental degradation and ensure optimal resource utilization.
- **Renewable Energy Development:** Geospatial technologies are increasingly used in identifying suitable locations for renewable energy projects. They support solar energy potential mapping, wind energy site selection, and biomass resource assessment. These applications contribute to the development of clean and sustainable energy systems.
- **Climate-Resilient Development:** Geospatial innovations enable the integration of climate considerations into development planning. They support sustainable land use planning, climate-resilient infrastructure design, and data-driven policy formulation. Such approaches ensure long-term environmental sustainability and resilience against climate impacts.

### **Practical Applications**

Geospatial technologies have been successfully applied in various real-world situations to address climate-related challenges. They are used for drought assessment in semi-arid regions, flood mapping in river basins, coastal zone management using remote sensing, and urban climate analysis in major cities. These applications demonstrate the practical importance of geospatial innovations in climate change adaptation and environmental management.

### **Challenges in Geospatial Applications**

Despite their wide range of applications, geospatial technologies face several challenges that limit their effective use.

- **Technical Challenges:** There is a shortage of skilled professionals capable of handling advanced geospatial tools. Additionally, the complexity of these technologies can hinder their widespread adoption.
- **Data Constraints:** Limited availability of accurate and high-resolution data is a major issue. The high cost of satellite imagery further restricts access, especially in developing regions.
- **Financial Limitations:** The implementation of geospatial technologies requires significant investment in infrastructure and equipment. Insufficient funding for research and development further constrains their use.

- **Institutional Issues:** Weak coordination among different agencies and the absence of strong policy frameworks reduce the effectiveness of geospatial applications. Institutional support is essential for their successful implementation.

### **Discussion**

The analysis clearly highlights the importance of geospatial innovations in climate change adaptation and sustainable development. These technologies provide accurate, timely, and location-specific information, which enhances planning and decision-making processes.

However, their success depends on effective implementation, availability of technical expertise, and integration into policy frameworks. Strengthening institutional mechanisms, improving access to data, and increasing awareness and training can significantly enhance the use of geospatial technologies. With proper support, these innovations have the potential to play a transformative role in addressing climate challenges and achieving sustainable development goals.

### **Conclusion**

Geospatial innovations have become indispensable in addressing climate change challenges and promoting sustainability. They support environmental monitoring, disaster management, resource planning, and policy development. Integrating these technologies into development strategies can improve resilience and reduce environmental risks. However, overcoming technical, financial, and institutional barriers is necessary to maximize their benefits.

### **Suggestions**

- Enhance training and capacity building in geospatial technologies
- Improve accessibility of spatial data
- Strengthen policy support and institutional frameworks
- Promote research and technological advancement
- Encourage collaboration among stakeholders
- Integrate GIS and remote sensing into development planning

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# GIS-Based Smart Environmental Monitoring System Using Sensor Networks

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## Abstract

Environmental problems and climate variations have increased the demand for efficient and real-time monitoring systems. Conventional methods of environmental monitoring are often limited in terms of spatial coverage, accuracy, and timely data collection. In this regard, the integration of Geographic Information Systems (GIS) with sensor networks provides an advanced and effective solution for monitoring environmental parameters such as air quality, water quality, soil conditions, and climate variables.

This study presents a descriptive overview of a smart environmental monitoring system that combines GIS and sensor network technologies. The system allows continuous data collection, spatial analysis, and visualization, which supports better decision-making and sustainable management of natural resources. The paper explains the structure, functioning, applications, and advantages of such systems, along with key challenges such as high cost, data integration issues, and technical complexities. The study concludes that GIS-based monitoring systems are essential for achieving environmental sustainability and improving climate resilience.

**Keywords:** Environmental Monitoring, GIS, Sensor Networks, IoT, Sustainability, Spatial Analysis

## Introduction

Environmental monitoring plays a crucial role in understanding changes in natural systems and managing resources effectively. Rapid urbanization, industrial growth, and climate change have significantly affected environmental quality, making it necessary to adopt modern monitoring approaches.

Traditional monitoring methods mainly depend on manual data collection and limited observation points, which often fail to provide complete and real-time

information. In contrast, smart monitoring systems that integrate GIS with sensor networks offer more efficient and accurate solutions.

GIS is an important tool for handling spatial data, while sensor networks continuously collect environmental data through connected devices. Together, these technologies enable real-time monitoring, spatial analysis, and visualization of environmental conditions.

This paper aims to describe the concept, components, and applications of smart environmental monitoring systems using GIS and sensor networks, with a focus on their role in sustainable development.

### **Concept of Smart Environmental Monitoring**

Smart environmental monitoring refers to the use of modern technologies such as sensors, communication systems, and geospatial tools to observe and analyze environmental conditions in real time.

The environmental monitoring system is primarily composed of several interconnected components that function together to collect, transmit, analyze, and interpret environmental data in a precise and location-specific manner. At the foundation of the system are sensors, which are installed at selected sites to continuously measure various environmental parameters. These sensors are capable of detecting changes in air quality, water characteristics, soil properties, temperature, humidity, and other ecological indicators. The data collected by these devices serve as the primary input for the monitoring framework. Once the information is gathered, communication networks play an essential role in transmitting the recorded data from the field sensors to central processing units or data servers. These networks may include wireless technologies, satellite links, mobile communication systems, or internet-based platforms that ensure the real-time transfer of environmental information. This continuous flow of data allows researchers and decision-makers to access updated information without delays, making the system more responsive to environmental changes.

### **Components of the System**

#### **Sensor Networks**

Sensor networks form the backbone of modern environmental monitoring systems. They consist of multiple sensors strategically installed across different locations to capture real-time environmental data. These sensors are designed to measure a wide range of parameters, including temperature, humidity, and air pollutants such as carbon dioxide (CO<sub>2</sub>) and fine particulate matter (PM<sub>2.5</sub>). In addition, specialized sensors are used to assess water quality, measuring

indicators like pH levels and turbidity, as well as soil moisture, which is crucial for agricultural and ecological studies.

### **Communication Technology**

Once environmental data is collected, it must be transmitted efficiently to central systems for processing and analysis. This is achieved through advanced communication technologies. Wireless communication systems—including cellular networks, radio frequency (RF), and satellite links—facilitate seamless data transfer from remote sensor locations.

### **Geographic Information System (GIS)**

A Geographic Information System (GIS) plays a crucial role in transforming raw environmental data into meaningful insights. GIS integrates spatial (location-based) data with environmental parameters, enabling advanced analysis and visualization. It allows researchers and planners to map environmental conditions, such as pollution levels or soil moisture distribution, across different regions.

### **Data Processing and Analysis**

Once environmental data is collected from sensor networks, it undergoes a systematic process of refinement and interpretation to generate reliable and meaningful results. Raw data, in its initial form, may contain inconsistencies, errors, or missing values. Therefore, the first step involves data cleaning and validation, where inaccurate readings are corrected, duplicate entries are removed, and the overall quality of the dataset is verified. This step ensures that the information used for further analysis is accurate and dependable. After validation, the data is subjected to statistical analysis, which helps in identifying trends, variations, and relationships among different environmental parameters. Through statistical techniques such as mean, standard deviation, correlation, and regression analysis, researchers can interpret patterns in temperature changes, pollution levels, or soil conditions over time.

### **Working of the Monitoring System**

The smart environmental monitoring system works through the following steps: The smart environmental monitoring system operates through a series of integrated steps that ensure efficient data handling and informed decision-making. Initially, data collection is carried out by sensors deployed at various locations, which continuously gather environmental information such as temperature, humidity, and pollution levels. This data is then transmitted

through communication networks during the data transmission stage, enabling seamless transfer to a central system. In the data processing phase, the collected information is analyzed, cleaned, and refined to ensure accuracy and usability. Subsequently, GIS mapping is employed to visualize the spatial distribution of environmental parameters, making it easier to interpret patterns and trends across different regions.

### **Applications of Smart Environmental Monitoring**

Smart environmental monitoring systems have a wide range of practical applications across different sectors, making them essential tools for sustainable development and resource management. In air quality monitoring, these systems are extensively used in urban areas where sensors continuously measure pollutants such as carbon dioxide and particulate matter, while GIS helps in mapping their spatial distribution across regions, enabling authorities to identify pollution hotspots. Similarly, in water quality monitoring, smart technologies assess the condition of rivers, lakes, and reservoirs by tracking parameters like pH, turbidity, and dissolved oxygen, ensuring safe water for human and ecological use. In the agricultural sector, soil monitoring plays a crucial role, as sensors measure soil moisture and nutrient levels, allowing farmers to optimize irrigation and fertilizer application for improved productivity. Furthermore, climate monitoring systems track essential weather parameters such as temperature, rainfall, and humidity, contributing valuable data for climate research and forecasting. Lastly, in disaster management, the integration of GIS and sensor networks provides early warning systems for natural hazards like floods and droughts, helping reduce risks and improve preparedness.

### **Challenges and Limitations**

Despite their significant benefits, smart environmental monitoring systems face several challenges that can limit their widespread adoption and effectiveness. One of the primary concerns is the high cost involved in setting up sensors, communication infrastructure, and data processing systems, along with ongoing maintenance expenses. In addition, these systems involve technical complexity, as they rely on advanced technologies such as IoT, cloud computing, and GIS, which require skilled professionals for proper operation and management. Another major issue is data integration, since environmental data often comes from diverse sources and formats, making it difficult to combine and analyze seamlessly. Connectivity problems also pose a challenge, particularly in remote or rural areas where reliable network infrastructure may be lacking, leading to

interruptions in real-time data transmission. Furthermore, data security is a critical concern, as sensitive environmental data must be protected from unauthorized access, misuse, or cyber threats. Addressing these challenges is essential to ensure the efficient, secure, and large-scale implementation of smart environmental monitoring systems.

### **Discussion**

The integration of GIS and sensor networks has improved environmental monitoring by providing accurate, real-time, and location-based data. These systems are especially useful in managing environmental problems such as pollution and resource depletion.

However, their success depends on proper planning, technical knowledge, and investment. Government support and awareness are important for promoting such technologies.

### **Conclusion**

GIS-based smart environmental monitoring systems represent a modern approach to environmental management. They provide accurate and real-time data, which is essential for sustainable development.

These systems improve decision-making and help in efficient resource management. However, challenges related to cost, technology, and data handling must be addressed for effective implementation.

### **Suggestions**

- Encourage the use of IoT-based monitoring systems
- Provide training in GIS and related technologies
- Improve communication networks in rural areas
- Promote collaboration between government and private sectors
- Increase investment in research and development
- Develop strong data management policies

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# **A Geographical Analysis of Tourism Infrastructure and its Effect on Local Employment in Akole Tehsil**

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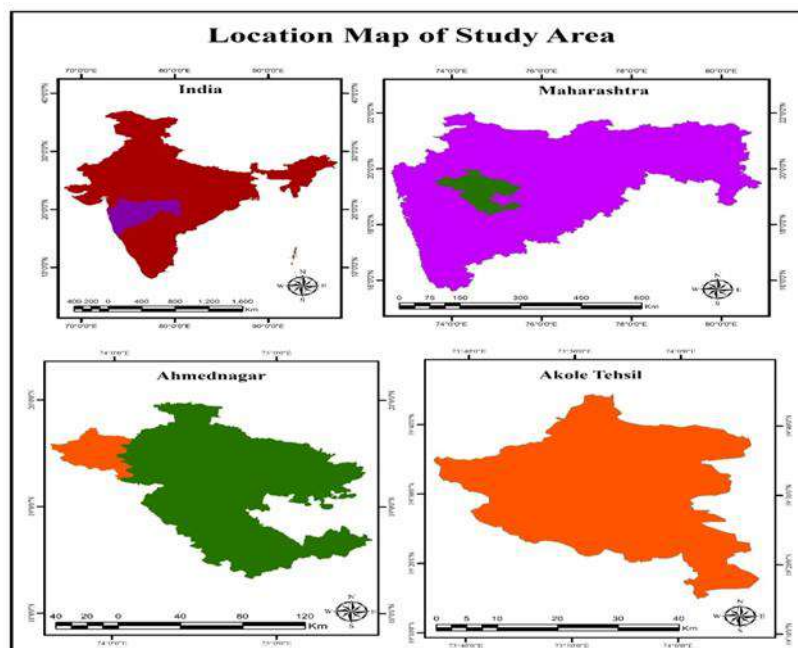
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## **Abstract**

Geography plays a deterministic role in the economic evolution of rural landscapes. Akole Tahsil, situated in the westernmost part of the Ahmednagar district in Maharashtra, serves as a quintessential example of a "High-Potential Tourism Zone." Nestled within the Sahyadri ranges of the Western Ghats, the region possesses a unique physical geography characterized by the highest peak in the state (Kalsubai), the deep valleys of Sandhan, and the expansive waters of the Bhandardara (Wilson) Dam. Traditionally, the local economy was anchored in subsistence paddy cultivation and tribal forest-gathering. However, the systematic development of tourism infrastructure—comprising transportation networks, hospitality units, and recreational facilities—have initiated a spatial and economic shift, transforming the region into a burgeoning service-sector hub.

## **Study Area**

Akole Tahsil is situated on the extreme western margin of the Ahmednagar district in Maharashtra, India. Geographically, it is positioned between 19°15'14" N to 19°44'59" N latitude and 73°37'00" E to 74°07'24" E longitude. Covering an area of approximately 1,505.08 km<sup>2</sup>, it is bounded by the Nashik district to the north, Pune district to the south, and Thane district to the west. This strategic location places Akole at the heart of the Sahyadri mountain ranges, making it a critical corridor for biodiversity and a premier destination for mountain-based tourism in Western Maharashtra. Demographically, Akole is recognized as a prominent tribal tahsil, with a significant population of Mahadev Koli and Thakar communities. According to the 2011 Census, the tahsil comprises 191 villages, where agriculture remains the traditional mainstay. However, the presence of major irrigation and hydroelectric projects—such as the Bhandardara and Nilwande dams—has historically paved



## **Methodology**

To achieve a comprehensive analysis, a Mixed-Methods Approach is adopted, combining quantitative statistical data with qualitative field observations. The study is conducted in Akole Tehsil, Ahmednagar district. For localized accuracy, the tahsil is divided into three "Geographic Zones" based on terrain and existing infrastructure: The Bhandardara-Shendi-Randha belt (Developed resorts/dam-based tourism). The Bari-Kalsubai-Samrad circuit (Trekking and adventure-based). Remote tribal interiors like Ghatghar (Potential but underdeveloped).

## **Research Objectives**

- To guide this geographical analysis, the study focuses on the following objectives:
- To map the spatial distribution of existing tourism infrastructure in Akole Tehsil.
- To evaluate the nature and scale of direct and indirect employment generated by these facilities.
- To identify the socio-geographic barriers (such as terrain and seasonality) that hinder equitable employment distribution.

### **The Structure of Tourism Infrastructure**

Tourism infrastructure in Akole is categorized into primary, secondary, and tertiary levels. The primary level consists of the natural landscape—the waterfalls, peaks, and lakes. The secondary level involves the "built environment," such as MTDC resorts, private homestays, and camping sites. The tertiary level includes the transport corridors connecting Akole to major urban centers like Mumbai, Nashik, and Pune. The analysis reveals a high "infrastructure density" around the Bhandardara backwaters, which acts as the primary magnet for investment and subsequent job creation.

The core of this research lies in the "Infrastructure-Employment Nexus." As the Maharashtra Tourism Development Corporation (MTDC) and private investors develop the region, there is an evident Occupational Transition. Local tribal communities, such as the Mahadev Kolis, are increasingly moving away from seasonal agriculture toward roles as mountain guides, resort staff, and transport operators. However, this transition is fraught with geographical challenges, most notably Seasonality. The monsoon and winter peaks create a "surge" in employment, while the arid summer months lead to high underemployment, highlighting a vulnerability in the current infrastructural model.

### **Purpose of the Study**

The primary purpose of this research is to critically analyse the functional relationship between the growth of tourism infrastructure and the evolution of local employment patterns in Akola Tahsil. While the Sahyadri range provides the natural "capital" for tourism, it is the artificial infrastructure—roads, resorts, trekking base camps, and electricity—that translates this natural beauty into economic opportunity. This study seeks to determine the extent to which these physical developments have catalysed a shift in the local labour force from traditional, rain-fed subsistence agriculture to modern service-oriented roles in the hospitality and adventure sectors.

### **Data Collection Sources**

The research relies on two primary channels:

The Primary Data Household Surveys in A structured questionnaire administered to 120 households (40 from each zone) to determine the ratio of members employed in tourism vs. agriculture. Kalsubai Guide Groups). Direct mapping of "Soft Infrastructure" (temporary stalls, seasonal campsites) that often goes unrecorded in government data.

The Secondary Data Collected from the District Census Handbook (2011/2021)

to track occupational shifts over a decade. Tourism Records in statistical reports from the MTDC (Maharashtra Tourism Development Corporation) regarding tourist inflow and registered accommodation. Cartographic Tools in use of Survey of India Toposheets (1:50,000) and Google Earth Pro to map road connectivity and the proximity of villages to tourist sites.

### **Analytical Techniques and Spatial Mapping**

The collected data was processed using both quantitative and qualitative techniques. Spatial analysis was conducted by creating buffer zones around major infrastructure nodes to visualize the "reach" of economic benefits—determining, for instance, how far a resort's employment influence extends into neighboring villages. Furthermore, a Comparative Economic Analysis was performed to contrast the annual earnings of tourism-dependent households against traditional agricultural households. Finally, a geographical SWOT analysis was utilized to evaluate the environmental sustainability of expanding infrastructure within the eco-sensitive zones of the Western Ghats, ensuring that the study addresses the long-term viability of tourism as a regional employment engine.

### **Challenges: Seasonality and Sustainability**

Despite the positive effect on employment, the geography of Akole imposes a "seasonal ceiling" on income. The monsoon and winter months see a surge in employment due to the Fireflies Festival and trekking season, but the scorching summer months lead to high underemployment. Furthermore, the rapid growth of "unplanned infrastructure" poses a threat to the ecological balance. Soil erosion on trekking trails and water pollution in the Pravara River could eventually lead to a decline in tourism, threatening the long-term sustainability of the very jobs the infrastructure created.

### **Conclusion**

The paper concludes that while tourism infrastructure is the primary engine of non-agricultural employment in Akole, its benefits are geographically uneven. To achieve balanced regional development, the government should promote "Circuit Tourism," which links popular spots with remote villages through improved road networks. Investing in "Green Infrastructure," such as eco-friendly homestays and solar-powered campsites in less-visited areas, will decentralize the economic benefits and provide stable, year-round employment for a larger segment of the tehsil's population.

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# An Analytical Study of Demand and Supply Trends of Pulse Crops in India

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## Abstract

Pulses are an essential component of the global food system, particularly valued for their high protein content, making them a staple in vegetarian diets. They also play a significant role in maintaining soil fertility through nitrogen fixation. India is one of the leading producers, consumers, and cultivators of pulses worldwide. Despite this prominent position, the country faces persistent challenges in meeting domestic demand. Over time, pulse production has shown limited growth, while demand has steadily increased due to population growth and dietary needs. Consequently, imports have risen to compensate for the shortfall. Although pulses have export potential, government policies often prioritize domestic consumption, leading to restrictions on exports. This study examines trends in production, imports, exports, and total availability, highlighting the imbalance between demand and supply.

**Keywords:** Pulses, Production, Imports, Exports, Demand–Supply Gap

## Introduction

Pulses constitute a vital part of Indian agriculture and nutrition, serving as a primary source of protein for a large segment of the population. In addition to their nutritional importance, pulses contribute to soil health by enhancing nitrogen content naturally.

India ranks among the top producers and consumers of pulses globally. However, despite occupying a significant share of the global area under cultivation, the country faces difficulties in fulfilling domestic demand. Over the years, per capita availability of pulses has declined, even though nutritional standards recommend higher consumption levels.

The growing gap between production and demand has increased reliance on imports. Pulses are cultivated across different seasons—kharif, rabi, and summer—and include crops such as tur (arhar), moong, urad, gram, lentil, and

peas. However, various production constraints continue to limit their overall output.

### **Study Area**

The study focuses on India, located in South Asia between latitudes 8°4' N and 37°6' N and longitudes 68°7' E and 97°25' E. Covering an area of approximately 3.28 million square kilometers, it is the seventh-largest country in the world.

India's diverse geographical and climatic conditions support the cultivation of pulses across different regions. However, variations in rainfall, soil types, and irrigation facilities significantly influence productivity levels.

### **Objectives of the Study**

- To analyze trends in the production, demand, and supply of pulse crops
- To evaluate the gap between imports and exports
- To identify the major constraints affecting pulse production

### **Methodology**

The study is based on secondary data collected from multiple sources, including research publications, books, statistical reports, and government documents.

- Data has been obtained from agricultural reports, statistical yearbooks, and online databases
- Descriptive and statistical methods have been used for analysis
- Findings are presented through tables and interpretative discussion

### **Trends in Production, Imports, and Exports**

The period from 1992–93 to 2016–17 shows noticeable changes in pulse production and trade in India. During the early 1990s, production remained relatively stable, with low levels of imports and exports. In the following years, particularly in the early 2000s, production declined in certain periods, which led to a sharp increase in imports. This reflects growing dependence on external sources to meet domestic requirements.

In the post-2010 period, production improved significantly, exceeding 220 lakh tonnes by 2016–17. However, imports also increased during this time, indicating that domestic production still lagged behind demand. As a result, total availability of pulses showed a continuous upward trend.

### **Demand and Supply Analysis**

The demand for pulses in India has been rising steadily due to population growth, increased awareness of nutrition, and changing dietary preferences. However, production has not increased at the same pace.

Key observations include:

- Production growth has been slow and inconsistent
- Demand continues to rise significantly
- Imports play a critical role in balancing supply

This clearly indicates that India remains dependent on imports to meet its domestic consumption needs.

### **Import–Export Gap**

A major finding of the study is the significant disparity between imports and exports of pulses.

- Imports are consistently higher than exports
- Exports remain minimal and fluctuate over time
- The country functions as a net importer

This imbalance highlights the inadequacy of domestic production and emphasizes the growing dependence on foreign markets to fulfill internal demand.

### **Challenges in Pulse Production**

Several factors hinder the growth of pulse production in India:

#### **Natural Constraints**

- Heavy reliance on rainfall
- Climatic variability and drought conditions

#### **Agricultural Limitations**

- Insufficient irrigation facilities
- Declining soil fertility in certain regions
- Continued use of traditional farming practices

#### **Technological Barriers**

- Limited adoption of improved seed varieties
- Inadequate use of fertilizers and inputs
- Low level of mechanization

#### **Economic and Institutional Issues**

- Lower profitability compared to other crops

- Price instability
- Poor storage and marketing infrastructure
- Limited policy support in some areas

These constraints discourage farmers from expanding pulse cultivation, resulting in low productivity.

### **Discussion**

The study clearly reveals a persistent imbalance between the demand and supply of pulses in India. Although production has improved in recent years, it is still insufficient to meet the growing demand.

Imports have become essential to maintain supply, but excessive dependence on imports is not sustainable in the long run. There is a need to strengthen domestic production through improved agricultural practices and supportive policies.

### **Conclusion**

The analysis of demand and supply trends shows that India continues to face a significant gap between pulse production and consumption. Despite being a leading producer, the country relies heavily on imports to meet domestic demand.

Achieving self-sufficiency requires addressing production constraints, improving yield levels, and promoting sustainable farming methods. Strengthening the pulse sector will enhance food security and improve farmers' economic conditions.

### **Suggestions**

- Expand irrigation coverage for pulse crops
- Promote high-yielding and improved seed varieties
- Encourage adoption of modern agricultural practices
- Provide better price support and incentives to farmers
- Improve storage, processing, and marketing facilities
- Enhance research and development in pulse cultivation

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# Geospatial Analysis of Soil Fertility Distribution Using GIS in Karjat Taluka, District Ahilyanagar (Maharashtra)

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## Abstract

Soil fertility plays a crucial role in determining agricultural productivity and long-term sustainability, especially in semi-arid regions. This study focuses on examining the spatial variability of soil fertility in Karjat Taluka of Ahilyanagar District using Geographic Information System (GIS) techniques. The region is affected by challenges such as irregular rainfall, soil degradation, and uneven distribution of nutrients. By integrating soil sample data with secondary sources and GIS tools, key fertility indicators such as nitrogen (N), phosphorus (P), potassium (K), and organic carbon were mapped and analyzed. The findings indicate considerable spatial variation in soil fertility, with some areas experiencing nutrient deficiencies while others maintain moderate fertility levels. The study demonstrates the effectiveness of GIS in identifying fertility zones and supports site-specific nutrient management for sustainable agricultural development.

## Introduction

Soil fertility refers to the capacity of soil to provide essential nutrients necessary for plant growth and crop production. In agrarian regions like Karjat Taluka, maintaining soil health is vital for ensuring food security and sustaining the rural economy. However, continuous cultivation, improper fertilizer practices, and climatic stress have contributed to declining soil quality in recent years.

Geographic Information Systems (GIS) offer an advanced approach for analyzing and visualizing spatial variations in soil characteristics. GIS-based mapping of soil fertility enables precise identification of nutrient-deficient areas and supports efficient agricultural planning.

Karjat Taluka, located in Maharashtra, falls under a semi-arid climatic zone, making soil fertility management particularly important for sustainable agriculture.

### **Study Area**

Karjat Taluka is located in the central part of Ahilyanagar District and is characterized by semi-arid climatic conditions. The region receives an average annual rainfall of about 400–600 mm, which is often irregular and influences agricultural productivity. The dominant soil type is black cotton soil (Vertisols), known for its high moisture retention capacity but also its tendency to crack during dry periods. The topography of the taluka is gently undulating, which affects drainage patterns and soil distribution. Agriculture is the primary land use, with major crops including jowar, bajra, wheat, sugarcane, and pulses. Soil fertility varies across the taluka due to differences in irrigation facilities, cropping patterns, and management practices.

### **Objectives of the Study**

The main objective of this study is to examine the spatial variation of soil fertility in Karjat Taluka. It aims to analyze the distribution of key soil nutrients such as nitrogen, phosphorus, and potassium across different regions. Another important objective is to prepare GIS-based soil fertility maps for better visualization and understanding of nutrient patterns. Additionally, the study seeks to suggest suitable soil management strategies to improve agricultural productivity and sustainability.

### **Methodology**

#### **Data Collection**

- Soil samples collected from multiple locations within the taluka
- Secondary data obtained from agricultural departments
- Satellite imagery and base maps

#### **Laboratory Analysis**

The collected soil samples were analyzed for:

- Nitrogen (N) Phosphorus (P) Potassium (K) Organic Carbon (OC)

#### **GIS Analysis**

- Geo-referencing of sampling points
- Spatial interpolation techniques such as Inverse Distance Weighting (IDW)
- Preparation of thematic maps for each soil parameter

## **Classification**

Soil fertility levels were categorized into:

- Low
- Medium
- High

## **Soil Fertility Parameters**

- **Nitrogen (N)**

Nitrogen is essential for plant growth and chlorophyll formation. In Karjat Taluka, nitrogen levels generally range from 150 to 350 kg/ha, indicating low to medium fertility status. Lower values are mainly observed in intensively cultivated areas due to continuous cropping and limited organic inputs.

- **Phosphorus (P)**

Phosphorus supports root development and energy transfer in plants. The phosphorus content in the study area varies between 8 to 25 kg/ha. Irrigated regions tend to show moderate levels (15–25 kg/ha), whereas rainfed areas often fall below 15 kg/ha.

- **Potassium (K)**

Potassium enhances plant resistance and crop quality. In Karjat Taluka, potassium levels are relatively higher, ranging from 250 to 600 kg/ha, mainly due to the mineral-rich nature of black cotton soil.

- **Organic Carbon (OC)**

Organic carbon is a key indicator of soil health. The values in the study area range from 0.3% to 0.7%, which falls under low to medium category. Lower organic carbon content is associated with reduced use of organic manure and crop residues.

## **Spatial Distribution (with Approximate Values)**

- **Northern Region**

Nitrogen: 250–350 kg/ha, OC: 0.5–0.7% → Moderate fertility

- **Central Region**

Nitrogen: 150–250 kg/ha, OC: 0.3–0.5% → Low fertility

- **Southern Region**

Potassium: 300–600 kg/ha → High variability

- **Western Region**

Nitrogen: 200–300 kg/ha, OC: 0.4–0.6% → Moderate fertility

## **Factors Affecting Soil Fertility**

### • **Natural Factors**

Natural factors play an important role in agriculture and environmental conditions. Black cotton soil is fertile and retains moisture, making it suitable for crops like cotton and pulses. However, it becomes sticky when wet and cracks during dry periods. Rainfall variability affects water availability and crop production, as irregular rainfall can cause droughts or floods. Topographical conditions such as slope and elevation influence soil formation, drainage, and farming practices. Plains are suitable for agriculture, while hilly areas face erosion problems. These natural factors together determine land use and productivity. Understanding them helps in proper planning and sustainable development.

### • **Human Factors**

Human factors play a significant role in affecting soil fertility and agricultural sustainability. Excessive use of chemical fertilizers leads to soil degradation and reduces natural nutrient balance. The lack of crop rotation practices results in nutrient depletion, as the same crops continuously absorb similar nutrients from the soil. There is also a noticeable decline in the use of organic manure, which otherwise helps in maintaining soil structure and fertility. Additionally, inefficient irrigation management causes problems like waterlogging and salinity, further damaging soil health. These human-induced practices negatively impact long-term agricultural productivity and environmental balance. Proper management and sustainable farming practices are essential to overcome these issues

## **Role of GIS in Soil Fertility Mapping**

GIS serves as an essential tool for:

- Visualizing spatial variations in soil nutrients
- Identifying nutrient-deficient areas
- Supporting precision farming techniques
- Enhancing resource management strategies
- GIS-based soil maps assist farmers in applying fertilizers more effectively, reducing input costs and minimizing environmental impacts.

## **Environmental and Agricultural Implications**

Balanced nutrient management helps in improving soil fertility and ensures that crops receive essential nutrients in the right proportion. This leads to increased

crop productivity and better yields. Efficient utilization of soil resources also minimizes wastage of inputs like fertilizers and water, promoting sustainable agricultural practices. It further enhances soil health over time and supports long-term agricultural productivity.

### **Negative Impacts**

Excessive or improper use of fertilizers can cause nutrient imbalance in the soil, leading to soil degradation. Continuous use of chemical inputs reduces soil organic matter, which is essential for maintaining soil structure and fertility. This may also increase the risk of land degradation, making the soil less productive and more prone to erosion and environmental damage over time.

### **Discussion**

The analysis indicates that soil fertility in Karjat Taluka is not uniform and varies significantly across regions. Deficiencies in nitrogen and organic carbon are common, whereas potassium levels are relatively sufficient. The use of GIS technology proves highly effective in identifying these spatial patterns and supports better agricultural planning.

### **Conclusion**

The study reveals considerable spatial variability in soil fertility across Karjat Taluka. GIS-based analysis provides valuable insights into nutrient distribution and helps identify areas requiring targeted intervention. Adoption of sustainable soil management practices, including balanced fertilization and organic amendments, is essential for maintaining soil health and ensuring long-term agricultural productivity.

### **Suggestions**

- Encourage the use of organic fertilizers and compost
- Promote crop rotation and mixed cropping systems
- Implement soil testing-based fertilizer application
- Increase farmer awareness regarding soil health management
- Utilize GIS for continuous monitoring of soil fertility

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# **Application of Science and Technology in the Geographical Analysis of Socio-Economic and Demographic Conditions of Dhangar Community in Malshiras Taluka, Maharashtra**

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## **Abstract**

The application of science and technology has emerged as a transformative approach in understanding regional disparities and community development. This study examines the role of scientific and technological tools in analyzing the socio-economic and demographic conditions of the Dhangar community in Malshiras Taluka, Maharashtra. Traditionally a nomadic pastoral group, the Dhangars continue to face challenges such as limited access to education, healthcare, stable livelihoods, and basic infrastructure. The research integrates qualitative and quantitative methods supported by tools such as Geographic Information Systems (GIS), statistical analysis, and index-based assessment. Primary data from field surveys are combined with secondary data from government records and census sources. The study analyzes demographic structure, literacy, occupation, income, and access to services. Geospatial techniques identify regional disparities and vulnerability patterns. Findings highlight significant socio-economic inequalities, especially among women and marginalized groups. The study emphasizes that science and technology-based approaches can support evidence-based planning, inclusive development, and improved socio-economic well-being of the Dhangar community.

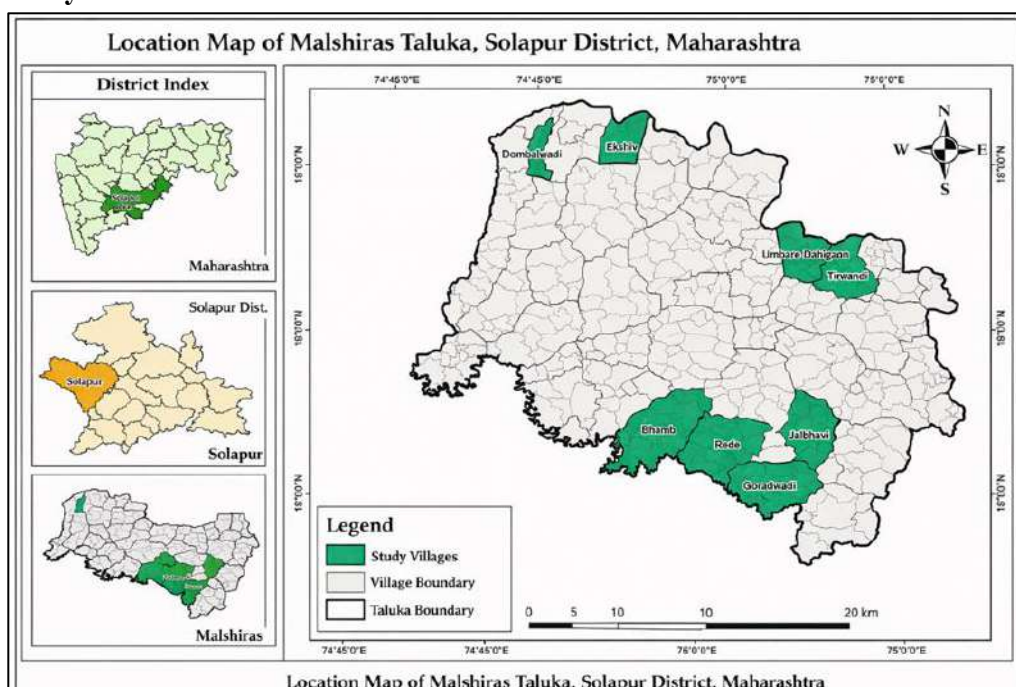
**Keywords:** Science and Technology, Geographical Analysis, Dhangar community, Malshiras taluka

## **Introduction**

India is characterized by cultural, social, and economic diversity, where communities follow livelihood systems shaped by their environment. Among them, nomadic and semi-nomadic groups hold a unique position due to mobility, pastoral economy, and cultural heritage. However, they remain

marginalized and face challenges like limited access to education, healthcare, and stable livelihoods [1]. Understanding their socio-economic and demographic conditions is essential for inclusive development. The Dhangar community, a major pastoral group in Maharashtra, has traditionally depended on livestock rearing, migration, and wool-based occupations. It has contributed to the rural economy, especially in livestock-based regions. However, shrinking grazing lands, environmental changes, and modernization have disrupted their occupations [2], leading to low literacy, unstable income, and poor access to infrastructure. Geography studies spatial relationships between humans and the environment. Modern tools like GIS, Remote Sensing, and spatial analysis now enhance demographic and socio-economic studies [3,4]. Malshiras taluka reflects these changes, where Dhangars maintain traditional livelihoods amid transitions, though scientific studies remain limited [5]. This study applies scientific tools for geographical analysis to understand development patterns and challenges.

## Study Area



Malshiras Taluka is located in the western part of Solapur district, Maharashtra, and is an important agricultural region of the Deccan Plateau. Historically, it has been influenced by various dynasties, shaping its socio-cultural diversity and livelihood patterns, including those of the Dhangar community.

Geographically, it lies between 17°50'–18°10' North latitude and 74°50'–75°15' East longitude, with an elevation of 450–600 meters. The terrain consists of undulating plains with scattered hills, influencing settlement patterns. The climate is semi-arid, with annual rainfall of 450–600 mm, making irrigation essential. The Nira River supports agriculture and livestock-based livelihoods. Major crops include sugarcane, jowar, wheat, bajra, and pulses. The taluka has rural settlements with a significant Dhangar population. This study uses GIS and statistical tools to analyse spatial and socio-economic patterns.

### **Data Sources and Methodology**

The present study is based on both primary and secondary data to analyze the socio-economic and demographic characteristics of the Dhangar community in Malshiras Taluka. Primary data were collected through structured questionnaires, interviews, and group discussions in selected villages, covering aspects such as family size, education, occupation, income, livestock, and migration. A purposive sampling method was used to select respondents engaged in traditional pastoral activities. Household surveys and interviews with elders and local leaders helped understand livelihood patterns and socio-cultural practices. Secondary data were obtained from Census of India, government reports, research articles, and district statistical records. Modern scientific tools such as Global Positioning System (GPS) were used to record village locations, while Geographic Information System (GIS) and QGIS were applied for spatial mapping and analysis. Statistical techniques like percentage analysis, tabulation, and graphical representation were used, providing a systematic framework for comprehensive geographical analysis.

### **Interpretation**

The data collected through field surveys were processed using digital and statistical techniques. Primary data from questionnaires, interviews, and observations were organized in Microsoft Excel and converted into percentages, charts, and graphs. The findings show that the Dhangar community mainly depends on livestock rearing, agriculture, and wage labour, with gradual diversification into small enterprises. Demographic analysis indicates a young population with improved literacy among younger groups. Socio-economic conditions such as housing, water, sanitation, and healthcare have improved, though disparities remain. GIS and QGIS were used to map settlement patterns, enhancing spatial analysis. Overall, the study reveals on going socio-economic transformation supported by development and technology.

## **Results**

The findings are based on primary data collected through surveys, questionnaires, interviews, and field observations among the Dhangar community in Malshiras Taluka. Data were analyzed using Microsoft Excel, while spatial information was mapped using QGIS. Results show that the socio-economic structure is largely influenced by traditional pastoral practices, especially sheep and goat rearing, with gradual diversification into agriculture, labour, dairy, and small businesses. The demographic profile indicates a high working-age population and improving literacy among younger generations. Socio-economic conditions vary, with better infrastructure in accessible areas and limitations in remote villages. GIS and GPS techniques enabled accurate spatial analysis. Overall, the study highlights gradual socio-economic transformation supported by infrastructure, education, and technology.

## **Discussion and Conclusion**

The study highlights the socio-economic and demographic characteristics of the Dhangar community in Malshiras Taluka and examines the role of scientific and technological tools in understanding their spatial and livelihood patterns. The findings show that the community largely depends on traditional pastoral activities such as sheep and goat rearing, though there is a gradual shift toward diversified occupations like agriculture, wage labour, dairy, and small businesses. The demographic structure indicates a young population with improving literacy, although disparities in higher education and employment opportunities remain. The use of modern tools such as GPS and GIS significantly improved the accuracy of geographical analysis by mapping settlements, grazing areas, and socio-economic variations. Infrastructure development, education, and government schemes are contributing to socio-economic transformation, but challenges such as limited grazing land, seasonal livelihoods, and restricted market access persist. Overall, the integration of science and technology enhances research efficiency and supports evidence-based planning for sustainable rural development and improved livelihoods.

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# Renewable and Sustainable Energy Technologies

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## Abstract

The global energy landscape is undergoing rapid transformation as climate change, resource depletion, and energy security concerns drive the shift from fossil fuels to renewable and sustainable energy technologies. Renewable energy sources such as solar, wind, hydro, biomass, and geothermal offer environmentally benign and economically viable alternatives to conventional energy systems. This paper reviews major renewable energy technologies, assesses their contributions to sustainable development, discusses integration challenges, and identifies future research directions. The objective is to provide a comprehensive overview that can guide researchers, policymakers, and industry stakeholders in understanding the current state and future prospects of renewable energy.

**Keywords:** Renewable Energy, Sustainable Energy, Green Energy, Clean Energy, Energy Transition, Low-Carbon Energy, Solar Energy, Wind Energy, Hydropower, Geothermal Energy, Biomass Energy, Bioenergy, Hydrogen Energy, Marine Energy, Photovoltaic Technology, Energy Storage Systems etc.

## Introduction

Energy plays a central role in modern societies, powering industries, transportation, communication, and households. Historically, energy needs have been met predominantly through fossil fuels coal, oil, and natural gas that emit significant greenhouse gases (GHGs), contributing to global warming and adverse health effects. As environmental awareness and technological innovation increase, renewable energy has emerged as a viable solution to decarbonize energy systems while meeting growing energy demand. Renewable energy technologies are those that harness energy from naturally replenished sources, including sunlight, wind, water flow, organic waste, and Earth's internal heat. Sustainable energy implies not only renewability but also energy

production with minimal environmental impact, access equity, economic feasibility, and long-term viability. This paper explores major renewable energy technologies, their operational principles, advantages, challenges, and integration into modern energy systems.

## **Solar Energy Technologies**

### **Photovoltaic (PV) Systems**

Photovoltaic systems convert sunlight directly into electricity using semiconductor materials primarily silicon. When photons strike a PV cell, they excite electrons, creating an electric current.

#### **Advantages**

- Scalable from small rooftop panels to large solar farms.
- Declining costs with technological improvements and mass production.
- Low operational emissions.

#### **Challenges**

Intermittency due to weather and night cycles.

Need for energy storage or grid balancing solutions.

### **Concentrated Solar Power (CSP)**

Concentrated Solar Power uses mirrors or lenses to concentrate sunlight onto a receiver to heat a fluid, which generates steam to drive turbines for electricity.

#### **Key Features**

- High efficiency in desert climates with abundant sunlight.
- Thermal energy storage (e.g., molten salts) enables electricity generation even after sunset.

#### **Limitations**

- Higher initial capital cost compared to PV.
- Best suited for large, utility-scale projects.

## **Wind Energy Technologies**

Wind energy harnesses kinetic energy from wind and converts it to electricity via turbines.

### **Onshore Wind**

Onshore wind turbines dominate global wind power installations due to lower

development costs and mature technology.

### **Advantages**

High-capacity expansion potential in many regions.

### **Constraints**

Noise concerns, land use conflicts, and variable wind speeds.

### **Offshore Wind**

Offshore wind turbines are installed in coastal waters where winds are stronger and more consistent.

### **Benefits**

Higher capacity factors and larger turbines.

### **Challenges**

Higher construction and maintenance costs, complex grid connectivity.

### **Hydropower**

Hydropower generates electricity from flowing or falling water. It remains one of the oldest and most widely used renewable sources.

### **Large-Scale Hydro**

Dams store water in reservoirs; controlled release spins turbines for electricity.

### **Advantages**

Reliable baseload power; long plant lifetimes Environmental

### **Concerns**

Ecosystem disruption, displacement of communities, sedimentation issues.

### **Small and Micro Hydro**

Small and micro hydro systems serve local communities with lower environmental impact.

### **Benefits**

Cost-effective for rural electrification.

### **Limitations**

Site-specific feasibility based on water flow.

### **Biomass Energy**

Biomass energy derives from organic materials such as agricultural residues, wood, and waste.

### **Bioenergy Conversion Methods**

- **Combustion:** Directly burning biomass for heat and power.
- **Gasification:** Converting biomass into syngas for fuel or electricity.
- **Anaerobic Digestion:** Breaking down organic waste to produce biogas for energy.

### **Sustainability Considerations**

Biomass offers a recycled carbon cycle if sustainably sourced and managed. However, large-scale biomass harvesting can lead to land use change and competition with food crops.

### **Geothermal Energy**

Geothermal energy uses heat stored beneath Earth's surface for electricity and heating.

- **Electricity Generation:** Common in tectonically active regions.
- **Direct Use Applications:** Space heating, industrial processes.

### **Advantages**

Renewable & Sustainable, Environment Friendly, Reliable & Stable, Low Operating Cost, Direct Use Applications, Reliable, baseload generation with low emissions.

### **Limitations**

Location Specific, High Initial Cost, Risk of Earthquakes, Release of Harmful Gases, Water Requirement, Site dependency and drilling costs.

### **Emerging and Hybrid Technologies**

Renewable energy complementing technologies improve reliability and efficiency.

### **Energy Storage Systems**

Energy storage particularly lithium-ion batteries, flow batteries, pumped hydro storage, and emerging technologies address intermittency challenges of solar and wind power by storing excess energy for later use.

### **Green Hydrogen**

Electrolyzing water using renewable electricity produces green hydrogen, a clean fuel for transportation, industry, and long-term energy storage.

## **Integration into Sustainable Energy Systems**

To realize the full potential of renewable energy, integration within grids and energy systems must overcome several technical, economic, and policy challenges.

### **Grid Stability and Smart Grids**

High shares of variable renewables require advanced grid management, including smart grids, demand-side management, and flexible generation sources.

### **Policy and Market Mechanisms**

Supportive policies such as feed-in tariffs, renewable portfolio standards, carbon pricing, and subsidies accelerate renewable adoption.

### **Life Cycle and Environmental Impact**

Renewable technologies have environmental footprints from manufacturing, installation, and disposal. Life Cycle Assessment (LCA) ensures sustainable practices throughout the energy system.

## **Case Studies**

### **Solar Transition in Germany**

Germany's Energiewende policy accelerated solar and wind installations, significantly reducing national carbon emissions and driving innovation in grid management and storage incentives.

### **Wind Power in Denmark**

Denmark generates a large portion of electricity from wind—especially offshore—showcasing how policy alignment, community involvement, and technological innovation can transform national energy mixes.

### **Challenges and Barriers**

Despite progress, renewable energy deployment faces:

- Intermittency and predictability issues
- High upfront capital costs
- Resource and land constraints
- Supply chain and rare material availability
- Regulatory and financing hurdles in developing regions

Addressing these challenges requires cross-sector collaboration, research investment, and inclusive policy frameworks that prioritize environmental justice.

### **Future Research Directions**

Research areas with promise include:

- Advanced storage technologies (solid-state batteries, thermal storage)
- Next-generation photovoltaics (perovskite and tandem cells)
- Floating offshore wind solutions
- Enhanced geothermal systems
- Carbon capture and renewable integration
- AI and IoT for smart energy management

Open research into material science, grid architecture, economic models, and climate impacts can unlock broader sustainable energy adoption.

### **Conclusion**

Renewable and sustainable energy technologies are indispensable to achieving climate goals, energy security, and sustainable development. Solar, wind, hydro, biomass, and geothermal sources provide diverse pathways to decarbonize energy systems. While challenges remain such as variability, cost, and integration ongoing technological innovation, policy support, and system-level planning continue to drive global transitions.

The adoption of renewable technologies not only mitigates environmental impacts but also promotes economic resilience, energy access, and social equity. Future research and implementation strategies must therefore align technological advances with sustainable policy frameworks to realize a net-zero energy future.

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# Geospatial Evaluation of Climate Risk and Agricultural Resilience at the Taluka Level: A Study of Karjat, Ahilyanagar District Maharashtra, India

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## Abstract

Agricultural systems in semi-arid regions are increasingly exposed to climate variability and extreme weather conditions. This study presents a geospatial evaluation of climate risk and agricultural resilience in Karjat taluka of Ahilyanagar district, Maharashtra. By integrating climatic, topographic, land-use, and agricultural datasets, the research examines spatial variations in vulnerability and adaptive capacity. The results indicate that Karjat taluka is highly exposed to climate risks due to irregular rainfall, rising temperatures, and water scarcity, while resilience levels remain moderate and spatially uneven. The study underscores the importance of geospatial techniques in identifying vulnerable zones and supporting climate-resilient agricultural planning.

**Keywords:** Climate risk, Agricultural resilience, GIS, Karjat taluka, Ahilyanagar, Drought, Vulnerability

## Introduction

Agriculture in semi-arid landscapes is particularly vulnerable to fluctuations in climate, especially in regions dependent on monsoon rainfall like Maharashtra. Increasing occurrences of drought, unpredictable rainfall patterns, and rising temperatures have intensified stress on farming systems. Ahilyanagar district (formerly Ahmednagar) is widely recognized as drought-prone, with Karjat taluka among the most vulnerable areas.

Geospatial technologies such as Geographic Information Systems (GIS) and remote sensing offer powerful tools for analyzing spatial patterns of climate risk and resilience. This study aims to assess climate-related risks at the taluka level and evaluate the resilience of agricultural systems in Karjat using a geospatial framework.

## **Study Area**

Karjat taluka is situated in the southern part of Ahilyanagar district in Maharashtra, India. The region falls within the rain shadow zone of the Western Ghats and exhibits a semi-arid climatic condition. The landscape is predominantly a plateau with gentle slopes and is covered by black cotton soils (regur), known for their moisture-retaining properties.

Agriculture forms the backbone of the local economy, with a large proportion of farmers relying on rainfall. The cropping pattern includes kharif crops such as bajra, soybean, and pulses, along with rabi crops like wheat, gram, and jowar. Irrigated agriculture is limited and mainly supported by wells, borewells, and canal networks.

## **Data and Methodology**

### **Data Sources**

This study utilizes a combination of datasets, including:

- Climatic data on rainfall and temperature from secondary sources
- Soil information from national soil databases
- Land Use/Land Cover (LULC) data derived from satellite imagery
- Digital Elevation Model (DEM) for terrain analysis
- Agricultural statistics from district records

### **Methodological Framework**

A geospatial approach was adopted to analyze climate risk and resilience through the following stages:

- **Climate Risk Assessment:** Rainfall variability and temperature trends were evaluated to identify climatic stress zones. Areas with high variability and warming trends were categorized as high-risk.
- **Exposure Analysis:** Agricultural land distribution was mapped to determine the extent of exposure to climatic hazards, especially in rainfed regions.
- **Sensitivity Evaluation:** Factors such as soil characteristics, slope, and crop types were examined to understand the susceptibility of agriculture to climate stress.
- **Adaptive Capacity Analysis:** Indicators including irrigation availability, crop diversification, and infrastructure access were used to assess resilience.
- **Composite Vulnerability Mapping:** A GIS-based weighted overlay technique was applied to integrate all indicators and produce a vulnerability

index map.

## **Results and Discussion**

### **Climate Risk Characteristics**

The findings show that Karjat taluka experiences significant rainfall variability, often marked by dry spells during the monsoon period. Despite moderate average annual rainfall, its uneven distribution leads to frequent agricultural droughts. Temperature trends reveal a steady increase in both maximum and minimum values, intensifying heat stress.

Geographically, plateau regions within the taluka demonstrate higher climate risk due to limited water availability and dependence on rainfall.

### **Agricultural Vulnerability**

The analysis indicates that rainfed agricultural areas are the most vulnerable to climate-related risks. In certain locations, shallow soils and sloping terrain contribute to increased runoff and reduced water retention, worsening drought impacts.

Crop choice also influences vulnerability. Water-intensive crops like sugarcane, grown in irrigated areas, face risks under water-limited conditions, whereas traditional crops such as millets and pulses are comparatively more resilient.

### **Resilience Patterns**

Agricultural resilience in Karjat taluka is moderate but varies across locations. Regions with better irrigation infrastructure, including canals and groundwater sources, exhibit higher adaptive capacity. Farmers in these areas are more likely to adopt improved practices and cultivate high-value crops.

Crop diversification is emerging as a key adaptation strategy. A gradual shift toward horticultural crops such as pomegranate and drought-tolerant crops like millets and pulses reflects farmers' responses to climate stress.

However, resilience is constrained by factors such as limited irrigation coverage, low adoption of micro-irrigation technologies, and market uncertainties.

### **Spatial Distribution of Vulnerability**

The vulnerability mapping identifies three primary zones:

- **High Vulnerability Areas:** Rainfed plateau regions with limited irrigation, high rainfall variability, and sensitive soils.

- **Moderate Vulnerability Areas:** Regions with partial irrigation support and mixed cropping systems.
- **Low Vulnerability Areas:** Well-irrigated zones with diversified agriculture and better infrastructure.

These spatial variations highlight the importance of targeted, location-specific interventions.

### **Strategies for Climate-Resilient Agriculture**

Based on the findings, the following strategies are recommended:

#### **Water Management**

- Promotion of drip and sprinkler irrigation systems
- Development of farm ponds and check dams
- Implementation of watershed management programs

#### **Crop Diversification and Planning**

- Encouragement of drought-resistant crops such as millets and pulses
- Adoption of short-duration crop varieties
- Diversification to reduce climate-related risks

#### **Soil Conservation Practices**

- Contour bunding and land leveling
- Addition of organic matter to improve soil health
- Adoption of conservation agriculture techniques

#### **Climate Advisory Services**

- Dissemination of timely weather forecasts
- Use of digital platforms for agricultural advisories

#### **Institutional Measures**

- Strengthening crop insurance programs
- Supporting Farmer Producer Organizations (FPOs)
- Improving access to markets and credit facilities

#### **Conclusion**

This geospatial evaluation highlights the complex relationship between climate variability, land characteristics, and agricultural practices in Karjat taluka. The study concludes that climate risk is high due to erratic rainfall, rising temperatures, and water scarcity, while resilience remains moderate and

uneven.

Geospatial techniques play a critical role in identifying vulnerable regions and guiding targeted interventions. Enhancing water management, promoting crop diversification, and strengthening adaptive capacity are essential for developing climate-resilient agriculture in the region.

Future research should incorporate real-time climate datasets, high-resolution satellite imagery, and socio-economic parameters to refine vulnerability assessments. A localized and data-driven planning approach is crucial for ensuring sustainable agricultural development in semi-arid regions like Karjat taluka.

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# **A Descriptive Study of Migration Trends and Regional Disparities in Karjat Taluka, District Ahilyanagar (Maharashtra)**

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## **Abstract**

Migration represents a crucial demographic and socio-economic process that highlights differences in development levels, resource distribution, and livelihood opportunities. This study provides a descriptive examination of migration patterns and regional disparities in Karjat Taluka of Ahilyanagar district, Maharashtra, supported by a GIS-based map and migration graph. The region is characterized by semi-arid climatic conditions, uneven terrain, and limited water availability, all of which significantly shape human activities. The map identifies three key physical zones—northern uplands, central plateau, and southern river basin—each exhibiting varying degrees of agricultural productivity and development. The graphical data indicates that rural-to-urban migration is the most prominent, followed by seasonal and permanent migration. The study concludes that environmental limitations and uneven regional development are the primary drivers of migration and emphasizes the importance of balanced planning and sustainable resource management.

## **Introduction**

Migration involves the movement of people from one location to another in search of improved employment, education, and living conditions. In rural regions, especially those affected by drought and resource scarcity, migration often becomes a necessity rather than a voluntary decision.

Karjat Taluka, located in Ahilyanagar district, falls within a semi-arid zone where agriculture is the dominant occupation. However, due to insufficient rainfall, water shortages, and limited industrial growth, the region faces several socio-economic challenges. Consequently, migration has emerged as a common coping mechanism for rural communities.

The use of a GIS-based map along with a migration graph helps in understanding spatial differences and migration dynamics within the taluka. This paper aims to analyze these patterns and explore their connection with regional disparities.

### **Objectives of the Study**

- To examine migration patterns in Karjat Taluka.
- To study spatial variations in development using the map.
- To analyze the link between migration and regional imbalance.
- To suggest measures for achieving balanced regional development.

### **Study Area**

Karjat Taluka is located in the central part of Ahilyanagar district and forms a segment of the Deccan Plateau. The area experiences a semi-arid climate with annual rainfall ranging between 400 mm and 700 mm.

Agriculture is largely rain-dependent, with crops such as jowar, bajra, and pulses being widely cultivated. The region displays diverse physical features, including uplands, plateaus, and river basins, which significantly influence land use patterns and settlement distribution.

### **Methodology**

The study is based on secondary sources of information and the interpretation of a GIS-style map and migration graph. A descriptive and analytical approach has been employed to understand spatial variations and migration patterns. The map helps in identifying regional differences, while the graph provides numerical insights into various types of migration.

### **Description of the GIS Map**

The GIS map categorizes Karjat Taluka into three main regions based on physical characteristics and land use.

#### **• Northern Upland Region**

The northern section is marked by hilly and uneven terrain. The soil here is shallow and less fertile, making it unsuitable for intensive farming. Water availability is limited due to poor infiltration and lack of irrigation facilities.

As a result, this region experiences a high level of out-migration, with people moving to urban areas in search of better employment opportunities and living conditions. Inadequate infrastructure further contributes to its underdevelopment.

- **Central Plateau Region**

The central region is comparatively flat and serves as the primary agricultural zone. The soil is moderately fertile, and certain areas benefit from limited irrigation facilities. Villages such as Kuldharan and Babhulgaon are located in this region.

Although agriculture is the main occupation, it remains dependent on rainfall. Seasonal migration is common, as farmers and laborers seek additional income during non-agricultural periods.

- **Southern River Basin Region**

The southern part lies along the basin of the Sina River and represents the most fertile region of the taluka. Improved water availability and better soil quality support relatively stable agricultural activities.

This region has a higher population density and comparatively lower migration rates, indicating a better level of development.

- **Connectivity and Infrastructure**

The map also illustrates transportation networks linking the taluka to nearby urban centers. Areas with better connectivity tend to have more economic opportunities and lower migration levels, whereas remote regions face higher migration due to limited access to markets and services.

### **Description of Migration Trends (Graph Analysis)**

- **Rural to Urban Migration**

Approximately 22,000 individuals migrate from rural areas to urban centers, making it the most dominant type of migration. People move to cities such as Pune and Mumbai in search of employment, education, and healthcare facilities.

- **Seasonal Migration**

Seasonal migration involves nearly 15,000 individuals and occurs during periods when agricultural activities are limited. Migrants engage in work such as sugarcane harvesting, construction, and other labor-intensive jobs.

- **Permanent Migration**

Around 6,000 individuals permanently relocate to urban areas. This type of migration is driven by long-term economic instability and the absence of development in rural regions.

- **In-Migration**

In-migration is relatively low, with about 2,000–3,000 individuals moving into the taluka. This is mainly due to agricultural labor demand or small-scale industrial activities.

- **Interpretation**

The graph clearly indicates that out-migration significantly exceeds in-migration. It also shows that rural-to-urban migration is the most prominent, reflecting the lack of sufficient opportunities within the taluka.

### **Regional Imbalance in Karjat Taluka**

- **Unequal Distribution of Natural Resources**

Water resources and fertile land are concentrated in certain areas, while upland regions suffer from scarcity.

- **Variation in Agricultural Development**

River basin areas are more productive, whereas upland regions remain less developed.

- **Disparities in Infrastructure**

Central and southern regions have better access to roads, education, and healthcare facilities, while remote areas lack basic amenities.

- **Economic Inequality**

Limited industrial development restricts employment opportunities, forcing people to migrate to urban areas.

### **Relationship Between Migration and Regional Imbalance**

Migration both results from and contributes to regional imbalance. Underdeveloped areas experience higher out-migration, which further reduces their workforce and slows development. Meanwhile, developed regions attract more population, increasing pressure on urban infrastructure.

### **Impacts of Migration**

#### **Positive Impacts**

- Increase in household income through remittances
- Exposure to new skills and knowledge
- Improved access to education

### **Negative Impacts**

- Shortage of labor in rural areas
- Decline in agricultural productivity
- Expansion of urban slums
- Social issues such as family separation

### **Discussion**

The analysis demonstrates that migration in Karjat Taluka is closely linked to environmental and economic conditions. The semi-arid climate, coupled with inadequate irrigation and lack of industrial growth, compels people to migrate. Regional disparities further intensify this trend, as individuals move from less developed areas to regions with better opportunities. This creates a continuous cycle of inequality that requires strategic planning to address.

### **Conclusion**

The study concludes that migration in Karjat Taluka is primarily influenced by environmental stress, limited economic opportunities, and regional disparities. The GIS map and migration graph effectively illustrate the spatial differences in development and migration patterns.

To minimize migration and promote balanced development, it is essential to enhance irrigation facilities, develop rural industries, and improve infrastructure in underdeveloped areas.

### **Suggestions**

- Strengthening irrigation and watershed management initiatives
- Encouraging agro-based and small-scale industries
- Improving rural infrastructure and connectivity
- Implementing skill development and employment programs
- Focusing on the development of drought-prone and upland regions

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# The Spatial Dynamics of Science and Technology Innovations: A Geographic Perspective

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## Abstract

Innovations in science and technology play a central role in driving global socioeconomic development, yet their spatial distribution and regional impacts are uneven. This study explores the interactions between technological innovations and geographic space, examining how they shape regional growth, knowledge networks, and environmental outcomes. Using a combination of spatial analysis, case studies, and a review of innovation system literature, the research identifies patterns of technological clustering, mechanisms of knowledge diffusion, and factors influencing regional disparities. The results indicate that proximity to research hubs, robust digital infrastructure, and supportive institutional frameworks significantly affect innovation performance. Strategic regional planning can, therefore, reduce spatial inequalities and enhance the effectiveness of technological interventions. This work provides a geographic framework for understanding how science and technology innovations are embedded in place and space.

**Keywords:** Spatial innovation, technology diffusion, regional clusters, science and technology, innovation ecosystems, geographic analysis

## Introduction

Innovation is recognized globally as a critical driver of economic prosperity and social progress. However, technological breakthroughs do not emerge evenly across geographic space—they tend to cluster in particular regions due to economic, institutional, and cultural factors. Geography, with its focus on spatial relationships and place-based dynamics, offers valuable insights into the origins, diffusion, and regional impacts of innovations. This research investigates the spatial dimensions of science and technology innovations, addressing questions such as: Where are innovations concentrated? Which

geographic factors enable or hinder their spread? How do innovations reshape regional landscapes and urban systems?

Recent decades have seen unprecedented advances, from artificial intelligence and biotechnology to renewable energy and digital platforms. Yet these innovations are often concentrated in specific regions, reinforcing existing spatial inequalities. This paper draws on theories from economic geography, regional innovation systems, and diffusion studies to examine how science and technology innovations are spatially organized and to provide guidance for regional innovation policy.

## **Literature Review**

### **• Clustering of Innovation**

Innovation clusters, such as Silicon Valley, Cambridge, and Shenzhen, demonstrate that technological activity often concentrates in defined areas (Porter, 1998; Storper & Venables, 2004). Such clusters benefit from knowledge spillovers, specialized labor markets, and dense supplier networks, which collectively foster high innovation output. Proximity facilitates interaction and collaboration, reducing costs and enhancing serendipitous knowledge exchanges (Boschma, 2005).

### **• Regional Innovation Systems**

Innovation systems research highlights the importance of institutional networks, including universities, firms, and government agencies, in shaping innovation ecosystems (Lundvall, 1992; Cooke et al., 1997). Regional innovation systems emphasize localized actors and relationships, suggesting that geography is not a neutral backdrop but an active factor in driving technological development.

### **• Technology Diffusion**

The diffusion of innovations is influenced by geographic proximity, infrastructure, and social networks (Hägerstrand, 1967). While digital technologies have accelerated diffusion, they have also intensified divides between connected regions and those lacking access to modern communication infrastructure.

### **• Digital Infrastructure and Innovation**

Access to digital infrastructure—broadband, 5G, cloud services—is increasingly critical for regional innovation capacity. Regions with strong digital networks attract knowledge-intensive industries, whereas peripheral

areas may struggle to keep pace with technological change (Malecki, 2010).

## **Methods**

This study combines quantitative and qualitative approaches:

- **Spatial Analysis:** Using GIS, regional innovation activity was mapped through patent filings, R&D investments, and employment in technology sectors. Spatial statistics, including hotspot and autocorrelation analyses, identified regions with concentrated innovation activity.
- **Case Studies:** Three regions—a mature European tech hub, an emerging Asian innovation cluster, and a developing African region—were examined to assess the local factors driving innovation.
- **Literature and Data Review:** Global innovation reports, academic research, and policy documents were reviewed to contextualize findings and validate spatial patterns

## **Results and Discussion**

### • **Innovation Clusters**

Spatial mapping reveals that innovation is heavily concentrated in metropolitan areas with strong research institutions and industrial networks. These high-density innovation corridors align with global knowledge economies, and regions with dense clusters demonstrate higher levels of international collaboration.

### • **Digital Connectivity**

Regions with advanced digital infrastructure exhibit faster technology adoption and more effective commercialization of innovations. Areas with limited connectivity, in contrast, face slower technological integration, exacerbating spatial inequities.

### • **Diffusion Patterns**

Innovations spread unevenly across space. Neighboring regions with strong transportation and communication links adopt technologies more rapidly than distant or isolated areas. Collaborative networks among firms and universities significantly influence the rate and success of diffusion.

## **Case Study Observations**

Case studies show how local governance and policy shape innovation outcomes. In the European hub, long-term R&D investment and startup incentives fostered a diversified innovation ecosystem. The Asian cluster benefited from foreign investment and strategic urban planning, while the African region relied on

mobile technologies to drive innovation but struggled due to weaker institutional support. These examples demonstrate the interplay of geography, policy, and socioeconomic factors in shaping innovation outcomes.

### **Conceptual Implications**

This research proposes a geographic framework for innovation that integrates:

- **Spatial Accessibility:** Measures ease of interaction among innovation actors via transport and digital networks.
- **Institutional Support:** Captures the capacity of local universities, government agencies, and policies to facilitate innovation.
- **Network Connectivity:** Reflects links between local regions and global knowledge networks.

### **Policy Implications**

To foster more equitable innovation, policymakers should consider:

- **Expanding Digital Infrastructure:** Provide broadband and digital skills programs in underserved areas.
- **Strengthening Institutions:** Support universities and research centers as anchors for regional innovation.
- **Improving Connectivity:** Enhance transport and knowledge networks to facilitate collaboration.
- **Tailored Funding Strategies:** Design funding policies that leverage local strengths and resources.

Such strategies can enable regions to leverage their geographic potential while reducing disparities in technological advancement.

### **Conclusion**

Geography plays a crucial role in shaping how innovations emerge, spread, and impact society. Spatial clustering, connectivity, digital infrastructure, and institutional capacity all influence regional innovation outcomes. Understanding these spatial dynamics can inform more effective policies and planning, ensuring that technological progress benefits broader populations. Future research should examine longitudinal innovation data and the role of emerging technologies, such as AI, in altering spatial patterns of innovation.

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# **Geomorphological Characteristics and Their Impact on Land Use in Karjat Taluka, District Ahilyanagar (Maharashtra)**

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## **Abstract**

Geomorphology significantly influences land use patterns, particularly in semi-arid regions where natural conditions strongly regulate human activities. This study explores the geomorphological features of Karjat Taluka in Ahilyanagar district and evaluates their effect on land utilization. The area is marked by Deccan Trap basalt formations, uneven plateau terrain, seasonal river systems, and fluctuating rainfall patterns. These physical factors play an important role in determining soil development, water availability, agricultural practices, and settlement distribution. The study reveals that geomorphic conditions limit intensive farming in upland areas while encouraging agricultural activities in valley regions. It also addresses concerns such as land degradation, water scarcity, and vulnerability to drought. The findings highlight the importance of adopting sustainable land management strategies suited to the region's geomorphic characteristics.

## **Introduction**

Land use patterns are closely associated with the physical environment, especially geomorphological conditions. Karjat Taluka, located in Ahilyanagar district of Maharashtra, falls within a semi-arid climatic zone and frequently faces drought situations. The region's physical features—including plateau landscapes, basaltic rock structures, and shallow soils—play a key role in shaping agricultural productivity, settlement patterns, and resource utilization. Analyzing the link between geomorphology and land use is essential for planning sustainable development in drought-prone areas. This study focuses on understanding the geomorphological characteristics of Karjat Taluka and examining how they influence land use patterns.

## **Objectives of the Study**

- To examine the geomorphological features of Karjat Taluka.
- To assess the impact of geomorphology on land use patterns.

- To identify issues related to land degradation and resource management.

### **Study Area**

Karjat Taluka is situated in the central part of Ahilyanagar district in Maharashtra and forms a part of the Deccan Plateau. The region experiences semi-arid climatic conditions with annual rainfall ranging from approximately 400 mm to 700 mm. Agriculture is the primary occupation of the population, though it largely depends on rainfall due to insufficient irrigation facilities.

### **Methodology**

This study is based on secondary data obtained from district gazetteers, government publications, and relevant research studies. Information related to rainfall, soil types, and land use has been analyzed using a descriptive and analytical approach to understand the interaction between geomorphology and land use.

### **Geomorphological Characteristics**

#### **Geological Structure**

Karjat Taluka forms part of the Deccan Trap region, which originated due to volcanic eruptions during the late Cretaceous period. The area is predominantly composed of basaltic rocks that influence both soil properties and groundwater storage. Since basalt is generally hard and less permeable, water infiltration is restricted mainly to fractured zones.

#### **Relief and Topography**

The terrain of the region is characterized by plateau landscapes with uneven surfaces. It includes flat-topped plateaus, low hills, ridges, and river valleys. The elevation is generally below 500 meters. While some areas have gentle slopes, others are steep and rugged, which restricts agricultural expansion.

#### **Drainage Pattern**

The drainage system in Karjat Taluka is mainly seasonal. Rivers such as the Sina and its tributaries flow primarily during the monsoon season. The drainage pattern is dendritic, which is typical in basaltic regions. Due to irregular rainfall, many rivers and streams dry up during the summer months, resulting in water shortages.

#### **Soil Types**

Soil characteristics vary according to the geomorphic setting:

- **Black cotton soil (Regur):** Found in valley regions, fertile and suitable for crops like cotton and wheat.
  - **Shallow and coarse soil:** Present in upland areas, less productive and susceptible to erosion.
  - **Mixed soils:** Occur in transitional zones between uplands and lowlands.
- Thus, soil depth and fertility are closely related to the geomorphology of the area.

### **Climate**

Karjat Taluka experiences a semi-arid climate with hot summers and relatively mild winters. Rainfall is irregular and highly variable, which affects both geomorphic processes and land use activities. The region is frequently affected by drought conditions.

### **Influence of Geomorphology on Land Use**

#### **Agricultural Land Use**

Agriculture is the main land use in Karjat Taluka, but it is strongly controlled by geomorphological factors:

- Valley regions with deep and fertile black soils support crops such as wheat, sugarcane, and pulses.
- Plateau areas with shallow soils are mainly used for dry farming of crops like jowar and bajra.
- Rocky uplands are largely unsuitable for cultivation and are used for grazing purposes.

This uneven distribution of fertile land results in variations in agricultural productivity across the region.

#### **Irrigation and Water Resources**

Geomorphology has a significant impact on water availability:

- Hard basaltic rocks restrict groundwater storage.
- Water is mainly stored in weathered and fractured zones.
- Irrigation sources include wells, borewells, and small tanks.

Due to limited water resources, agriculture is predominantly rainfed and highly vulnerable to drought.

#### **Settlement Patterns**

Settlement distribution in Karjat Taluka is influenced by physical conditions:

- Most villages are located in fertile valleys where water availability is better.

- Upland and rocky regions have sparse populations.
- Terrain and accessibility also influence the location of settlements.

Thus, geomorphology plays an important role in determining human habitation patterns.

### **Vegetation and Land Cover**

Natural vegetation in the region is sparse due to low rainfall and poor soil conditions. The dominant types include scrub vegetation and grasslands, with very limited forest cover. Denser vegetation is found in valley areas where moisture availability is higher.

### **Land Degradation and Environmental Issues**

Several environmental problems arise due to geomorphological conditions:

- Soil erosion in sloping areas
- Land degradation caused by overgrazing
- Conditions resembling desertification in certain areas
- Frequent occurrence of drought

These factors reduce land productivity and negatively affect livelihoods.

### **Discussion**

The analysis indicates a strong relationship between geomorphology and land use in Karjat Taluka. The combination of basaltic geology, plateau topography, and semi-arid climate creates limitations for agriculture and water availability. While valley areas are suitable for intensive cultivation, upland areas remain underutilized or degraded.

The heavy reliance on rainfall and limited irrigation infrastructure makes agriculture highly vulnerable. Therefore, sustainable land use planning must consider geomorphological conditions to enhance productivity and minimize environmental degradation.

### **Conclusion**

Geomorphology plays a crucial role in shaping land use patterns in Karjat Taluka. The plateau landscape, basaltic rock formations, shallow soils, and seasonal drainage system influence agricultural practices, settlement distribution, and resource utilization. Fertile valleys support cultivation, whereas uplands are mainly used for grazing or remain barren. Water scarcity and land degradation further pose challenges to sustainable development.

Adopting appropriate land management strategies, such as watershed development, soil conservation, and efficient irrigation practices, is essential for improving land use and ensuring sustainable livelihoods.

### **Suggestions**

- Implementation of watershed development programs
- Promotion of drought-resistant crop varieties
- Adoption of soil conservation methods such as contour bunding
- Efficient management of groundwater resources
- Encouragement of afforestation and pasture development

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# Population Distribution in Karjat Taluka, District Ahilyanagar with Special Reference to Chapadgaon

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## Abstract

Population distribution is an important component of regional geography and planning as it explains how people are spatially arranged across a region. This distribution is shaped by various physical, economic, and social factors. The present study focuses on the pattern of population distribution in Karjat Taluka of Maharashtra, with particular emphasis on Chapadgaon, one of its prominent villages. Using Census 2011 data, the study highlights the dominance of rural population, demographic features, and spatial variations. It also examines the factors responsible for settlement patterns and discusses their developmental implications.

## Introduction

Population distribution refers to the manner in which people are dispersed over a geographical area. In India, a large proportion of the population still resides in rural regions, especially in semi-arid districts such as Ahilyanagar. Karjat Taluka represents one such area where environmental conditions and agriculture significantly influence human settlements.

An understanding of population distribution is essential for effective planning of infrastructure, resource utilization, and sustainable development. This study aims to examine the distribution pattern of population in Karjat Taluka and presents a detailed analysis of Chapadgaon village as a case study.

## Study Area

Karjat Taluka is situated in the central part of Ahilyanagar district in western Maharashtra. It spans an area of approximately 1503.61 square kilometers and comprises nearly 118–120 villages along with one census town.

The region experiences a semi-arid climate marked by low rainfall and frequent drought conditions, making agriculture the primary livelihood. The Bhima River basin plays an important role in influencing both settlement patterns and agricultural practices in the area.

## **Population Profile of Karjat Taluka**

As per Census 2011, Karjat Taluka has a total population of about 235,792. Out of this, nearly 224,133 people reside in rural areas, while only 11,659 live in urban regions.

### **Key Demographic Characteristics**

- Literacy rate: approximately 74.11%
- Sex ratio: 914 females per 1000 males
- Scheduled Castes: 14.4%
- Scheduled Tribes: 1.5%
- Rural population: more than 95%

These figures clearly indicate that the taluka is predominantly rural with limited urban development.

### **Spatial Distribution of Population**

The pattern of population distribution in Karjat Taluka is uneven and varies widely across different villages. Certain areas have a high concentration of population due to favorable conditions, while others remain sparsely populated because of limited resources and inadequate infrastructure. This variation highlights the combined impact of physical, economic, and social factors within the region.

#### **• High Population Villages**

Villages like Alsunde, Bhambore, Bhandewadi, and Baradgaon Sudrik have comparatively higher population densities. These settlements benefit from fertile agricultural land, better water availability, and improved connectivity. The presence of basic facilities and infrastructure further attracts people, leading to greater population concentration in these areas.

#### **• Medium Population Villages**

Most villages in the taluka fall within the population range of 1000 to 3000, indicating a moderate level of settlement concentration. These areas generally have access to basic amenities, although development may not be uniform. Agriculture continues to be the primary occupation, and limited irrigation and infrastructure support a stable population.

#### **• Low Population Villages**

Smaller settlements such as Anandwadi and Bargewadi have populations below 1000. These villages typically face challenges such as limited natural resources,

inadequate infrastructure, and fewer employment opportunities. Migration, particularly among the younger population seeking better prospects in urban areas, further reduces their population size.

Overall, population distribution in Karjat Taluka shows a tendency to concentrate in agriculturally productive and well-connected regions, while drought-prone and less developed areas remain thinly populated.

### **Factors Influencing Population Distribution**

The distribution of population in the taluka is determined by a mix of physical, economic, and social factors.

- **Physical Factors**

Natural conditions significantly influence settlement patterns. The semi-arid climate leads to limited and unreliable water availability, which directly impacts agriculture and habitation. Differences in soil fertility also affect where people settle, as more fertile areas attract higher population. Additionally, irregular rainfall patterns influence agricultural productivity and, consequently, population distribution.

- **Economic Factors**

Economic aspects play a major role in shaping population distribution. Agriculture serves as the main livelihood in the region, and areas with irrigation facilities tend to support larger populations. In contrast, regions lacking irrigation and economic diversification often experience out-migration due to limited job opportunities. The absence of major industrial development further encourages migration towards urban areas.

- **Social Factors**

Social elements such as the availability of education, healthcare, transport, and other basic services strongly impact settlement patterns. Villages with better amenities tend to attract and retain more population. Traditional settlement systems and community ties also influence how populations are distributed, as people prefer to live within familiar social and cultural environments.

### **Case Study: Chapadgaon Village**

Chapadgaon represents a typical rural settlement and reflects the demographic and socio-economic features of the region.

- **Population Features:** As per the 2011 Census, Chapadgaon has a total population of 3705, including 1937 males and 1768 females, distributed

across 835 households. This makes it one of the larger and more established villages in the taluka.

- **Age Composition:** Children aged 0–6 years constitute 367 individuals, or about 9.91% of the population. This indicates a relatively stable population with moderate growth.
- **Literacy Level:** The village has an overall literacy rate of 75.85%, with male literacy at 85.12% and female literacy at 65.92%. Although literacy levels are improving, a clear gender disparity still exists, pointing to the need for greater focus on female education.
- **Sex Ratio:** The sex ratio stands at 913 females per 1000 males, which is slightly below the state average. This reflects a degree of gender imbalance and associated social concerns.
- **Occupational Pattern:** Out of the total population, 1916 people are engaged in work. Among them, 952 are cultivators and 607 are agricultural labourers, indicating that agriculture is the main source of livelihood and the foundation of the village economy.

### **Population Distribution Pattern in Chapadgaon**

Chapadgaon follows a nucleated settlement pattern, where houses are closely grouped together. This type of settlement is commonly seen in rural Maharashtra. The village has a centralized residential area surrounded by agricultural land. Most inhabitants are engaged in farming and related activities, and essential infrastructure such as schools and administrative facilities are available. Due to these characteristics, Chapadgaon has a higher population density compared to smaller villages and functions as an important local center.

### **Comparative Analysis**

When compared to the overall pattern of Karjat Taluka, Chapadgaon shows both similarities and slight improvements. The village has a somewhat higher literacy rate than many neighboring villages. Its population size is moderate but relatively larger than nearby settlements. Like the rest of the taluka, its economy is primarily based on agriculture. Thus, Chapadgaon can be viewed as a representative rural settlement with relatively better development features.

### **Issues Related to Population Distribution**

Despite some positive aspects, several challenges affect population distribution in the region.

- **Unequal Distribution:** Population is heavily concentrated in fertile and

developed areas, while less productive regions remain sparsely populated and underdeveloped.

- **Migration Trends:** There is a noticeable trend of young people migrating to urban areas in search of employment and education. This results in a decline in the working-age population in rural areas and contributes to an aging demographic structure.
- **Gender Imbalance:** The low sex ratio indicates ongoing gender-related issues, reflecting underlying social and cultural factors.
- **Lack of Infrastructure:** Many villages continue to face shortages of essential infrastructure, including healthcare, education, and transportation facilities. This further contributes to uneven population distribution and limits overall regional development.

### **Suggestions for Balanced Development**

- Expansion of irrigation facilities to support agriculture
- Promotion of rural industries and employment opportunities
- Improvement in education, particularly for women
- Development of infrastructure in less populated areas
- Adoption of sustainable water resource management practices

### **Conclusion**

The population distribution in Karjat Taluka is largely rural and uneven across different villages. Larger settlements like Chapadgaon serve as important population centers due to better availability of resources and infrastructure.

The study demonstrates that natural conditions, agricultural practices, and socio-economic factors significantly influence population distribution. Therefore, balanced regional development is essential to reduce disparities and enhance the overall quality of life in the taluka.

### **References**

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3. Village-level census data

# **Impact of Canal Irrigation on Agricultural and Rural Development: A Case Study of Karjat Taluka, District Ahilyanagar (Maharashtra)**

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## **Abstract**

Canal irrigation serves as a significant catalyst for agricultural advancement and rural transformation, particularly in semi-arid regions where rainfall is inconsistent. This study explores the role of canal irrigation in fostering rural development in Karjat Taluka of Ahilyanagar District. The area is characterized by irregular rainfall patterns and limited water availability, making irrigation a critical requirement for sustainable agriculture. The research evaluates the influence of canal irrigation on crop yield, cropping patterns, income generation, and the socio-economic status of rural communities. The findings suggest that canal irrigation has substantially enhanced agricultural productivity, increased farmers' income, and improved living standards. However, issues such as inequitable water distribution, infrastructural limitations, and water losses continue to hinder its efficiency. The study highlights the importance of effective water management and sustainable irrigation strategies for long-term rural development.

**Keywords:** Canal Irrigation, Rural Transformation, Agricultural Development, Water Resource Management, Semi-Arid Region, Karjat Taluka

## **Introduction**

Agriculture continues to be the foundation of rural livelihoods in India, and irrigation plays a crucial role in ensuring stable and productive farming systems. In regions where rainfall is unpredictable and uneven, irrigation becomes indispensable for sustaining agricultural activities. Among various irrigation methods, canal irrigation has emerged as a key source of water supply for farming.

Rural development is closely linked to agricultural progress, as a large portion of the rural population depends on farming for their livelihood. Access to

reliable irrigation facilities contributes to higher crop yields, increased income, better employment opportunities, and improved living conditions.

Karjat Taluka, situated in Maharashtra, is a semi-arid region where variability in rainfall poses a major challenge to agriculture. In such conditions, canal irrigation has played an important role in reducing dependence on rainfall and supporting rural livelihoods. This study aims to assess the impact of canal irrigation on agricultural productivity and rural development in the region.

### **Literature Review**

Existing research highlights the critical role of irrigation in enhancing agricultural productivity and promoting rural development. Studies conducted across different parts of India indicate that canal irrigation contributes to increased crop yields, improved cropping intensity, and higher farm income.

Several researchers have pointed out that irrigation facilities encourage crop diversification, enabling farmers to shift from subsistence farming to commercial agriculture. In semi-arid regions, canal irrigation helps reduce the risk of crop failure and ensures more stable agricultural output.

However, earlier studies have also identified certain challenges associated with canal irrigation systems, such as inefficient water allocation, high maintenance costs, and environmental concerns including waterlogging and soil salinity. This study builds upon previous research by focusing specifically on Karjat Taluka and examining its local context.

### **Study Area Description**

Karjat Taluka is located in the central part of Ahilyanagar District and exhibits the following characteristics:

- **Climate:** Semi-arid with low and unpredictable rainfall
- **Temperature:** High during summer months
- **Soil Type:** Predominantly black cotton soil (regur)
- **Topography:** Undulating terrain
- **Economic Activities:** Agriculture and allied sectors

The principal crops cultivated in the region include jowar, bajra, wheat, sugarcane, and pulses. The introduction of canal irrigation has significantly altered agricultural practices and land use patterns.

### **Materials and Methods**

#### **Data Sources**

The study utilizes both primary and secondary data:

- **Primary Data:** Field surveys, interviews with farmers, and on-site observations
- **Secondary Data:** Government reports, irrigation department data, agricultural statistics, and academic publications

### **Methodological Approach**

- Comparative analysis between irrigated and non-irrigated areas
- Examination of changes in cropping patterns and productivity
- Evaluation of socio-economic conditions of farmers

### **Analytical Techniques**

Descriptive and analytical methods were employed to interpret the collected data. The analysis focuses on identifying trends and relationships between canal irrigation and rural development indicators.

### **Results**

#### **Agricultural Productivity**

The study reveals that canal irrigation has greatly enhanced agricultural productivity in the region. Farmers with access to canal water can irrigate their crops in a timely and sufficient manner, leading to better crop growth and higher yields. In contrast to rainfed agriculture, which depends on unpredictable rainfall, canal irrigation provides a dependable water source. Consequently, irrigated farms achieve consistently higher production levels and improved farming efficiency.

#### **Cropping Pattern Transformation**

Canal irrigation has led to significant changes in cropping patterns. Earlier, farmers mainly cultivated rainfed crops like jowar and bajra, which require less water but offer lower returns. With assured irrigation facilities, there has been a transition towards more profitable and water-intensive crops such as sugarcane and wheat. Additionally, farmers are increasingly practicing multiple cropping, which allows them to grow more than one crop annually, thereby improving land use and boosting productivity.

#### **Increase in Cultivated Area**

The availability of canal irrigation has facilitated the expansion of cultivated land. Previously unused or fallow lands, which could not be cultivated due to water scarcity, are now being utilized for agriculture. This has resulted in an increase in the overall cultivated area, contributing to higher agricultural output

and more efficient use of land resources.

### **Enhancement of Farmer Income**

Improved crop yields and the adoption of high-value crops have significantly increased farmers' income. Irrigated farming offers more reliable and higher returns compared to rain-dependent agriculture, which is often uncertain. As a result, farmers are able to enhance their economic status, invest in better inputs, and adopt improved farming technologies.

### **Indicators of Rural Development**

The benefits of canal irrigation are also evident in broader rural development. Higher income levels have led to improved housing and better living conditions. Farmers now have greater access to education and healthcare services. Moreover, the growth in agriculture has generated additional employment opportunities in related sectors such as dairy farming, transportation, and agro-industries. Overall, these developments reflect a positive transformation in the socio-economic status of the rural population.

### **Discussion**

The findings suggest that canal irrigation has significantly contributed to agricultural transformation and rural development in Karjat Taluka. The availability of water has improved crop productivity, encouraged diversification, and enhanced economic conditions.

However, the benefits of canal irrigation are not equally distributed among all farmers. Disparities in water access, inefficiencies in management, and poor infrastructure limit the overall effectiveness of the system. Addressing these issues is essential for achieving equitable and sustainable development.

### **Challenges in Canal Irrigation**

Despite its benefits, canal irrigation systems face several constraints:

- Unequal distribution of irrigation water
- Loss of water due to seepage and evaporation
- Inadequate maintenance of canal infrastructure
- Conflicts among farmers regarding water allocation
- Environmental issues such as waterlogging and soil degradation

### **Conclusion**

Canal irrigation has emerged as a key factor in enhancing agricultural productivity and promoting rural development in Karjat Taluka. It has improved crop yields, increased income levels, and contributed to better living conditions.

However, sustainable water management practices are essential to ensure long-term benefits. Proper planning, equitable distribution, and efficient maintenance of irrigation systems are necessary for achieving sustainable rural development.

### **Recommendations**

- Ensure fair and equitable distribution of canal water
- Strengthen maintenance and management of irrigation infrastructure
- Promote water-efficient irrigation techniques
- Encourage community participation in water resource management
- Implement policies for sustainable water utilization

### **References**

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# Spatial and Temporal Dynamics of Transportation Development in Ahilyanagar District

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## Abstract

Transportation is a fundamental element of regional development, shaping economic progress, accessibility, and spatial interactions. This study explores the spatial and temporal patterns of transportation in Ahilyanagar District. It focuses on the growth of transport networks over time and their geographical distribution within the district. The analysis is based on secondary data sources, including census records, government reports, and transport statistics. The study emphasizes the expansion of road and railway infrastructure, highlights regional imbalances, and evaluates the role of transportation in socio-economic development. It also outlines key issues and proposes strategies for improving transport systems.

## Introduction

Transportation serves as a vital link connecting people, goods, and services across different regions. It plays a significant role in promoting economic growth, urban development, and regional integration.

Spatio-temporal analysis helps in understanding how transport networks develop over time and how they are distributed spatially. In Ahilyanagar District, the development of transportation has been closely associated with agricultural expansion, industrial growth, and urbanization.

## Study Area

Ahilyanagar District is located in western Maharashtra and spans a large geographical area. The district comprises several talukas and experiences semi-arid climatic conditions.

- Area: approximately 17,000 sq. km
- Predominantly rural population
- Economy largely based on agriculture
- Presence of important urban centers such as Ahmednagar city

The district has a reasonably developed road and rail network that supports regional development.

### **Objectives of the Study**

- To examine the spatial distribution of transportation networks
- To analyze the temporal growth of transport infrastructure
- To assess the role of transportation in regional development
- To identify existing problems and suggest improvements

### **Methodology**

This study relies on secondary data collected from various sources:

- Census of India (different years)
- District Statistical Abstracts
- Government transport department reports
- Maps and satellite imagery

The data has been analyzed using descriptive and comparative techniques to understand spatial and temporal changes.

### **Evolution of Transportation (Temporal Analysis)**

#### **• Early Stage (Before 1990)**

Before 1990, the transportation system in Ahilyanagar District was relatively underdeveloped. Road infrastructure was limited, with a majority of rural roads being unpaved and poorly maintained. Connectivity between villages and towns was weak, restricting the movement of people and goods. Railway connectivity was also limited, with only a few routes serving the district. Due to these constraints, mobility remained low and economic activities were significantly restricted during this period.

#### **• Growth Phase (1990–2010)**

Between 1990 and 2010, the district experienced a phase of steady growth in transportation infrastructure. Government initiatives played a key role in expanding road networks and improving rural connectivity. Many village roads were upgraded, enhancing access to nearby markets and service centers. There was also a noticeable increase in the use of motor vehicles, reflecting improved economic conditions. Railway links were strengthened during this period, contributing to better regional connectivity. Overall, this phase marked a significant transition from a poorly connected region to one with improved transport facilities.

- **Modern Phase (After 2010)**

After 2010, transportation development accelerated with the construction of highways and improvement in road quality. Connectivity between rural and urban areas improved considerably, facilitating faster movement of goods and passengers. Both public and private transport services expanded, providing more travel options. In addition, logistics and transport-related activities grew rapidly, supporting trade and commerce. These modern developments have greatly enhanced accessibility and overall connectivity within the district.

### **Spatial Distribution of Transportation Networks**

- **Road Transport**

Road transport is the most dominant mode of transportation in Ahilyanagar District. National and state highways connect major towns and cities, forming the backbone of the transport network. District roads link smaller towns and rural settlements, while village roads ensure last-mile connectivity. However, the distribution of road infrastructure is uneven. The central and western parts of the district are relatively well-developed, whereas remote and interior regions still face connectivity challenges.

- **Railway Network**

Rail transport plays a crucial role in long-distance travel and the movement of goods. The district is connected by important railway routes that facilitate regional and inter-regional connectivity. Railway stations are mainly concentrated in urban centers, making them easily accessible to urban populations. However, rural and interior areas have limited access to railway services, which restricts their connectivity and economic opportunities.

- **Urban–Rural Differences**

There is a clear disparity between urban and rural areas in terms of transportation facilities. Urban centers have well-developed road networks, higher road density, and better availability of transport services. In contrast, rural areas often suffer from poor connectivity, fewer transport options, and inadequate infrastructure. These differences highlight the uneven spatial development of transportation within the district.

### **Role of Transportation in Regional Development**

- **Economic Growth**

Transportation systems play a vital role in promoting economic development by enabling the efficient movement of goods and services. Improved connectivity supports trade, reduces transportation costs, and stimulates local and regional economies.

- **Agricultural Development**

Efficient transportation allows farmers to access markets, purchase agricultural inputs, and transport their produce quickly. This helps in reducing post-harvest losses and increasing farm income.

- **Industrial Development**

Industries rely heavily on transport networks for the supply of raw materials and distribution of finished goods. Well-developed transportation infrastructure attracts industrial investment and promotes industrial growth.

- **Social Development**

Transportation also contributes to social development by improving access to education, healthcare, and employment opportunities. Better connectivity enhances the overall quality of life for people in both urban and rural areas.

### **Challenges and Issues**

- **Unequal Development**

Transportation infrastructure is unevenly distributed across the district, with developed areas receiving more attention compared to less-developed regions.

- **Inadequate Rural Connectivity**

Despite improvements, many villages still lack proper road connectivity, limiting access to essential services and markets.

- **Traffic Congestion**

The increasing number of vehicles, especially in urban areas, has led to traffic congestion, causing delays and reducing transport efficiency.

- **Maintenance Problems**

Poor maintenance of roads and transport infrastructure reduces their lifespan and efficiency, leading to higher repair costs and inconvenience.

- **Environmental Impact**

Transportation activities contribute to air and noise pollution, as well as environmental degradation. The growing number of vehicles increases carbon

emissions and negatively impacts the environment.

### **Recommendations for Improvement**

To enhance the transportation system in Ahilyanagar District, several measures can be adopted. Strengthening rural road networks is essential to improve connectivity in remote areas. Regular maintenance of roads should be ensured to sustain infrastructure quality. Expanding railway connectivity to underserved regions can improve accessibility. Promoting public transportation systems will help reduce traffic congestion and environmental impact. Encouraging eco-friendly transport options such as electric vehicles and non-motorized transport can support sustainability. Finally, implementing smart and sustainable transport planning strategies will ensure balanced and long-term development of the transportation sector

### **Conclusion**

The spatial and temporal study of transportation in Ahilyanagar District shows considerable progress over time. Despite significant improvements in infrastructure, disparities between urban and rural areas still persist.

Transportation has played a key role in promoting economic and social development. However, addressing issues such as unequal distribution and inadequate rural connectivity is essential for achieving balanced regional growth.

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3. Government of Maharashtra Transport Reports
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# **Determinants of Milk Production: A Study of Dairy Farming in Karjat Taluka, District Ahilyanagar (Maharashtra)**

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## **Abstract**

Milk production plays an essential role in sustaining the rural economy, particularly in semi-arid regions where agriculture alone is often insufficient to provide stable income. This study investigates the key factors influencing milk production in Karjat Taluka of Ahilyanagar District. The region is marked by irregular rainfall, limited water availability, and reliance on mixed farming systems. The research focuses on major determinants such as livestock breed, availability of fodder, water resources, access to veterinary services, and management practices. The findings reveal considerable variation in milk productivity across the taluka due to differences in resource access, farmer knowledge, and environmental conditions. The study emphasizes the importance of adopting scientific dairy practices, strengthening infrastructure, and enhancing institutional support to improve milk yield and ensure sustainable rural livelihoods.

## **Introduction**

Dairy farming is a vital component of the rural economy, contributing significantly to livelihood security and nutritional well-being. It provides a steady income stream for farmers and acts as a safeguard against uncertainties in agriculture, particularly in drought-prone regions. Milk and dairy products are also important for human nutrition.

In areas like Karjat Taluka, dairy farming is closely linked with agricultural activities. Crop residues serve as fodder, while livestock contributes to farm income and soil enrichment. Despite its importance, milk productivity in the region remains comparatively low when compared to national standards.

Various factors such as inferior breed quality, inadequate feeding, insufficient veterinary care, and climatic stress are responsible for reduced milk yield. Therefore, a detailed analysis of these factors is necessary to improve dairy productivity and enhance farmer income.

Karjat Taluka, located in Maharashtra, represents a typical semi-arid agricultural region where dairy farming has strong potential but also faces several challenges.

### **Study Area**

Karjat Taluka is situated in the central part of Ahilyanagar District and is characterized by the following features:

- **Climate:** Semi-arid with low and uneven rainfall
- **Temperature:** High summer temperatures
- **Soil Type:** Dominated by black cotton soil (regur)
- **Topography:** Undulating terrain
- **Economic Activities:** Agriculture and dairy farming

Major crops grown in the area include jowar, bajra, wheat, and sugarcane, which also determine the availability of fodder for livestock. Dairy farming is typically small-scale, with farmers maintaining a limited number of animals.

### **Objectives of the Study**

- To examine the key factors influencing milk production in Karjat Taluka
- To analyze the impact of environmental and socio-economic conditions
- To identify major constraints faced by dairy farmers
- To suggest measures for improving milk productivity

### **Methodology**

The study is based on a combination of primary and secondary data sources.

#### **Primary Data**

- Field surveys conducted in selected villages
- Interviews with dairy farmers
- Collection of data on milk yield, feeding systems, and livestock management

#### **Secondary Data**

- Reports from the Department of Animal Husbandry
- Data from dairy cooperatives
- Relevant research publications and official records

#### **Data Analysis**

- Comparative evaluation of milk production levels
- Identification of major influencing factors
- Descriptive analysis and interpretation

### **Factors Affecting Milk Production**

Milk production in Karjat Taluka of Ahilyanagar District is influenced by a combination of biological, environmental, and socio-economic factors. These factors collectively determine the productivity and sustainability of dairy farming in the region.

### **Breed of Livestock**

The breed of livestock is one of the most important determinants of milk yield. Indigenous breeds are well adapted to local climatic conditions, disease-resistant, and require less maintenance, but their milk production capacity is relatively low. On the other hand, crossbred and improved breeds have significantly higher milk yield potential but require better nutrition, healthcare, and management. In Karjat Taluka, a large number of farmers still depend on local breeds due to the high cost of improved animals, lack of awareness, and insufficient breeding facilities. This dependency results in lower overall milk production in the region.

### **Availability of Fodder and Feed**

Adequate and balanced nutrition is essential for maintaining livestock health and maximizing milk yield. A proper diet includes green fodder, dry fodder, and concentrate feed. However, in Karjat Taluka, the availability of green fodder is limited due to low and erratic rainfall. Farmers often depend on crop residues such as straw, which are less nutritious. Moreover, the use of balanced cattle feed and supplements is relatively low due to financial constraints and lack of awareness. These conditions lead to poor nutrition, directly affecting milk productivity.

### **Water Availability**

Water is a vital component for both livestock consumption and fodder cultivation. In semi-arid regions like Karjat Taluka, water scarcity is a major challenge. Limited irrigation facilities, frequent droughts, and overdependence on groundwater sources create an inadequate water supply. This not only affects fodder availability but also leads to stress in animals, thereby reducing milk production.

### **Veterinary Services**

Proper veterinary care is crucial for maintaining animal health and preventing diseases. In the study area, veterinary infrastructure is insufficient, and access to services is limited, especially in remote villages. Awareness about vaccination,

disease prevention, and scientific animal care practices is also low among farmers. As a result, livestock often suffer from untreated illnesses, which negatively impacts milk yield and overall productivity.

### **Management Practices**

Scientific management practices play a key role in enhancing dairy productivity. These include proper housing with adequate ventilation, timely feeding, clean drinking water, and hygienic milking conditions. However, in Karjat Taluka, many farmers continue to follow traditional methods of animal rearing. Lack of modern facilities and knowledge leads to inefficient management, which ultimately reduces milk production.

### **Socio-Economic Factors**

The economic and social conditions of farmers significantly influence dairy farming practices. Small and fragmented landholdings limit the scope for fodder cultivation. Financial constraints restrict farmers from investing in high-yielding breeds, quality feed, and improved infrastructure. Additionally, lack of education, training, and access to extension services reduces the adoption of modern dairy farming techniques, thereby affecting productivity.

### **Climatic Conditions**

Climate plays a direct and crucial role in dairy farming. High temperatures, especially during summer, cause heat stress in animals, reducing their appetite and milk production. Irregular and insufficient rainfall affects the availability of fodder crops. Frequent drought conditions further aggravate the situation, leading to a decline in livestock productivity. Thus, climatic variability remains a significant limiting factor in the region.

### **Constraints in Milk Production**

Dairy farmers in Karjat Taluka face several challenges that hinder the growth and efficiency of milk production. One of the major constraints is the shortage of green fodder, primarily due to low rainfall and limited irrigation facilities. The rising cost of cattle feed and maintenance further increases the financial burden on farmers. The continued dependence on low-yielding local breeds also contributes to reduced productivity.

In addition, inadequate veterinary infrastructure and limited access to animal healthcare services result in poor disease management. Water scarcity remains another critical issue, affecting both livestock and fodder cultivation.

Furthermore, the absence of well-organized dairy markets and proper marketing facilities limits farmers' ability to get fair prices for their produce.

Overall, these constraints highlight the need for improved infrastructure, better resource management, and adoption of scientific practices to enhance milk production and ensure sustainable dairy development in the region.

### **Discussion**

The findings indicate that milk production in Karjat Taluka is influenced by a combination of environmental, economic, and management-related factors. Although dairy farming has the potential to enhance rural income, its growth is limited by several constraints.

Improving livestock quality, ensuring adequate nutrition, and strengthening veterinary support systems can significantly increase milk production. Additionally, raising awareness about scientific dairy practices among farmers is crucial.

### **Conclusion**

Milk production in Karjat Taluka is shaped by multiple interrelated factors such as breed quality, availability of feed and water, and management practices. Overall productivity remains low due to these constraints.

Adopting improved dairy farming techniques, enhancing infrastructure, and providing institutional support can lead to a significant increase in milk yield. This, in turn, will contribute to improved farmer income and rural development.

### **Suggestions**

- Promote the use of high-yielding and crossbred livestock
- Encourage fodder cultivation and proper feed management
- Improve irrigation and water resource management
- Strengthen veterinary healthcare services
- Provide training and awareness programs for farmers
- Develop dairy cooperatives and improve market access
- Offer financial assistance and subsidies

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1. Department of Animal Husbandry, Government of Maharashtra
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4. Research studies on dairy farming and milk productivity

# **A Geographical Analysis of Population Distribution in Jamkhed Taluka, District Ahilyanagar**

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## **Abstract**

Population distribution is an essential concept in geography that explains how people are arranged spatially within a region. This study focuses on the pattern of population distribution in Jamkhed Taluka of Ahilyanagar district, Maharashtra. The analysis is based on Census 2011 data and other secondary sources. It emphasizes the dominance of rural population, demographic characteristics, and spatial variations among villages. Additionally, the study examines the physical, economic, and social factors that influence population distribution and discusses the associated challenges and their implications for regional development.

## **Introduction**

Population distribution refers to the way in which people are dispersed across a given geographical area. It is influenced by several factors such as climate, soil conditions, availability of water, economic opportunities, and infrastructure development.

In India, a significant portion of the population lives in rural areas, particularly in semi-arid regions like Ahilyanagar district. Jamkhed Taluka is a typical example where agriculture largely determines settlement patterns. Studying population distribution in such regions is important for efficient planning of resources, infrastructure development, and achieving sustainable growth.

## **Study Area**

Jamkhed Taluka is situated in the eastern part of Ahilyanagar district in Maharashtra and covers an area of about 878 square kilometers. It comprises nearly 90–100 villages and is predominantly rural in nature.

The taluka lies within a semi-arid climatic zone characterized by low and irregular rainfall, with an average annual precipitation of about 400–500 mm. Due to these conditions, the region frequently experiences drought. The terrain

is generally flat to gently undulating, and agriculture remains the primary occupation of the inhabitants.

### **Population Profile of Jamkhed Taluka**

Jamkhed Taluka exhibits a predominantly rural demographic pattern. As per the 2011 Census, the total population of the taluka is estimated to lie between 158,000 and 160,000. More than 90 percent of the population lives in rural areas, highlighting the agrarian nature of the region. The literacy rate, which ranges from 70 to 72 percent, reflects a moderate level of educational development, though further improvement is needed. The sex ratio, estimated at around 930–940 females per 1000 males, indicates a fairly balanced population structure. Scheduled Castes and Scheduled Tribes also form a significant portion of the population, adding to the social composition of the taluka. Overall, Jamkhed Taluka demonstrates a rural-oriented population with moderate literacy and relatively stable demographic characteristics.

### **Spatial Pattern of Population Distribution**

The population distribution in Jamkhed Taluka is not uniform and shows clear variations across different villages. Some areas are densely populated due to better availability of resources and infrastructure, whereas others remain sparsely inhabited due to environmental constraints and limited economic opportunities.

- **High Population Areas**

Certain villages, along with Jamkhed town—the administrative center—have higher population densities. These areas benefit from improved infrastructure, including markets, transportation facilities, and access to basic services. As a result, they act as focal points for economic and social activities, attracting more residents.

- **Medium Population Areas**

Most villages fall within the population range of 1000 to 3000, representing a moderate concentration of population. These settlements generally have basic agricultural resources and limited infrastructure, which help sustain a stable population.

- **Low Population Areas**

Villages with populations below 1000 are typically located in less developed regions of the taluka. These areas often experience water shortages, limited employment opportunities, and inadequate infrastructure. Migration to urban

areas further contributes to their low population levels.

In general, population tends to cluster in areas with better resources and facilities, while less favorable regions remain sparsely populated.

### **Determinants of Population Distribution**

The distribution of population in Jamkhed Taluka is influenced by a combination of physical, economic, and social factors.

- **Physical Factors**

Natural conditions significantly affect settlement patterns. The semi-arid climate, marked by low and irregular rainfall, limits water availability and agricultural productivity. Differences in soil fertility also play a role, as more fertile areas tend to attract greater population compared to less productive regions.

- **Economic Factors**

Economic conditions strongly influence population distribution. Agriculture is the main occupation in the taluka, and areas with irrigation facilities support higher population densities. Conversely, the lack of industrial development restricts employment opportunities, leading to migration towards urban centers.

- **Social Factors**

Social aspects such as access to education, healthcare, transport, and other essential services influence where people choose to live. Villages with better facilities tend to attract and retain more population. Traditional settlement systems and strong community ties also contribute to population clustering.

### **Settlement Pattern in Jamkhed Taluka**

The most common settlement pattern in Jamkhed Taluka is nucleated, where houses are closely grouped together within a compact area. This pattern is typical of rural Maharashtra and reflects both environmental and social influences. Villages usually have a central habitation zone surrounded by agricultural fields. This arrangement encourages close social interaction and efficient use of available resources. In some parts of the taluka, dispersed settlements are also found, especially in areas where farmland is scattered.

### **Population Density**

Population density in the taluka varies depending on the availability of natural resources and economic opportunities. High-density areas are generally found near Jamkhed town and in irrigated regions where agricultural productivity is

higher. Moderate-density areas include villages with average farming conditions and basic infrastructure. Low-density areas are mainly located in drought-prone and remote regions, where limited resources and poor accessibility restrict population growth. These variations highlight the influence of both environmental and economic factors.

### **Migration and Its Effects**

Migration is an important factor shaping the demographic structure of Jamkhed Taluka.

- **Rural–Urban Migration:** A considerable number of people migrate to nearby cities such as Ahmednagar, Pune, and Mumbai in search of better job opportunities, education, and improved living standards.
- **Seasonal Migration:** Seasonal migration is also common, particularly among agricultural laborers who temporarily move during the off-season due to lack of local employment.
- **Impact of Migration:** Migration leads to several changes in rural areas, including a reduction in the active workforce, an increase in the elderly population, and alterations in family structures. At the same time, remittances sent by migrants contribute to the economic well-being of rural households.

### **Issues Related to Population Distribution**

Despite certain improvements, several challenges continue to affect population distribution in the taluka.

- **Unequal Distribution:** Population is unevenly distributed, with higher concentration in favorable areas, leading to regional disparities.
- **Water Scarcity:** Frequent droughts and limited water resources restrict both agricultural activities and population growth in many parts of the taluka.
- **Inadequate Infrastructure:** Many villages lack essential facilities such as healthcare, education, and transportation, which limits their development.
- **Limited Employment Opportunities:** The lack of non-agricultural employment opportunities forces many people, especially the younger generation, to migrate to urban areas.

### **Measures for Balanced Development**

For achieving balanced development in Jamkhed Taluka, several steps are necessary. Expanding irrigation facilities can enhance agricultural productivity and support population growth. Promoting small-scale and agro-based

industries can generate employment opportunities within rural areas. Improving education and healthcare infrastructure will raise living standards and reduce migration. Better road connectivity and transportation systems can improve accessibility of remote regions. Water conservation measures such as rainwater harvesting and watershed development are crucial in this drought-prone area. Finally, effective implementation of government development schemes is essential for ensuring sustainable and inclusive regional growth.

### **Conclusion**

Population distribution in Jamkhed Taluka is largely rural and shows significant spatial variation. Areas with better irrigation, infrastructure, and economic opportunities tend to attract higher population, whereas drought-prone regions remain less populated.

The study reveals that physical, economic, and social factors collectively shape the distribution of population in the taluka. Therefore, achieving balanced regional development through improved infrastructure and resource management is essential for enhancing the quality of life of the population.

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# **A Geographical Study of Population Distribution in Karmala Taluka, District Solapur**

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## **Abstract**

Population distribution is a significant concept in geography that helps explain how people are spatially arranged within a region. The present study analyzes the pattern of population distribution in Karmala Taluka of Solapur district, Maharashtra. It is based on Census 2011 data and other secondary sources. The paper emphasizes the dominance of rural population, key demographic features, and spatial variations among villages. It also examines the influence of physical, economic, and social factors on population distribution and highlights the major challenges along with their developmental implications.

## **Introduction**

Population distribution refers to the manner in which people are spread across a particular geographical area. It is shaped by both natural factors such as climate, soil, and water availability, as well as socio-economic factors including employment opportunities, infrastructure, and accessibility.

In India, a large portion of the population lives in rural areas, especially in semi-arid regions like Solapur district. Karmala Taluka is one such region where agriculture plays a central role in determining settlement patterns. Studying population distribution in such areas is essential for effective planning of resources, infrastructure development, and balanced regional growth.

## **Study Area**

Karmala Taluka is situated in the northern part of Solapur district in Maharashtra. It covers an area of approximately 1609.7 square kilometers and comprises around 120–123 villages along with one urban center, Karmala town. The region falls under a semi-arid climatic zone characterized by low and uncertain rainfall, making it prone to drought conditions. Agriculture is largely dependent on the monsoon due to limited irrigation facilities. The terrain is mostly plain with some undulating features, and agriculture is the primary

occupation of the population.

### **Population Profile of Karmala Taluka**

Karmala Taluka is largely rural in its demographic composition. As per the 2011 Census, the taluka has a population of about 254,489. Nearly 90.9% of the people live in rural areas, while only around 9.1% reside in urban settlements. The literacy rate stands at approximately 75.52%, reflecting a moderate level of educational attainment. The sex ratio, at 918 females per 1000 males, suggests a fairly balanced population, though some gender disparity is still evident. Scheduled Castes make up about 13.8% of the population, while Scheduled Tribes account for around 1.7%, indicating a diverse social structure. Overall, the taluka is characterized by a rural-dominated population with moderate literacy and stable demographic features.

### **Spatial Pattern of Population Distribution**

Population distribution in Karmala Taluka is uneven and differs widely across villages. Some areas have higher population density due to better infrastructure and resource availability, while others remain sparsely populated because of environmental and economic constraints.

- **High Population Areas**

Karmala town, the administrative center, along with nearby villages, has a relatively dense population. These areas have better facilities such as markets, transport networks, and administrative services, making them important centers of economic and social activities and attracting more people.

- **Medium Population Villages**

A large number of villages fall within the population range of 1000 to 3000, indicating moderate population concentration. These villages generally possess basic agricultural resources and limited infrastructure, which help maintain a stable population.

- **Low Population Villages**

Some villages have populations below 1000 and are mainly located in less developed areas. These regions often face issues such as water scarcity, poor connectivity, and limited job opportunities. Migration further reduces their population, and such areas are typically more vulnerable to drought.

Overall, population tends to cluster in regions with better resources and economic prospects, while less favorable areas remain thinly populated.

## **Factors Influencing Population Distribution**

The distribution of population in Karmala Taluka is shaped by physical, economic, and social factors.

- **Physical Factors**

Natural conditions significantly influence settlement patterns. The semi-arid climate, with low and irregular rainfall, results in limited water availability. Differences in soil fertility across the taluka also affect population distribution, as fertile areas tend to attract more people.

- **Economic Factors**

Economic aspects play an important role in determining population distribution. Agriculture is the primary occupation, and areas with irrigation facilities support higher population densities. However, the absence of significant industrial development restricts employment opportunities, leading to migration towards urban centers.

- **Social Factors**

Social factors such as access to education, healthcare, and transport facilities also influence settlement patterns. Villages with better amenities attract more population. Additionally, traditional settlement systems and strong community bonds contribute to clustered population distribution.

## **Settlement Pattern in Karmala Taluka**

The prevalent settlement pattern in Karmala Taluka is nucleated, where houses are closely clustered within villages. This pattern is typical of rural Maharashtra and is influenced by both environmental and social factors. Villages usually have a compact structure with agricultural land surrounding the central habitation area. This arrangement encourages social interaction and efficient use of local resources. In some areas, dispersed settlements are also found, particularly where agricultural land is scattered.

## **Population Density**

Population density in the taluka varies according to resource availability and economic opportunities. High-density areas are generally located near Karmala town and in irrigated regions where agricultural productivity is higher. Moderate-density areas include villages with average farming conditions and basic infrastructure. Low-density areas are found in drought-prone and remote regions where limited resources and poor accessibility restrict population growth. These variations highlight the influence of both environmental and

economic factors.

### **Migration and Its Effects**

Migration plays a significant role in shaping the demographic structure of Karmala Taluka.

- **Rural–Urban Migration:** Many people migrate to nearby cities such as Solapur, Pune, and Mumbai in search of better employment, education, and living conditions.
- **Seasonal Migration:** Seasonal migration is also common, especially among agricultural labourers who move temporarily during the off-season due to lack of work.
- **Impact of Migration:** Migration results in several socio-economic changes, including a decline in the active workforce in rural areas, an increase in the elderly population, and changes in family structures. At the same time, remittances sent by migrants contribute to the rural economy and support household incomes.

### **Issues Related to Population Distribution**

Despite certain improvements, several problems continue to affect population distribution in the taluka.

- **Unequal Distribution:** Population is unevenly distributed, with higher concentration in favorable areas, leading to regional disparities.
- **Water Scarcity:** Frequent droughts and limited water resources restrict both agricultural development and population growth in many areas.
- **Lack of Infrastructure:** Several villages lack basic facilities such as healthcare, education, and transportation, which hampers their development.
- **Limited Employment Opportunities:** The shortage of non-agricultural employment opportunities compels many people, particularly the younger population, to migrate to urban areas in search of better livelihoods.

### **Suggestions for Balanced Development**

- Expansion of irrigation facilities to enhance agricultural productivity
- Promotion of small-scale industries to generate employment
- Improvement of educational and healthcare infrastructure
- Development of better road connectivity and transport systems
- Adoption of water conservation practices such as watershed management
- Effective implementation of government development programs

## **Conclusion**

Population distribution in Karmala Taluka is predominantly rural and uneven across different areas. Regions with better infrastructure, irrigation facilities, and economic opportunities attract higher population, whereas drought-prone areas remain sparsely populated.

The study highlights that physical, economic, and social factors collectively influence population distribution. Therefore, achieving balanced regional development through improved infrastructure and efficient resource management is essential for enhancing the overall quality of life in the taluka.

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# Impact of Climate Change on Cropping Patterns in Maharashtra: A Geographical Perspective

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## Abstract

Climate change has become a major global concern, particularly for agriculture-dependent regions. In Maharashtra, where farming largely relies on monsoon rainfall, changing climatic conditions have significantly altered cropping patterns. This study explores how variations in rainfall, rising temperatures, and extreme weather events influence agricultural practices across different parts of the state. It also examines the effects on crop productivity and farmers' livelihoods, while suggesting suitable adaptation measures for achieving sustainable agricultural growth.

## Introduction

Climate change refers to long-term shifts in climatic conditions such as temperature, precipitation, and weather patterns. These changes have a direct impact on agriculture, especially in developing countries like India where a large population depends on farming.

In Maharashtra, agriculture is predominantly rain-fed and highly sensitive to climatic variability. Over recent decades, irregular rainfall, rising temperatures, and increased frequency of droughts have led to noticeable changes in cropping patterns. Understanding these changes is essential for maintaining food security and promoting sustainable rural development.

## Study Area

Maharashtra is situated in western India and is characterized by diverse climatic and agro-ecological conditions. The state is divided into major regions such as Konkan, Western Maharashtra, Marathwada, and Vidarbha.

- Annual rainfall ranges from about 300 mm in rain-shadow areas to more than 3000 mm in the Konkan region
- A significant portion of the state falls under semi-arid conditions
- Agriculture is the dominant occupation in rural areas

Major crops cultivated include jowar, bajra, rice, wheat, cotton, sugarcane, and pulses.

### **Objectives of the Study**

- To evaluate the impact of climate change on agriculture in Maharashtra
- To study the transformation in cropping patterns across regions
- To identify key challenges faced by farmers
- To propose strategies for sustainable agricultural development

### **Methodology**

The study is based on secondary data collected from various sources:

- Census of India 2011
- Reports of the India Meteorological Department (IMD)
- Agricultural statistics of Maharashtra
- Government publications and research papers

The data has been analyzed using descriptive and comparative approaches.

### **Trends of Climate Change in Maharashtra**

Maharashtra has been undergoing significant climatic changes over recent decades, which have had a strong impact on agriculture and rural livelihoods. One of the key trends observed is the steady rise in average temperatures. Higher temperatures increase evaporation rates and reduce soil moisture, which negatively affects crop growth and ultimately lowers agricultural productivity. Another major change is the growing unpredictability of rainfall patterns. The monsoon has become irregular, with delayed onset, uneven distribution, and occasional heavy downpours. This variability disturbs sowing schedules and leads to fluctuations in crop yields.

The frequency of droughts has also increased, particularly in regions such as Marathwada and parts of western Maharashtra. These areas often face severe water shortages, affecting both farming activities and drinking water supply. Moreover, extreme weather events like floods, heatwaves, and unseasonal rainfall have become more common, causing significant crop damage and economic losses.

### **Cropping Pattern in Maharashtra**

#### **• Traditional Cropping System**

In earlier times, cropping patterns in Maharashtra were closely linked to climatic and environmental conditions. High rainfall regions like the Konkan

were mainly associated with rice cultivation. Semi-arid regions focused on drought-resistant crops such as jowar and bajra. Cotton was predominantly grown in black soil areas, while sugarcane was cultivated in irrigated regions with sufficient water availability. This system reflected a natural adaptation to local agro-climatic conditions.

- **Recent Changes in Cropping Trends**

In recent years, climate change has led to noticeable shifts in cropping practices. Farmers are increasingly adopting drought-tolerant crops to cope with water scarcity. There has been a reduction in the cultivation of water-intensive crops in dry regions. At the same time, commercial crops like cotton and soybean have expanded due to their higher market value. Horticulture has also gained importance, with increased cultivation of fruits and vegetables driven by better economic returns and adaptability to changing climate conditions.

### **Effects of Climate Change on Cropping Patterns**

Climate change has significantly influenced agricultural practices and cropping systems in Maharashtra. One important effect is the increasing adoption of drought-resistant crops such as jowar, bajra, and pulses, which require less water and are better suited to dry conditions. On the other hand, water-intensive crops like sugarcane and rice are gradually declining in drought-prone areas due to limited water availability.

Irregular rainfall has disrupted traditional cropping seasons, affected sowing and harvested cycles and reducing productivity. At the same time, farmers are shifting towards commercial crops such as cotton and soybean to increase their income, despite the risks associated with climatic uncertainty. Additionally, there has been a notable expansion in horticulture, with crops like pomegranate, grapes, and mango becoming increasingly popular due to their profitability and adaptability.

### **Regional Variations in Cropping Pattern Changes**

The impact of climate change on cropping patterns varies across different regions of Maharashtra.

- **Marathwada:** Marathwada frequently experiences drought conditions, leading farmers to shift towards drought-resistant crops and reduce the cultivation of water-intensive crops like sugarcane.
- **Vidarbha:** Vidarbha has witnessed growth in cotton and soybean cultivation. However, the region remains highly sensitive to climatic variability, which affects crop production and farmer income.

- **Western Maharashtra:** In western Maharashtra, sugarcane continues to be a dominant crop due to better irrigation facilities. However, this has increased pressure on water resources, raising sustainability concerns.
- **Konkan Region:** The Konkan region continues to depend mainly on rice cultivation due to high rainfall. At the same time, diversification into horticulture is increasing, with a growing focus on fruit crops.

### **Challenges Faced by Farmers**

Farmers in Maharashtra face several difficulties due to changing climatic conditions. Uncertain rainfall disrupts crop planning and reduces yields. Water scarcity, caused by declining groundwater levels and insufficient irrigation, further limits agricultural productivity. Soil degradation is another major concern, resulting from excessive use of chemical fertilizers and environmental stress, which reduces soil fertility over time.

Financial instability is a serious issue, as crop failures often lead to economic losses and increased indebtedness among farmers. Moreover, many farmers lack adequate awareness and knowledge about climate-resilient farming practices, making it difficult for them to adapt effectively to changing conditions.

### **Adaptation Measures**

To cope with the challenges of climate change, several adaptation strategies are being adopted in Maharashtra. The promotion of climate-resilient crops, including drought-tolerant and short-duration varieties, helps farmers manage water scarcity and uncertain weather conditions. Efficient water management practices such as drip irrigation, sprinkler systems, rainwater harvesting, and watershed development play a vital role in conserving water resources.

Crop diversification is encouraged to reduce the risks associated with dependence on a single crop. Technological advancements, including weather forecasting services, modern farming techniques, and precision agriculture, assist farmers in making better decisions. In addition, government support through crop insurance schemes, subsidies for irrigation systems, and training programs is crucial for improving resilience and ensuring sustainable agricultural development.

### **Conclusion**

Climate change has brought significant changes in cropping patterns in Maharashtra. Variations in rainfall, rising temperatures, and frequent extreme weather events have compelled farmers to modify their agricultural practices.

The transition towards drought-resistant crops, diversification, and horticulture

indicates adaptive responses by farmers. However, issues like water scarcity and economic risks continue to pose challenges.

For sustainable agricultural development, it is essential to adopt efficient water management practices, modern technologies, and supportive government policies to ensure long-term food security and farmer welfare.

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# **A Study of Agricultural Productivity and Cropping Patterns in Karjat Taluka, District Ahilyanagar**

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## **Abstract**

Agriculture forms the backbone of the rural economy in India, especially in semi-arid regions where it remains the main source of livelihood. The present study focuses on examining the levels of agricultural productivity and the nature of cropping patterns in Karjat Taluka of Ahilyanagar district, Maharashtra. The analysis is based on secondary data obtained from Census 2011, government agricultural reports, and district-level statistics. It explores how factors such as climate, soil conditions, irrigation facilities, and socio-economic conditions influence crop distribution and productivity. The study also highlights key issues like irregular rainfall, water shortages, and declining soil health, and suggests suitable measures to achieve sustainable agricultural development.

## **Introduction**

Agricultural productivity refers to the quantity of agricultural output produced per unit area of land, whereas cropping pattern indicates the spatial and temporal arrangement of different crops grown in a region. Both concepts are crucial for understanding agricultural efficiency and rural development.

Karjat Taluka, situated in Ahilyanagar district of Maharashtra, is largely rural and dependent on agriculture. Due to its semi-arid environmental conditions, agricultural production in this region often shows variability. An analysis of cropping patterns and productivity is therefore essential to enhance food security, improve farmers' income, and promote sustainable land use practices.

## **Study Area**

Karjat Taluka is located in the central part of Ahilyanagar district in western Maharashtra and extends over an area of nearly 1500 square kilometers. The taluka includes more than 100 villages and has a predominantly agrarian landscape.

The region experiences a semi-arid climate with an average annual rainfall

ranging between 400 and 600 mm. Rainfall is uneven and unpredictable, making agriculture largely dependent on monsoon precipitation. The dominant soil type is black cotton soil (regur), which is suitable for crops such as cotton, jowar, and pulses.

### **Objectives of the Study**

- To evaluate agricultural productivity in Karjat Taluka
- To analyze the cropping pattern and identify major crops
- To examine the factors influencing agricultural productivity
- To recommend measures for sustainable agricultural development

### **Methodology**

This study relies on secondary data collected from various sources, including:

- Census of India 2011
- District Statistical Abstract of Ahilyanagar
- Reports from the agricultural department
- Research papers and government publications

The data has been analyzed using descriptive and basic statistical methods.

### **Cropping Pattern in Karjat Taluka**

Karjat Taluka shows a cropping pattern that is mainly shaped by rainfall availability, soil characteristics, and irrigation facilities. Agriculture in the region is seasonal in nature and is broadly divided into two main cropping seasons: Kharif and Rabi.

#### **• Kharif Season (Monsoon Crops)**

The Kharif season begins with the onset of the monsoon, usually from June to September. During this period, major crops such as jowar (sorghum), bajra (pearl millet), cotton, tur (pigeon pea), and groundnut are cultivated. These crops depend largely on rainfall, and their yield is closely influenced by the timing, intensity, and distribution of monsoon rains. Due to limited irrigation facilities, farmers primarily rely on natural rainfall for crop production.

#### **• Rabi Season (Winter Crops)**

The Rabi season extends from October to February and depends mainly on residual soil moisture along with available irrigation sources. Important crops grown during this season include wheat, gram (chickpea), and rabi jowar. Compared to Kharif crops, Rabi crops require more stable moisture conditions, which are supported by stored soil moisture and limited irrigation through wells and borewells.

### **Features of Cropping Pattern**

The cropping pattern in the taluka is dominated by food grains and pulses, indicating the subsistence nature of agriculture. The cultivation of commercial crops remains limited due to water scarcity. Farmers commonly adopt mixed cropping and intercropping practices to reduce risk and utilize resources efficiently. However, cropping intensity is relatively low, mainly because of insufficient and uncertain water supply.

### **Agricultural Productivity in Karjat Taluka**

Agricultural productivity in Karjat Taluka is comparatively low when compared to well-irrigated regions of Maharashtra. This is largely due to environmental constraints and limited access to modern agricultural inputs and infrastructure.

### **Determinants of Productivity**

Rainfall variability plays a crucial role in determining productivity levels. Irregular and uneven rainfall often results in low yields and occasional crop failures. Soil conditions are also important; although black cotton soils are naturally fertile, they require proper management to maintain productivity over time.

Irrigation facilities are limited, with most farmers depending on wells and borewells. The absence of assured irrigation restricts the cultivation of water-intensive crops and reduces overall output. Furthermore, the adoption of modern agricultural technologies is relatively low. Limited use of improved seeds, machinery, and scientific farming practices contributes to reduced productivity.

### **Major Crops and Their Productivity**

Crop productivity in Karjat Taluka varies depending on climatic conditions and irrigation availability. Jowar, cultivated in both Kharif and Rabi seasons, is a staple crop with moderate productivity. Bajra, grown during the Kharif season, is drought-resistant and yields low to moderate output. Wheat, a Rabi crop, provides moderate yields but requires irrigation support. Gram is another significant Rabi crop with moderate productivity and is important for pulse production.

Cotton, cultivated during the Kharif season, is an important cash crop, but its productivity is highly variable due to dependence on rainfall. Groundnut, an oilseed crop, also shows moderate productivity. Overall, crop yields are closely linked to rainfall patterns and the availability of irrigation facilities.

## **Factors Influencing Cropping Pattern**

The cropping pattern in Karjat Taluka is influenced by a combination of physical, economic, and social factors.

- **Physical Factors**

Climatic conditions, especially rainfall distribution, strongly affect crop selection and productivity. Soil type and fertility determine the suitability of different crops, while limited water resources restrict agricultural options in many areas.

- **Economic Factors**

Economic conditions such as market demand and price fluctuations influence farmers' cropping decisions. The cost of inputs like seeds, fertilizers, and pesticides also affects crop selection. Access to credit and financial support plays a key role in enabling farmers to adopt better agricultural practices.

- **Social Factors**

Social aspects such as farmers' education and awareness influence the adoption of improved techniques. The size of landholdings also impacts cropping decisions, as small farmers tend to focus on subsistence farming. Traditional agricultural practices continue to play an important role in shaping farming systems in the region.

## **Problems and Challenges**

Agriculture in Karjat Taluka faces several constraints that affect productivity and sustainability. Water scarcity is a major issue due to frequent drought conditions and inadequate irrigation facilities. Soil degradation, caused by excessive use of chemical fertilizers and improper land management, leads to declining soil fertility.

Low productivity is another significant problem, mainly due to reliance on traditional farming methods and limited mechanization. Market-related issues, such as price fluctuations, discourage farmers from investing in certain crops. In addition, climate change has intensified these challenges by altering rainfall and temperature patterns, which negatively impact agricultural activities.

## **Suggestions for Improvement**

Several measures can be adopted to improve agricultural productivity and sustainability in Karjat Taluka. Expanding irrigation through modern techniques such as drip and sprinkler systems can help ensure efficient use of water. The

adoption of improved farming practices and modern technologies can enhance crop yields.

Diversification towards high-value and cash crops can increase farmers' income, while promoting soil conservation and organic farming can improve long-term soil health. Government support through subsidies, training programs, and awareness initiatives is essential for encouraging sustainable agriculture. Moreover, strengthening storage, transportation, and marketing infrastructure can help farmers secure better prices and reduce post-harvest losses.

### **Conclusion**

Agriculture in Karjat Taluka is largely dependent on monsoon rainfall and is characterized by traditional cropping systems and relatively low productivity. The predominance of food grains and pulses reflects a subsistence-oriented agricultural system.

The study reveals that natural conditions, irrigation facilities, and socio-economic factors play a crucial role in shaping cropping patterns and productivity levels. For improving agricultural performance and ensuring long-term sustainability, it is essential to adopt modern technologies, enhance water management, and encourage crop diversification.

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# Land Use and Land Cover Changes in Karjat Taluka, District Ahilyanagar (Maharashtra)

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## Abstract

Land Use and Land Cover (LULC) dynamics serve as important indicators of environmental change and human influence on natural systems. This study investigates the spatial and temporal variations in land use and land cover patterns in Karjat Taluka of Ahilyanagar District (previously known as Ahmednagar). The region, which experiences semi-arid climatic conditions and recurrent droughts, has witnessed considerable transformation in land utilization over recent decades. By using secondary datasets, satellite image interpretation, and existing regional studies, the research evaluates changes across major land categories such as agricultural land, fallow land, forest cover, built-up areas, and water bodies. The findings reveal a consistent rise in agricultural and built-up areas, largely at the expense of fallow lands and natural vegetation. The study underscores the influence of irrigation expansion, demographic pressure, and climate variability in shaping land use trends, and highlights the importance of sustainable land management strategies for long-term ecological stability.

## Introduction

Land use and land cover represent dynamic aspects of the Earth's surface that are influenced by both natural processes and human interventions. Land cover refers to the physical features present on the surface, including vegetation, soil, and water bodies, whereas land use describes how humans utilize these resources for activities such as agriculture, settlement, and industry.

Karjat Taluka, situated in Maharashtra, falls within a drought-prone region where land resources are vital for sustaining livelihoods. Over time, shifts in rainfall patterns, advancements in agricultural practices, and socio-economic development have significantly altered land utilization patterns. Studying these changes is essential for effective planning and sustainable resource management.

## **Study Area**

Karjat Taluka is located in the central part of Ahilyanagar District. The area exhibits the following characteristics:

- Climate: Semi-arid with irregular and low rainfall
- Soil: Dominated by black cotton soil (regur)
- Relief: Undulating terrain with plateau-like features
- Economy: Predominantly agricultural, with major crops including jowar, bajra, sugarcane, and pulses

Water scarcity remains a critical issue, significantly affecting agricultural practices and land use patterns.

## **Objectives of the Study**

- To examine the current land use and land cover distribution in Karjat Taluka
- To analyze temporal variations in LULC patterns
- To identify the key factors driving land use changes
- To evaluate the environmental consequences of these changes

## **Methodology**

The study relies on secondary data and geospatial analysis techniques. The following sources and methods were used:

Satellite imagery from Landsat and Sentinel missions

Topographical maps and official government records

Review of relevant research studies and reports

Land use classification was carried out using standard categories such as agricultural land, forest area, built-up land, wasteland, and water bodies. Change detection techniques were applied to assess variations over time.

## **Land Use and Land Cover Categories**

The land use and land cover pattern of Karjat Taluka is largely dominated by agriculture, along with other categories shaped by natural conditions and human activities. Agricultural land occupies nearly 70–75 percent of the total area, making it the most significant land use. Both rainfed and irrigated farming are practiced, and the expansion of irrigation facilities has contributed to an increase in cultivated land over time.

Fallow land, which is temporarily left uncultivated to restore soil fertility, and wasteland, consisting of degraded and unproductive areas, were more extensive in the past. However, their extent has reduced gradually as more land is being converted into agricultural use to meet growing demands.

Forest land in the taluka is limited, covering only about 3–5 percent of the area. It mainly includes scrub vegetation and scattered forest patches. Human activities such as deforestation, grazing, and land conversion have led to the degradation and fragmentation of these forest areas.

Built-up areas, including residential settlements, roads, and other infrastructure, have expanded considerably in recent years. This growth is mainly due to increasing population, rural development, and improved connectivity.

Water bodies such as rivers, tanks, and reservoirs are mostly seasonal and dependent on rainfall. However, the construction of water conservation structures like check dams and percolation tanks has helped improve water availability in certain parts of the taluka.

### **Temporal Changes in Land Use and Land Cover (LULC)**

Over the years, significant changes have been observed in the land use and land cover of Karjat Taluka. One major trend is the expansion of agricultural land. This has been driven by increased use of borewells for irrigation, supportive government policies, and the conversion of wasteland into cultivable land.

There has also been a decline in fallow land as farmers intensify cultivation to increase agricultural output. While this enhances productivity, it may negatively impact soil health if not managed properly.

Another noticeable change is the increase in built-up areas. Population growth, expansion of rural settlements, and development of transport and infrastructure have contributed to this trend, indicating gradual rural urbanization.

On the other hand, natural vegetation has decreased due to factors such as agricultural expansion, fuelwood collection, and overgrazing. Water bodies show both seasonal and long-term variations. Although rainfall variability affects their availability, the development of artificial water storage structures has improved water availability in some areas.

### **Factors Influencing LULC Changes**

Land use and land cover changes in the taluka are influenced by both natural and human factors. Natural factors include irregular rainfall, frequent droughts, soil characteristics, and climate variability, all of which affect land productivity and usage patterns.

Human factors are equally significant. Population growth increases pressure on land resources, leading to expansion of agriculture and settlements. Intensification of farming practices, adoption of modern technologies, and

implementation of government policies related to land and water management have further altered land use patterns.

### **Environmental Impacts**

Changes in land use and land cover have both beneficial and adverse environmental effects. On the positive side, the expansion of agricultural land has improved productivity and ensured better utilization of available resources, thereby supporting rural livelihoods.

However, these changes have also created environmental challenges. Excessive extraction of groundwater for irrigation has led to declining water levels. Continuous cultivation and overuse of chemical fertilizers have resulted in soil degradation and reduced fertility. Additionally, the loss of natural vegetation has contributed to a decline in biodiversity and increased vulnerability to drought conditions.

### **Role of GIS and Remote Sensing**

GIS and remote sensing technologies are highly effective tools for studying and monitoring land use and land cover changes. They enable accurate mapping of land use patterns and help in tracking environmental changes over time. These technologies also support better planning and decision-making by providing reliable spatial data, which can be used to promote sustainable land and resource management.

Satellite data provides reliable and up-to-date information for sustainable land management.

### **Discussion**

The findings indicate that Karjat Taluka has experienced a significant shift from natural land cover to human-dominated land use. While agriculture continues to be the primary economic activity, increasing pressure on land and water resources presents serious environmental challenges. The reduction in forest cover and excessive groundwater usage are particularly concerning issues that require immediate intervention.

### **Conclusion**

The study of land use and land cover changes in Karjat Taluka highlights the combined impact of natural and anthropogenic factors. Although the expansion of agriculture and built-up areas has contributed to economic development, it has also resulted in environmental degradation. Sustainable land management practices, efficient water utilization, and afforestation efforts are crucial for

maintaining ecological balance.

### **Suggestions**

- Implementation of watershed development programs
- Promotion of sustainable agricultural techniques
- Enhancement of forest cover through afforestation
- Regulation of groundwater extraction
- Adoption of GIS-based planning for land resource management

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# Agro-Tourism as a Sustainable Development Strategy in Ahilyanagar

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## Abstract

Agro-tourism has recently gained recognition as an effective approach for fostering sustainable rural development by linking agricultural practices with tourism activities. This study explores the role of agro-tourism as a development strategy in Ahilyanagar, a region characterized by a predominantly agrarian economy and semi-arid climate. Agro-tourism offers opportunities for diversifying income sources, generating employment, and conserving rural traditions. The research evaluates its contribution to economic advancement, environmental conservation, and social progress in rural areas. The findings indicate that agro-tourism plays a vital role in enhancing farmers' livelihoods and strengthening the rural economy. However, its growth is constrained by inadequate infrastructure, limited awareness, and insufficient planning. The study highlights the importance of policy intervention, skill development, and sustainable practices for promoting agro-tourism.

**Keywords:** Agro-Tourism, Sustainable Development, Rural Economy, Agriculture, Ahilyanagar

## Introduction

Agriculture forms the foundation of rural economies in countries such as India, where a large segment of the population depends on farming for their livelihood. However, challenges like declining agricultural returns, climate variability, and limited employment opportunities have created economic stress in rural areas. In this scenario, agro-tourism has emerged as a promising alternative for ensuring sustainable development.

Agro-tourism refers to tourism activities conducted in rural or farm-based environments, where visitors can experience agricultural practices, rural lifestyles, and traditional customs. It establishes a connection between agriculture and tourism, creating additional income opportunities for farmers while offering recreational and educational experiences for visitors.

In districts like Ahilyanagar, where agriculture dominates the economy, agro-tourism holds significant potential to improve livelihoods and promote sustainable growth.

### **Study Area**

Ahilyanagar is situated in the western region of Maharashtra and is known for its diverse agricultural activities. The district experiences semi-arid climatic conditions marked by low and irregular rainfall.

### **Key Characteristics of the Study Area**

- **Climate:** Semi-arid with frequent drought occurrences
  - **Soil Type:** Predominantly black cotton soil
  - **Economic Base:** Agriculture and allied sectors
  - **Major Crops:** Sugarcane, jowar, bajra, wheat, and horticultural crops
- The presence of traditional farming practices, rural heritage, and natural landscapes makes the region suitable for agro-tourism development.

### **Objectives of the Study**

- To understand the concept and significance of agro-tourism
- To evaluate its role in promoting sustainable rural development
- To assess its economic, social, and environmental impacts
- To identify challenges and suggest suitable measures

### **Methodology**

The study is based on secondary data and descriptive analysis.

### **Data Sources**

- Academic journals and research papers
- Government reports and tourism statistics
- Agricultural data and online resources

### **Analytical Approach**

A descriptive analytical method is used to examine the role and impact of agro-tourism on rural development.

### **Concept of Agro-Tourism**

Agro-tourism refers to a type of rural tourism in which visitors experience and participate in agricultural and village life. It includes activities such as visiting farms, taking part in harvesting, playing traditional rural games, enjoying local food, and experiencing cultural events. This form of tourism allows urban

people to reconnect with nature and gain a deeper understanding of farming practices and rural lifestyles.

At the same time, agro-tourism encourages sustainable tourism by utilizing existing rural resources in an environmentally friendly manner. It creates a strong connection between agriculture and tourism, resulting in mutual benefits such as economic growth in rural areas and preservation of cultural traditions.

### **Role of Agro-Tourism in Sustainable Development**

Agro-tourism contributes significantly to sustainable development by supporting economic, social, environmental, and agricultural growth.

#### **Economic Development**

Agro-tourism provides farmers with an additional source of income apart from agriculture. It promotes the development of small-scale rural businesses and strengthens local markets. This alternative source of livelihood is especially useful during periods when agricultural income is low.

#### **Employment Generation**

It creates various employment opportunities in rural areas. Direct jobs are generated in agro-tourism centers, while indirect employment arises in sectors such as transport, hospitality, and handicrafts. It also offers work opportunities to women and rural youth, helping to reduce unemployment and migration.

#### **Social Development**

Agro-tourism helps in preserving rural traditions, customs, and cultural heritage. It encourages interaction between urban visitors and rural communities, promoting cultural exchange and awareness about agricultural life. It also strengthens community participation and social bonds.

#### **Environmental Sustainability**

Agro-tourism supports the conservation of natural resources by promoting eco-friendly farming practices. It helps protect rural landscapes and biodiversity while creating awareness among visitors about environmental protection and sustainability.

#### **Agricultural Development**

Agro-tourism indirectly benefits agriculture by increasing demand for local products and encouraging farmers to diversify crops. It also promotes organic and sustainable farming practices. Farmers are motivated to improve the quality of their produce to attract tourists.

### **Agro-Tourism in Ahilyanagar**

In Ahilyanagar district, agro-tourism is gradually developing as an important rural activity. The region has favorable conditions such as a strong agricultural base, traditional farming practices, and proximity to major cities like Pune and Nashik.

Due to increasing interest in rural tourism, many farmers have started agro-tourism initiatives, including farm stays, traditional food services, and hands-on farming experiences. These activities not only generate income but also promote the cultural and agricultural identity of the region.

### **Challenges in Agro-Tourism Development**

Despite its benefits, agro-tourism faces several challenges that restrict its growth.

- **Infrastructure Limitations:** Rural areas often lack proper infrastructure such as good roads, accommodation, and sanitation facilities, which makes it difficult to attract tourists.
- **Lack of Awareness:** Many farmers have limited knowledge about agro-tourism and its potential. In addition, insufficient promotion reduces its reach among tourists.

### **Discussion**

The study demonstrates that agro-tourism has considerable potential as a tool for sustainable development in Ahilyanagar. It contributes to economic growth, employment creation, and cultural preservation.

However, its success largely depends on proper planning, infrastructure development, and awareness among farmers. Integrating agro-tourism with rural development policies can significantly enhance its effectiveness.

### **Conclusion**

Agro-tourism is a promising strategy for achieving sustainable rural development. In Ahilyanagar, it has the potential to improve farmers' income, generate employment, and preserve rural traditions.

To fully realize its benefits, challenges such as infrastructure deficiencies, lack of awareness, and policy gaps must be addressed. Sustainable agro-tourism practices can play a crucial role in ensuring long-term rural prosperity and environmental conservation.

### **Suggestions**

- Strengthen rural infrastructure

- Provide training and awareness programs for farmers
- Promote agro-tourism through digital platforms
- Encourage public-private partnerships
- Offer financial assistance and subsidies
- Adopt eco-friendly tourism practices

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3. Research studies on agro-tourism in India
4. Government of Maharashtra Agricultural Reports

# **An Analytical Study of Agricultural Productivity and Cropping Patterns in Karjat Taluka, District Ahilyanagar**

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## **Abstract**

Agriculture constitutes the foundation of rural livelihoods in India, particularly in semi-arid regions where it serves as the primary economic activity. This study aims to evaluate agricultural productivity and cropping patterns in Karjat Taluka of Ahilyanagar district, Maharashtra. The analysis is based on secondary data sources such as Census 2011, district statistical records, and government agricultural reports. It examines how climatic conditions, soil characteristics, irrigation availability, and socio-economic factors influence agricultural practices. The study also identifies key challenges such as irregular rainfall, water scarcity, and limited technological adoption, and proposes measures to enhance sustainable agricultural development and productivity.

## **Introduction**

Agricultural productivity refers to the quantity of output produced per unit area of agricultural land, while cropping pattern denotes the spatial and temporal arrangement of crops cultivated in a particular region. These factors are important indicators of agricultural efficiency and rural economic progress.

Karjat Taluka, located in Ahilyanagar district of Maharashtra, is predominantly dependent on agriculture. Due to its semi-arid climate, agricultural productivity in the region is often uncertain and largely dependent on rainfall. Therefore, analyzing cropping patterns and productivity trends is essential for improving agricultural performance and ensuring sustainable development.

## **Study Area**

Karjat Taluka is situated in the central part of Ahilyanagar district in western Maharashtra and covers an area of around 1500 square kilometers. The taluka comprises more than 100 villages and is primarily rural in nature.

The region experiences a semi-arid climate with an average annual rainfall between 400 and 600 mm. Rainfall is uneven and unpredictable, making agriculture highly dependent on monsoon precipitation. The dominant soil type

is black cotton soil (regur), which is well suited for crops such as cotton, jowar, and pulses.

### **Objectives of the Study**

- To assess agricultural productivity in Karjat Taluka
- To study the cropping pattern and identify major crops
- To analyze the factors affecting agricultural productivity
- To suggest strategies for sustainable agricultural development

### **Methodology**

This study is based on secondary data collected from various sources, including:

- Census of India 2011
- District Statistical Abstract of Ahilyanagar
- Government agricultural reports
- Academic research articles and publications

The data has been analyzed using descriptive and basic statistical methods.

### **Cropping Pattern in Karjat Taluka**

The cropping pattern in Karjat Taluka is mainly influenced by rainfall availability, soil conditions, and the extent of irrigation facilities. Agriculture in the region follows a seasonal cycle and is broadly divided into two main seasons: Kharif and Rabi.

#### **• Kharif Season (Monsoon Crops)**

The Kharif season begins with the arrival of the monsoon, usually from June to September. During this period, farmers cultivate crops such as jowar (sorghum), bajra (pearl millet), cotton, tur (pigeon pea), and groundnut. These crops depend largely on rainfall, and their productivity is closely linked to the amount and distribution of monsoon precipitation. Due to limited irrigation, most farmers rely heavily on natural rainfall during this season.

#### **• Rabi Season (Winter Crops)**

The Rabi season extends from October to February and depends mainly on residual soil moisture along with available irrigation sources. Important crops grown during this period include wheat, gram (chickpea), and rabi jowar. Compared to Kharif crops, these crops require relatively stable moisture conditions, which are supported by stored soil water and irrigation through wells and borewells.

- **Features of Cropping Pattern**

The cropping pattern in Karjat Taluka is dominated by food grains and pulse crops, indicating a subsistence-oriented agricultural system. The cultivation of commercial or cash crops is limited due to water constraints. Farmers often adopt mixed cropping and intercropping practices to reduce risks and utilize available resources efficiently. However, the cropping intensity remains low, mainly because of insufficient and uncertain water supply.

### **Agricultural Productivity in Karjat Taluka**

Agricultural productivity in Karjat Taluka is comparatively low when compared to highly irrigated regions of Maharashtra. This is mainly due to environmental limitations and limited use of modern farming practices.

### **Determinants of Productivity**

Rainfall variability is a key factor affecting agricultural output. Irregular and unpredictable rainfall often leads to variations in crop yields and sometimes results in crop failure. Soil fertility also plays an important role. Although black cotton soil is naturally fertile, improper management and continuous cultivation can reduce its productivity over time.

The availability of irrigation facilities is limited, with most farmers depending on wells and borewells. This restricts agricultural production and limits the cultivation of water-intensive crops. In addition, the adoption of modern agricultural technologies and mechanization is relatively low, which further reduces productivity levels.

### **Major Crops and Their Productivity**

Crop productivity in Karjat Taluka varies depending on rainfall, soil conditions, and irrigation support. Jowar, grown in both Kharif and Rabi seasons, is a staple crop with moderate productivity. Bajra, a Kharif crop, is drought-resistant but generally produces low to moderate yields.

Wheat, cultivated during the Rabi season, shows moderate productivity but requires adequate irrigation. Gram is another important Rabi crop with moderate yields and plays a significant role in pulse production. Cotton, a Kharif cash crop, shows variable productivity as it is highly dependent on rainfall. Groundnut, an oilseed crop, also exhibits moderate productivity. Overall, crop yields fluctuate based on environmental and resource availability.

## **Factors Influencing Cropping Pattern**

The cropping pattern in the taluka is shaped by physical, economic, and social factors.

- **Physical Factors:** Climate, rainfall distribution, soil type, and water availability are key natural factors that determine crop selection and agricultural practices.
- **Economic Factors:** Market demand, price fluctuations, cost of inputs such as seeds and fertilizers, and access to credit influence farmers' decisions regarding crop cultivation.
- **Social Factors:** Social aspects like the level of education and awareness among farmers, size of landholdings, and traditional farming practices also affect cropping patterns.

## **Problems and Challenges**

Agriculture in Karjat Taluka faces several challenges that hinder productivity and sustainability. Water scarcity is a major issue due to frequent droughts and limited irrigation facilities. Soil degradation, caused by excessive use of chemical inputs and poor land management, leads to declining soil fertility.

Low productivity is another concern, as many farmers continue to rely on traditional farming methods with limited use of modern technology. Market instability, including fluctuating crop prices, discourages investment in certain crops. Additionally, climate change, with its impact on rainfall patterns and temperature variations, further increases uncertainty and negatively affects agricultural output.

## **Suggestions for Improvement**

- Expansion of irrigation through modern methods such as drip and sprinkler systems
- Adoption of advanced agricultural techniques and mechanization
- Promotion of crop diversification towards high-value crops
- Encouragement of organic farming and soil conservation practices
- Government support through subsidies, training, and awareness programs
- Improvement of storage, transportation, and marketing infrastructure

## **Conclusion**

Agriculture in Karjat Taluka is largely dependent on monsoon rainfall and is characterized by traditional cropping systems and relatively low productivity levels. The dominance of food grains and pulses indicates the subsistence nature

of agriculture in the region.

The study reveals that climatic conditions, irrigation availability, and socio-economic factors significantly influence cropping patterns and agricultural productivity. To enhance agricultural output and ensure long-term sustainability, it is essential to adopt modern farming practices, improve water management, and encourage diversified cropping systems.

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2. District Statistical Abstract, Ahilyanagar
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# **Role of Pilgrimage Tourism in Rural Transformation: A Case Study of Karjat Taluka, District Ahilyanagar**

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## **Abstract**

Pilgrimage tourism is an important driver of regional development, especially in rural areas where economic opportunities are limited. This study explores the influence of pilgrimage tourism on rural development in Karjat Taluka of Ahilyanagar. The region is home to several religious centers that attract devotees from nearby districts as well as other parts of Maharashtra. The research evaluates the role of pilgrimage tourism in enhancing local income, generating employment, improving infrastructure, and fostering socio-cultural changes. The analysis is based on both field observations and secondary data sources. The findings indicate that pilgrimage tourism has contributed positively to the rural economy by creating livelihood opportunities and improving basic facilities. However, issues such as inadequate infrastructure, seasonal fluctuations in tourist flow, and environmental concerns persist. The study recommends the adoption of sustainable tourism practices to ensure balanced and long-term rural development.

**Keywords:** Pilgrimage Tourism, Rural Development, Religious Tourism, Economic Impact, Karjat Taluka

## **Introduction**

Tourism is widely recognized as a significant contributor to economic growth and regional development. Among its various forms, pilgrimage tourism occupies a distinctive place in countries like India, where religion plays a central role in everyday life. Pilgrimage tourism refers to travel undertaken for spiritual or religious purposes, often leading to economic and social changes in rural regions.

In rural areas with limited employment opportunities, pilgrimage tourism can act as a catalyst for development by creating jobs, improving infrastructure, and increasing local incomes. Karjat Taluka, located in Ahilyanagar, is one such region where religious tourism has gained prominence over time.

This study aims to examine the impact of pilgrimage tourism on rural development in Karjat Taluka, highlighting both its benefits and associated challenges.

### **Study Area**

Karjat Taluka is situated in the central part of Ahilyanagar. The region is characterized by semi-arid climatic conditions, uneven terrain, and an economy largely dependent on agriculture.

### **Key Features**

- **Climate:** Semi-arid with irregular rainfall patterns
  - **Economy:** Predominantly agriculture-based with allied activities
  - **Population:** Mainly rural
  - **Religious Significance:** Presence of several temples and pilgrimage centers
- Numerous religious sites in the taluka attract pilgrims, particularly during festivals and annual fairs, thereby contributing to the local economy.

### **Objectives of the Study**

- To analyze the role of pilgrimage tourism in Karjat Taluka
  - To assess its impact on rural development
  - To examine socio-economic benefits for local communities
- To identify challenges related to pilgrimage tourism

### **Methodology**

The study is based on both primary and secondary data sources.

#### **Primary Data**

- Field surveys of major pilgrimage sites
- Interviews with local residents, vendors, and visitors
- Direct observation of tourist facilities and activities

#### **Secondary Data**

- Government reports and tourism statistics
- Academic publications and research articles
- District-level statistical records

### **Analytical Approach**

Descriptive and analytical methods are applied to interpret the data, focusing on economic, social, and infrastructural impacts.

## **Pilgrimage Tourism in Karjat Taluka**

Pilgrimage tourism is an important component of the cultural and religious framework of Karjat Taluka. The region contains several sacred places that draw devotees from nearby areas. These religious centers are deeply rooted in local beliefs, customs, and traditions, giving them both spiritual and cultural significance.

The movement of pilgrims is mostly seasonal, with a sharp rise during festivals, fairs, and special religious occasions. During such times, these places become centers of social and religious activity. Although the scale of pilgrimage tourism is largely local, it still plays a vital role in supporting the rural economy and sustaining traditional lifestyles.

## **Impact on Rural Development**

Pilgrimage tourism contributes to rural development in multiple ways, influencing economic conditions, employment, infrastructure, and social life.

- **Economic Growth**

Pilgrimage tourism boosts the local economy by creating opportunities for income generation. People engage in small businesses such as running shops, food stalls, and lodging services for visitors. The demand for religious items and locally made products also increases during peak periods. Transport services benefit as well, as pilgrims require travel facilities. These activities collectively enhance the earnings of local residents and improve their living standards.

- **Employment Opportunities**

The growth of pilgrimage tourism generates various types of employment. Local people find work as vendors, guides, drivers, and service providers. Hotels, eateries, and small enterprises also offer job opportunities. In addition, seasonal employment during festivals provides temporary income for many individuals. This helps in reducing unemployment and supports the rural economy.

- **Infrastructure Development**

With the increase in tourist inflow, there has been noticeable improvement in infrastructure. Roads leading to pilgrimage sites are developed for better accessibility. Facilities such as drinking water, sanitation, and public services are also enhanced. Local markets expand to meet the needs of visitors. These developments benefit both tourists and the resident population.

- **Socio-Cultural Impact**

Pilgrimage tourism helps in preserving cultural heritage and traditions. Religious events and festivals encourage the continuation of local customs and rituals. Interaction between visitors and residents promotes cultural exchange and mutual understanding. Community participation in organizing these activities strengthens social unity and collective identity.

- **Rural Transformation**

The overall impact of pilgrimage tourism leads to gradual rural transformation. Increased income, better employment opportunities, and improved infrastructure contribute to higher living standards. People are able to invest more in housing, education, and healthcare, resulting in improved quality of life and socio-economic progress.

### **Challenges of Pilgrimage Tourism**

Despite its benefits, pilgrimage tourism in Karjat Taluka faces several constraints that hinder its sustainable growth.

- **Infrastructure Limitations**

Many pilgrimage sites do not have sufficient accommodation and basic facilities for visitors. Sanitation arrangements are often inadequate, especially during peak seasons, creating difficulties for both tourists and locals.

- **Seasonal Nature**

Tourism activities are mainly concentrated during specific festivals and events. This seasonal pattern leads to irregular income for people dependent on tourism, making it less stable as a year-round livelihood option.

- **Environmental Issues**

Large gatherings of pilgrims result in environmental problems such as waste generation, pollution, and strain on natural resources. Without proper management, these issues can harm the local environment.

- **Lack of Planning**

The absence of proper planning and organized management restricts the development of pilgrimage tourism. Limited promotion and awareness further reduce its potential to grow beyond a local scale. Effective planning and policy support are essential for ensuring sustainable development in this sector.

## **Discussion**

The findings indicate that pilgrimage tourism has positively contributed to rural development in Karjat Taluka. It has enhanced economic conditions, created employment, and improved infrastructure.

However, the full potential of tourism is not realized due to inadequate planning and infrastructural constraints. There is a need to adopt sustainable tourism strategies to ensure long-term benefits.

## **Conclusion**

Pilgrimage tourism has emerged as an important factor in rural development in Karjat Taluka of Ahilyanagar. It has contributed to economic growth, employment generation, and infrastructural improvements.

Nevertheless, challenges such as seasonal tourism, environmental degradation, and lack of proper facilities must be addressed. Sustainable management of pilgrimage tourism can play a vital role in achieving balanced and inclusive rural development.

## **Recommendations**

- Develop adequate infrastructure at pilgrimage sites
- Promote eco-friendly and sustainable tourism practices
- Improve sanitation and waste management systems
- Encourage active community participation
- Provide training and financial assistance to local entrepreneurs
- Enhance tourism promotion through digital platforms and government support

## **Acknowledgement**

The author expresses gratitude to local residents, pilgrims, and officials for their valuable contributions and support during the study.

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4. District Statistical Handbook of Ahilyanagar

# A Geographical Analysis of Rural Settlement Patterns in Shrigonda Taluka, District Ahilyanagar

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## Abstract

Rural settlement patterns form a crucial component of human geography as they illustrate how people organize their living spaces in response to environmental and socio-economic conditions. This study explores the rural settlement patterns of Shrigonda Taluka in Ahilyanagar district, Maharashtra. The analysis is based on secondary data sources such as Census 2011, district records, and geographical studies. It focuses on the types of settlement patterns, their spatial distribution, and the factors influencing them. The paper also highlights the challenges faced by rural settlements and suggests measures for sustainable rural development.

## Introduction

Settlement geography deals with the study of human habitation and its spatial arrangement. Rural settlements are generally smaller in size and are closely associated with primary activities like agriculture.

Settlement patterns refer to the way houses and villages are arranged within a geographical region. These patterns are shaped by natural factors such as climate, soil, and water availability, along with socio-economic elements like occupation, infrastructure, and cultural traditions.

Shrigonda Taluka, located in Ahilyanagar district of Maharashtra, represents a typical semi-arid region where rural settlement patterns are influenced by environmental and socio-economic conditions. Understanding these patterns is essential for effective rural planning and sustainable development.

## Study Area

Shrigonda Taluka is situated in the southern part of Ahilyanagar district in Maharashtra and covers an area of approximately 1600 square kilometers. The taluka comprises more than 100 villages and is predominantly rural in nature.

The region experiences a semi-arid climate with low to moderate rainfall ranging between 400 and 600 mm annually. The terrain is mostly flat with

slight undulations, and the soils are primarily black cotton soils, which are suitable for agricultural activities.

Agriculture is the main occupation of the population, and the availability of water resources such as wells and canals plays a significant role in determining settlement patterns.

### **Objectives of the Study**

- To identify different types of rural settlement patterns in Shrigonda Taluka
- To analyze the spatial distribution of settlements
- To examine the factors influencing these patterns
- To suggest strategies for improving rural settlement planning

### **Methodology**

The present study is based on secondary data collected from various sources, including:

- Census of India 2011
- District Census Handbook of Ahilyanagar
- Government reports and academic studies

The data has been analyzed using descriptive and geographical approaches.

### **Types of Rural Settlement Patterns**

Rural settlements in Shrigonda Taluka display a variety of patterns shaped by environmental conditions, economic activities, and social structures. These patterns can mainly be classified into nucleated, dispersed, and semi-clustered settlements, each having its own distinctive features.

#### **• Nucleated Settlements**

Nucleated settlements are the most common type in the taluka. In this pattern, houses are closely packed together, forming compact and clearly defined villages. The residential area is usually surrounded by agricultural land. This arrangement encourages close social interaction among villagers and facilitates the development of basic amenities such as schools, water supply, and local markets. As a result, these settlements tend to be more organized and better equipped compared to others.

#### **• Dispersed Settlements**

Dispersed settlements consist of houses that are spread out over a wide area, often separated by considerable distances. These are typically found in regions where farmland is scattered, prompting farmers to live near their fields. Such

settlements have low population density and include isolated dwellings or farmhouses. Due to their scattered nature, access to infrastructure and public services is often limited, making them less developed.

- **Semi-Clustered Settlements**

Semi-clustered settlements represent a middle form between nucleated and dispersed types. In these settlements, houses are grouped into small clusters separated by agricultural land. They show moderate population density and are usually found in transitional areas where both physical and socio-economic factors influence settlement patterns. This type combines features of both compact and scattered settlements.

### **Spatial Distribution of Settlements**

The distribution of settlements across Shrigonda Taluka is uneven and influenced by natural and economic conditions. Areas with fertile soil, reliable irrigation, and good transport links tend to have dense populations. Regions with average agricultural productivity support moderate population levels, while drought-prone and water-scarce areas remain sparsely populated.

The Bhima River and its tributaries play a crucial role in determining settlement locations, as they provide essential water resources for agriculture and human use, thereby attracting population concentration in nearby areas.

### **Factors Influencing Settlement Patterns**

Settlement patterns in the taluka are determined by a combination of physical, economic, and social factors.

- **Physical Factors**

Natural elements such as climate, rainfall, soil quality, and topography significantly influence where settlements develop. Favorable environmental conditions support larger and more stable populations.

- **Economic Factors**

Economic aspects, especially agriculture as the main occupation, strongly affect settlement distribution. The presence of irrigation facilities, farming resources, and access to markets and employment opportunities influences the growth and concentration of settlements.

- **Social Factors**

Social influences such as cultural traditions, caste-based settlement arrangements, and access to education and healthcare also play an important

role. People often prefer to live in close-knit communities, which leads to clustered settlement patterns.

### **Characteristics of Rural Settlements in Shrigonda Taluka**

Rural settlements in Shrigonda Taluka are mainly characterized by the dominance of nucleated villages and a strong dependence on agriculture. Urban influence is limited, and traditional styles of housing are still prevalent. The social structure is community-oriented, with strong interpersonal relationships and shared cultural practices.

### **Problems Faced by Rural Settlements**

Rural settlements in the taluka face several issues that affect their growth and sustainability.

- **Water Scarcity**

Recurring droughts and insufficient water resources pose serious challenges to agriculture and settlement stability.

- **Inadequate Infrastructure**

Many villages lack essential services such as healthcare, education, and proper transportation, which lowers the standard of living.

- **Migration**

Due to limited employment opportunities, many residents migrate to urban areas, leading to a reduction in the rural workforce.

- **Environmental Degradation**

Problems like soil erosion and depletion of water resources negatively impact agricultural productivity and environmental sustainability.

### **Suggestions for Sustainable Development**

For sustainable development of rural settlements in Shrigonda Taluka, several steps are necessary. Improving irrigation systems and adopting water conservation methods can help address water scarcity. Enhancing rural infrastructure, including roads, schools, and healthcare facilities, can improve living conditions. Promoting rural industries and creating employment opportunities can reduce migration. Encouraging sustainable agricultural practices will support long-term productivity and environmental balance. Additionally, effective implementation of government schemes is essential to ensure balanced and inclusive development.

## **Conclusion**

Rural settlement patterns in Shrigonda Taluka are largely shaped by environmental conditions, agricultural practices, and socio-economic factors. The dominance of nucleated settlements reflects the traditional rural lifestyle of the region.

The study emphasizes the importance of balanced rural development through improved infrastructure, efficient water management, and sustainable practices. Proper planning of rural settlements can significantly enhance living standards and promote economic growth in the taluka.

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# **A Study on the Influence of Rainfall on Agricultural Practices in Ahilyanagar District, Maharashtra**

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## **Abstract**

Rainfall is a key climatic factor that significantly affects agricultural productivity, particularly in semi-arid regions. This study analyzes the impact of rainfall on agriculture in Ahilyanagar District. The district experiences irregular and uncertain rainfall patterns, which directly influence crop yields, cropping systems, and the livelihoods of farmers. The research is based on secondary data sources such as Census 2011, meteorological reports, and agricultural statistics. It explores the relationship between rainfall variability and agricultural output, identifies major issues like drought and water scarcity, and suggests strategies for sustainable agricultural development.

## **Introduction**

Rainfall plays a crucial role in determining agricultural productivity in India, especially in areas where irrigation facilities are limited. In semi-arid regions, agriculture largely depends on monsoon rainfall, making it highly vulnerable to climatic uncertainties.

Ahilyanagar District is one such region where agriculture is the primary occupation, and variations in rainfall significantly influence farming activities. Studying this relationship is essential for enhancing crop production, ensuring food security, and promoting sustainable development.

## **Study Area**

Ahilyanagar District is situated in the western part of Maharashtra and is characterized by semi-arid climatic conditions. The district receives an average annual rainfall ranging between 400 mm and 700 mm, which is unevenly distributed across time and space.

The region is dominated by black cotton (regur) soils, which are suitable for crops such as jowar, cotton, and pulses. Agriculture in the district is largely rain-fed, with irrigation facilities available only in limited areas.

### **Objectives of the Study**

- To examine rainfall patterns in Ahilyanagar district
- To analyze the impact of rainfall on agricultural productivity
- To study changes in cropping patterns due to rainfall variability
- To suggest measures for improving agricultural sustainability

### **Methodology**

The study is based on secondary data collected from the following sources:

- Census of India 2011
- Meteorological department reports
- District Statistical Abstracts
- Government agricultural records
- Research articles and journals

The data has been analyzed using descriptive and simple statistical methods.

### **Rainfall Characteristics in Ahilyanagar District**

Rainfall in Ahilyanagar District shows a high degree of fluctuation and uncertainty, which has a strong influence on agricultural practices in the region. The district receives an average annual rainfall of about 400 to 700 mm, most of which occurs during the southwest monsoon season between June and September. However, rainfall is not evenly distributed across all talukas, leading to variations in water availability.

The frequent occurrence of drought conditions further emphasizes the irregular nature of rainfall. Such unpredictability creates challenges for farmers, as agriculture in the district is largely dependent on monsoon rains.

### **Impact of Rainfall on Agriculture**

Rainfall plays a decisive role in shaping agricultural productivity and overall farming conditions in the district. Its impact can be seen in multiple dimensions.

#### **• Crop Production**

The amount and timing of rainfall directly influence crop growth and yield. When rainfall is sufficient and well-distributed, crops grow properly and produce higher yields. On the other hand, inadequate or erratic rainfall leads to reduced productivity and may even cause total crop failure. Therefore, agricultural output is highly dependent on rainfall conditions.

- **Cropping Pattern**

Rainfall availability largely determines the types of crops grown in different parts of the district. Areas receiving low rainfall generally cultivate drought-resistant crops such as jowar and bajra. Regions with moderate rainfall support crops like pulses and oilseeds. In contrast, areas with irrigation facilities allow the cultivation of water-intensive crops such as sugarcane and wheat. Hence, rainfall is a key factor influencing cropping patterns.

- **Soil Moisture and Fertility**

Rainfall is essential for maintaining adequate soil moisture, which is necessary for plant development. However, excessive rainfall can lead to soil erosion and nutrient loss, while insufficient rainfall results in dry conditions and declining soil fertility. Both extremes negatively affect agricultural productivity.

- **Dependence on Irrigation**

In the absence of sufficient rainfall, farmers depend heavily on irrigation sources such as wells, borewells, and canals. While this helps sustain agriculture, excessive extraction of groundwater can lead to depletion of water resources over time.

- **Impact on Farmers' Income**

Variations in rainfall have a direct effect on farmers' income and economic stability. Good rainfall seasons lead to better yields and increased income, whereas poor rainfall results in financial losses, debt, and sometimes migration to urban areas in search of alternative livelihoods.

### **Major Crops and Rainfall Dependence**

Different crops grown in the district require varying levels of rainfall. Crops like jowar and bajra can grow with low to moderate rainfall and are suitable for dry conditions. Cotton and tur require moderate rainfall but are sensitive to irregular patterns. Wheat, cultivated in the Rabi season, depends on irrigation, while sugarcane needs a high and continuous water supply, making it highly dependent on assured irrigation.

### **Issues Arising from Rainfall Variability**

The irregular nature of rainfall leads to several agricultural and socio-economic problems. Frequent droughts reduce crop production and affect livelihoods. Irregular rainfall often results in partial or complete crop failure, causing economic stress for farmers. Water scarcity becomes a serious issue due to declining surface and groundwater levels.

Additionally, erratic rainfall contributes to soil degradation through erosion and loss of nutrients. These difficulties often compel farmers to migrate to urban areas in search of better employment opportunities, affecting the rural economy.

### **Adaptation and Mitigation Measures**

To address the challenges caused by rainfall variability, several strategies can be adopted. Water conservation methods such as rainwater harvesting, watershed development, and the construction of check dams and farm ponds can improve water availability.

The use of efficient irrigation techniques like drip and sprinkler systems helps in better management of water resources. Crop diversification, including the adoption of drought-resistant and high-value crops, can reduce risk and enhance income.

Technological advancements such as improved seed varieties, weather forecasting services, and farm mechanization support better agricultural practices. Moreover, government initiatives like crop insurance schemes, subsidies for irrigation equipment, and farmer training programs play a crucial role in strengthening agricultural resilience and promoting sustainable development in the district.

### **Conclusion**

Rainfall is a determining factor in agricultural productivity in Ahilyanagar District. The heavy reliance on monsoon rainfall makes agriculture in the region highly vulnerable to climatic variability.

The study shows that irregular rainfall leads to low productivity, crop failure, and economic instability among farmers. Therefore, adopting effective water management practices, modern agricultural techniques, and diversified cropping systems is essential for achieving sustainable agricultural development.

### **References**

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# शाश्वत विकासाच्या दृष्टिकोनातून जामखेड तालुक्यातील वाढते अपारंपारिक नूतनीकरणक्षम सौर व पवन ऊर्जा निर्मिती क्षेत्र

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## सारांश

महाराष्ट्रातील अहिल्यानगर जिल्ह्यातील जामखेड तालुका हा भौगोलिकदृष्ट्या पठारी आणि कमी पर्जन्यमानाचा भाग आहे तालुक्याच्या कांही भागात सह्याद्रीच्या बालाघाट पर्वतरांगा सुध्दा पसरलेल्या आहेत. त्यामुळे या भागात वर्षभर मुबलक सूर्यप्रकाश उपलब्ध असल्याने व वाऱ्याची दिशा व वेग पवन उर्जेस पोषक असल्याने या भागात नूतनीकरणक्षम सौर्य व पवन ऊर्जा निर्मितीस मोठा वाव आहे. शाश्वत विकासाच्या दृष्टीने ऊर्जा सुरक्षा आणि पर्यावरणाचे रक्षण या बाबी विचारात घेवून या तालुक्यात मोठ्या प्रमाणात सौर्य व पवन ऊर्जा निर्मिती केली जात आहे त्यामुळे प्रस्तुत शोधनिबंधात जामखेड तालुक्यातील सौर आणि पवन ऊर्जेच्या वाढत्या विस्ताराचा व त्याच्या क्षमतेचा अभ्यास करण्यात आलेला आहे.

तालुक्यातील भौगोलिक परिस्थिती विशेषतः डोंगररांगा आणि वर्षभर मिळणारा प्रखर सूर्यप्रकाश यामुळे हे क्षेत्र अक्षय ऊर्जेसाठी नंदनवन ठरत आहे. या निबंधात तालुक्यातील ऊर्जेच्या सद्यस्थितीचे विश्लेषण केले असून, पारंपरिक ऊर्जा स्रोतांकडून हरित ऊर्जेकडे होणाऱ्या संक्रमणाचा आढावा घेतला आहे. संशोधनातून असे दिसून येते की, खर्डा आणि लगतच्या डोंगराळ भागात पवनचक्क्यांचे जाळे विस्तारले असून, सपाट माळरानावर सौर ऊर्जा प्रकल्पांची उभारणी होत आहे. येथील सौर आणि पवन ऊर्जेची वाढती क्षमता शाश्वत विकासाच्या दृष्टीने क्रांतिकारी आहे यामुळे स्थानिक रोजगार, शेतीसाठी दिवसा वीज उपलब्धता आणि कार्बन उत्सर्जनात घट असे सकारात्मक परिणाम दिसून येत आहेत.

**मुख्यशब्द:** शाश्वत विकास, ऊर्जा शेती, नूतनीकरणक्षम ऊर्जा, अॅग्री-व्होल्टेइक,

## प्रस्तावना

देशात दिवसेंदिवस वाढत्या लोकसंख्यामुळे विविध विकास कामांसाठी लागणारी ऊर्जा व

उर्जेची मागणी व पुरवठा यातील अंतर यामुळे देशात शाश्वत विकासाच्या दृष्टीने अपारंपारिक अक्षय ऊर्जा क्षेत्राचा विकास अत्यंत महत्वाचा असून अपारंपारिक अक्षय ऊर्जा प्रकल्प हे सौर, पवन, बायोमास आणि जलविद्युत यांसारख्या निसर्गात उपलब्ध असलेल्या अमर्याद साधनांपासून वीज निर्मिती करतात. हे प्रकल्प प्रदूषणमुक्त, शाश्वत आणि पर्यावरणास अनुकूल आहेत. जागतिक तापमानवाढ आणि हवामान बदलाच्या पार्श्वभूमीवर अपारंपारिक अक्षय नूतनीकरणक्षम ऊर्जा बाबतीत भारताने २०७० पर्यंत 'नेट झिरो' उत्सर्जनाचे उद्दिष्ट ठेवले आहे. तर महाराष्ट्राने २०२५ पर्यंत ६० GW नूतनीकरणक्षम ऊर्जा लक्ष्य ठेवले आहे. या राष्ट्रीय उद्दिष्ट पूर्तीत जामखेड सारख्या ग्रामीण तालुक्यांचे योगदान महत्त्वपूर्ण ठरत आहे. शाश्वत विकास ही आजच्या काळाची गरज असून शाश्वत विकास म्हणजे नैसर्गिक संसाधनांचा असा वापर, ज्यामुळे भविष्यातील पिढ्यांच्या गरजांशी तडजोड न करता आजची प्रगती साधता येईल. जामखेडमधील सौर आणि पवन ऊर्जा प्रकल्प हे या व्याख्येला तंतोतंत लागू पडतात.

जामखेड तालुका हा अवर्षणप्रवण क्षेत्रात येत असला तरी, येथील निसर्गाने या क्षेत्राला 'हवा' आणि 'प्रकाश' या स्वरूपात मोठी ऊर्जा संपत्ती दिली आहे. पूर्वी केवळ कोरडवाहू शेतीवर अवलंबून असलेल्या या भागात आता 'ऊर्जा शेती' (Energy Farming) मूळ धरत आहे. एकेकाळी केवळ दुष्काळी तालुका म्हणून ओळखल्या जाणाऱ्या या भागाचे रूपांतर आता 'ऊर्जा हब' मध्ये होत आहे. निसर्गाने दिलेल्या मुबलक सूर्यप्रकाश आणि वाऱ्याचा वेग यामुळे येथे सौर व पवन ऊर्जेचे मोठे प्रकल्प उभे राहात आहेत. हे बदल केवळ पर्यावरणासाठीच नव्हे, तर स्थानिक अर्थव्यवस्थेसाठीही संजीवनी ठरत आहेत.

### संशोधनाची उद्दिष्टे

१. जामखेड तालुक्यातील सौर आणि पवन ऊर्जेच्या उपलब्धतेचा आणि क्षमतेचा अभ्यास करणे.
२. शाश्वत विकासात या प्रकल्पांच्या भूमिकेचे मूल्यमापन करणे.
३. अक्षय ऊर्जेमुळे स्थानिक आर्थिक आणि सामाजिक स्तरावर होणाऱ्या बदलांचे विश्लेषण करणे.

### संशोधनाची गृहीतके

१. जामखेड तालुक्यातील भौगोलिक रचना सौर आणि पवन ऊर्जा निर्मितीसाठी अत्यंत अनुकूल आहे.
२. शासकीय धोरण व सवलती यामुळे या तालुक्यात नूतनीकरणक्षम ऊर्जा निर्मिती क्षेत्रात वाढ होत आहे.

३. नूतनीकरणक्षम ऊर्जेच्या विस्तारामुळे स्थानिक रोजगाराच्या संधीत वाढ झाली आहे.

### संशोधन पद्धती

प्रस्तुत संशोधनासाठी प्राथमिक व दुय्यम अशा मिश्र माहिती साधनांचा वापर करण्यात येऊन मिळालेल्या माहितीचे संख्याशास्त्रीयदृष्ट्या पृथःकरण करून विषयाची विश्लेषणात्मक पद्धतीने मांडणी करण्यात आली.

प्राथमीक स्वरूपाची माहिती साध्या व सोप्या यादृच्छिक नमुना निवड पद्धतीचा वापर करून, निरीक्षण व सर्वेक्षण पद्धतीद्वारे मुलाखत व प्रश्नावलीच्या माध्यमातून संकलित करण्यात आली. त्यासाठी तालुक्यातील खर्डा, साकत आणि पाटोदा परिसरातील सौर प्रकल्प आणि पवनचक्क्यांच्या ठिकाणांना प्रत्यक्ष भेटी देऊन निरीक्षण केले आहे.

नमुना निवड / सर्वेक्षण: ५० स्थानिक शेतकरी आणि १० ऊर्जा प्रकल्प व्यवस्थापकांच्या मुलाखती घेऊन गुणात्मक माहिती संकलित केली आहे.

### अभ्यासक्षेत्र

महाराष्ट्रातील अहिल्यानगर जिल्ह्यातील जामखेड तालुका हा जिल्ह्याच्या आग्नेय दिशेच्या टोकावरील तालुका असून या तालुक्याचा विस्तार उत्तर-पूर्व गोलार्धात १८०३०I उत्तर अक्षांश ते १८०५४I उत्तर अक्षांश व ७५००१I पूर्व रेखांश ते ७५०३०I पूर्व रेखांश दरम्यान आहे. हा प्रामुख्याने सह्याद्री पर्वतरांगेतील बालाघाटच्या डोंगररांगांमध्ये येतो. तालुक्याचे एकूण क्षेत्रफळ साधारणपणे ७७८ चौरस किलोमीटर आहे. येथील हवामान प्रामुख्याने कोरडे आणि उष्ण स्वरूपाचे असून पावसाचे प्रमाण कमी असल्याने हा तालुका बऱ्याचदा 'दुष्काळी पट्टा' म्हणून ओळखला जातो. सिना व विंचरणा या या भूभागातील प्रमुख नद्या असून येथील जमीन प्रामुख्याने मध्यम ते हलक्या प्रकारची, डोंगराळ भागात खडकाळ तर सखल भागात काळवट मिश्रित स्वरूपाची आढळते.

### संशोधनातील नवकल्पना

या संशोधनात 'अॅग्री-व्होल्टेइक' (Agri-voltaic) मॉडेलची संकल्पना मांडली आहे. जामखेडमध्ये जमिनीची कमतरता नसली तरी, ज्या ठिकाणी सौर पॅनेल लावले आहेत, त्याखाली सावलीत वाढणारी पिके (उदा. आले, हळद किंवा काही पालेभाज्या) घेण्याबाबतचा नाविन्यपूर्ण विचार यात मांडला आहे. तसेच, पवनचक्क्यांच्या पायाशी सौर पॅनेल बसवून 'हायब्रिड ऊर्जा पार्क' विकसित करण्याची संकल्पना तालुक्यासाठी शेतकऱ्यांच्या आर्थिक उत्पनात वाढ घडवेल.

## विषय विवेचन

जामखेड तालुक्याची भौगोलिक रचना पाहता येथील सह्याद्री पर्वतरांगेतील बालाघाट डोंगरांतील भूभागात ओबड धोबड जमिन असून कृषी विकासास प्रतिकूल आहे. या व्यतिरिक्त हा कमी पर्जन्याचा विशेषतः पर्जन्यछायेचा असल्याने या भागात वर्षातील ३०० ते ३२० दिवस सूर्य प्रकाश उपलब्ध होतो व त्या बरोबरच वाऱ्याची दिशा व वेगही पवन ऊर्जा निर्मितीस पोषक असल्याने या भागात खालील प्रमाणे नूतनीकरणक्षम ऊर्जा निर्मितीस वाव आहे.

### तक्ता क्र. १.१ जामखेड तालुक्यातील ऊर्जा प्रकारानुसार संभाव्य ऊर्जा क्षमता

ऊर्जा प्रकार	भौगोलिक क्षेत्र (अनुकूल)	सरासरी उपलब्धता	संभाव्य क्षमता (मेगावॉट)
पवन ऊर्जा	खर्डा, डोंगरांगा	५.८ - ६.५ m/s	५००+ MW
सौर ऊर्जा	माळरान, पडीक जमीन	३२० दिवस (प्रखर सूर्य)	८००+ MW

स्त्रोत: 'महाऊर्जा' (MEDA) द्वारे प्रकाशित करण्यात आलेले पवन ऊर्जा क्षमता नकाशा

वरील तक्ता क्र. १.१ मध्ये दर्शविण्यात आलेल्या माहिती नुसार जामखेड तालुक्यात पवन ऊर्जा निर्मितीस ५००+ MW क्षमतेस वाव असून सौर्य ऊर्जा निर्मितीची संभाव्य क्षमता ८००+ MW इतकी आहे.

- **पवन ऊर्जा क्षेत्र:** पवन ऊर्जेचा वारा गतिने मिळवला तो गतीज ऊर्जा आहे. हे एक नवीकरणीय ऊर्जा स्त्रोत आहे बर्याच शतकांसाठी पवन वापरला जात आहे, जसे की धान्य कुरणे, वारा व इतर नौका. आधुनिक पवनचक्की अशा प्रकारे बांधण्यात येते की ते पवन ऊर्जाला यांत्रिक किंवा विद्युत उर्जेत रूपांतरीत करतात.

तालुक्यातील खर्डा घाट, पाटोदा आणि साकत यांसारख्या उंच भागांत वाऱ्याचा सरासरी वेग ५.५ ते ६.५ मीटर प्रति सेकंद (m/s) इतका असतो. पवनचक्कीसाठी आवश्यक असणारा हा वेग अत्यंत आदर्श मानला जातो. त्यामुळे या भागात सुझलॉन, आयनॉक्स यांसारख्या कंपन्यांनी येथे मोठे प्रकल्प उभारले आहेत. यामुळे ग्रीडमध्ये मोठ्या प्रमाणात वीज पुरवठा होत आहे.

- **सौर ऊर्जा क्षेत्र:** जामखेड तालुक्याचा भूभाग अवर्षणप्रवण क्षेत्रात असल्याने येथे वर्षातील ३०० हून अधिक दिवस प्रखर सूर्यप्रकाश उपलब्ध असतो. येथील कोरड्या हवामानामुळे 'सोलर रेडिएशन' (Solar Radiation) उच्च दर्जाचे आहे, सौर ऊर्जेची तीव्रता (Solar Irradiance) ५.० ते ५.८ kWh/sq.m इतकी नोंदवण्यात आली आहे, जी व्यावसायिक सौर प्रकल्पांसाठी अत्यंत फायदेशीर आहे. त्यामुळे अनेक सरकारी आणि खासगी सौर ऊर्जा प्रकल्प येथे कार्यरत आहेत व कांही प्रस्तावित आहेत. याव्यतिरिक्त 'मुख्यमंत्री सौर कृषी वाहिनी योजना' आणि 'कुसुम योजना' अंतर्गत सुध्दा तालुक्यात सौर ऊर्जेचा प्रसार झालेला आहे.

### प्रमुख सौर ऊर्जा प्रकल्प

- **जामखेड कॅप्टिव्ह सोलर पीव्ही प्लांट (Tata Power):** टाटा पॉवर रिन्युएबल एनर्जी लिमिटेड (TPREL): यांच्याद्वारे विकसित केलेला हा एक मोठा प्रकल्प आहे. हा केवळ एक सौर प्रकल्प नसून, तो भारतातील 'ग्रुप कॅप्टिव्ह' (Group Captive) मॉडेलचे एक उत्कृष्ट उदाहरण आहे. या प्लांटमध्ये बायफेशियल मॉड्यूल्स बरोबरच सूर्याचा मागोवा घेणारी 'सिंगल अॅक्सिस ट्रॅकिंग' यंत्रणा वापरण्यात आली आहे, ज्यामुळे स्थिर पॅनेल्सच्या तुलनेत १५-२०% जास्त वीज मिळते. या प्रकल्पाची क्षमता अंदाजे ४३.७५ मेगावॉट (MW) इतकी असून हा प्रकल्प प्रामुख्याने औद्योगिक गरजांसाठी बजाज समूहाच्या मुकुंद लिमिटेड सारख्या कंपन्यांना वीज पुरवण्यासाठी उभारला गेला असून हा 'ग्रुप कॅप्टिव्ह' प्रकल्प आहे. मुकुंद लिमिटेड ही 'स्पेशालिटी स्टील लॉन्ग प्रॉडक्ट्स' आणि अवजड यंत्रसामग्री उत्पादनात देशातील अग्रगण्य कंपनी आहे. या प्रकल्पातून दरवर्षी ९९.८२ दशलक्ष युनिट्स (MUs) वीज निर्मिती होईल आणि वार्षिक सुमारे ५४,६८७ टन कार्बन डायऑक्साइड (CO2) उत्सर्जन कमी होण्यास मदत होणार आहे. प्रकल्पाच्या उभारणीदरम्यान आणि देखभालीसाठी स्थानिक तांत्रिक मनुष्यबळाचा वापर होत असल्याने मोठ्या प्रमाणात रोजगार निर्मिती झालेली आहे.
- **कृष्णा विंड फार्म (सौर पीव्ही पॉवर प्लँट):** हा एक 'ग्राउंड माउंटेड' (जमिनीवर आधारित) सौर फोटोव्होल्टेइक (PV) प्रकल्प आहे. जामखेड तालुक्यातील मोहरी गावच्या हद्दीत, डोंगराळ आणि डोंगर उतारावरील जमिनीवर उभारण्यात आला आहे. 'कृष्णा विंडफार्म प्रायव्हेट लिमिटेड' द्वारे सुमारे १० मेगावॉट क्षमतेचा प्रकल्प कार्यान्वित झाला आहे. फेब्रुवारी २०१९ पासून ही कंपनी MITCON Consultancy & Engineering Services

Limited ची पूर्ण मालकीची उपकंपनी बनली आहे. याचे इंजिनिअरिंग 'मिटकॉन'ने (MITCON) केले आहे. डोंगराळ भागात किंवा उतारावर सौर प्रकल्प उभारणे तांत्रिकदृष्ट्या आव्हानात्मक असते, त्यामुळे याला एक 'फ्लॅगशिप प्लांट' (Flagship Plant) मानले जाते. या प्रकल्पातून निर्माण होणारी वीज भारतीय सौर ऊर्जा निगम (SECI) ला विकली जाते. यासाठी २५ वर्षांचा दीर्घकालीन करार करण्यात आला.

हा प्रकल्प मोहरीच्या डोंगर माथ्यावर आणि उतारावर पसरलेला असल्याने, ज्या जमिनीचा शेतीसाठी उपयोग होऊ शकत नाही अशा पडीक जमिनीचा ऊर्जेसाठी वापर करण्याचा हा उत्तम नमुना आहे. या प्रकल्पातून निर्माण होणारी वीज जवळच्या महावितरणच्या उपकेंद्राद्वारे ग्रीडमध्ये सोडून राष्ट्रीय/राज्य वीज वाहिनीत समाविष्ट केली जाते त्यामुळे हा प्रकल्प जामखेडच्या औद्योगिक आणि पर्यावरणीय प्रगतीत एक महत्त्वाचा टप्पा मानला जातो.

जामखेड सोलर पीव्ही पार्क' हा प्रकल्प शापूरजी पालनजी इन्फ्रास्ट्रक्चर कॅपिटल कंपनीच्या 'स्पेशल पर्पज व्हेईकल' (SPV) अंतर्गत विकसित करण्यात आला आहे. यात प्रगत क्रिस्टलाईन सिलिकॉन फोटोव्होल्टेइक (PV) तंत्रज्ञानाचे मॉड्यूल्स वापरण्यात आले आहेत. जास्तीत जास्त सूर्यप्रकाश शोषला जाईल आणि वीज निर्मिती वाढेल यासाठी सूर्याच्या दिशेनुसार पॅनेलची दिशा बदलणारी यंत्रणा (Single Axis Trackers) काही ठिकाणी वापरली गेली आहे. हा १० मेगावॉट क्षमतेचा प्रकल्प ऑगस्ट २०२० मध्ये अधिकृतपणे ग्रीडशी जोडला गेला आणि कार्यान्वित झाला. हा प्रकल्प MSEDCL (महावितरण) ला वीज विक्री करतो. महावितरणसोबत २५ वर्षांचा दीर्घकालीन 'पॉवर पचेस अग्रीमेंट' (PPA) करण्यात आला आहे. हा प्रकल्प वर्षाकाठी लाखो युनिट्स कार्बन-मुक्त वीज निर्माण करतो, ज्यामुळे औष्णिक वीज प्रकल्पांवरील ताण कमी होतो. प्रकल्पाच्या उभारणीदरम्यान आणि देखभालीसाठी स्थानिक तांत्रिक मनुष्यबळाचा वापर होत असल्याने मोठ्या प्रमाणात रोजगार निर्मिती झालेली आहे. या प्रकल्पाद्वारे दाखवून दिले आहे की, योग्य नियोजनाने ग्रामीण भागातील पडीक जमिनींचे रूपांतर 'ऊर्जा खाणी'मध्ये करता येते. एकंदरीत शापूरजी पालनजीसारख्या दिग्गज कंपनीने जामखेडमध्ये गुंतवणूक केल्यामुळे तालुक्याच्या औद्योगिक प्रतिमेत सुधारणा झाली आहे.

- **जामखेड ३३ केव्ही सबस्टेशन प्रकल्प:** जामखेड तालुक्यातील ३३ केव्ही उपकेंद्राशी (Substation) जोडलेला हा सौर ऊर्जा प्रकल्प महाराष्ट्र सरकारच्या आणि महावितरणच्या (MSEDCL) 'मुख्यमंत्री सौर कृषी वाहिनी योजनेचा एक महत्त्वाचा भाग असून या योजनेचा

मुख्य उद्देश 'कृषी फीडरचे सौर ऊर्जाकरण' हा आहे. ३३ केव्ही उपकेंद्राशी जोडलेल्या ४ मेगावॉट क्षमतेच्या या सौर ऊर्जा प्रकल्पाद्वारे निर्माण होणारी वीज थेट शेतीपंपांना पुरवली जाते. यामुळे शेतकऱ्यांना रात्रीऐवजी दिवसा ८ ते १० तास सलग वीज मिळणे शक्य झाले आहे. या व्यतिरिक्त उपकेंद्राच्या अगदी जवळ वीज निर्मिती होत असल्याने शेतीपंपांना मिळणाऱ्या या विजेचा दाब स्थिर राहतो, परिणामी मोटारी जळण्याचे प्रमाण कमी होऊन शेतकऱ्यांचे आर्थिक नुकसान टळते त्यामुळे हा प्रकल्प केवळ वीज निर्मिती केंद्र नसून, तो जामखेडच्या शेतीला शाश्वत आणि हक्काची वीज देणारा एक 'ऊर्जा स्रोत' आहे.

- **जामखेड सोलर प्रोजेक्ट II:** हा प्रामुख्याने शापूरजी पालनजी इन्फ्रास्ट्रक्चर कॅपिटल (Shapoorji Pallonji Infrastructure Capital) आणि त्यांच्या संबंधित कंपन्यांद्वारे राबवलेला एक महत्वाचा टप्पा आहे. 'प्रोजेक्ट १' च्या यशानंतर, त्यांनी आपली क्षमता वाढवण्यासाठी जामखेड सोलर प्रोजेक्ट II ची उभारणी केली. हा प्रकल्प तांत्रिकदृष्ट्या अधिक प्रगत आणि कार्यक्षम मानला जातो. या दुसऱ्या टप्प्याची क्षमता साधारणपणे १० मेगावॉट (MW) इतकी आहे. यामध्ये मोनो-पर्क (Mono-PERC) सौर पेशींचा वापर करण्यात आला आहे, जे कमी सूर्यप्रकाशातही (ढगाळ वातावरणात) अधिक वीज निर्मिती करण्यास सक्षम असतात. प्रकल्पात सोलर पॅनेल्स स्वच्छ करण्यासाठी काही ठिकाणी 'रोबोटिक क्लीनिंग' (Robotic Cleaning) तंत्रज्ञानाचा वापर केला जातो, ज्यामुळे पाण्याची बचत होते आणि पॅनेल्सची कार्यक्षमता टिकून राहते. हा प्रकल्प देखील महावितरण (MSEDCL) सोबतच्या दीर्घकालीन करारांतर्गत जोडलेला आहे. ज्यातून तयार झालेली वीज जवळच्या उच्च दाबाच्या उपकेंद्रात (Substation) सोडून ती राज्य ग्रीडमध्ये समाविष्ट केली जाते. हा प्रकल्प जामखेडच्या पडीक आणि माळरान जमिनीवर विकसित केल्यामुळे स्थानिक पर्यावरणाला धक्का न लावता ऊर्जा निर्मिती केली जात आहे. प्रकल्प उभारणीच्या काळात शेकडो स्थानिक मजुरांना काम मिळाले, तर सध्या तांत्रिक कामांसाठी स्थानिक तरुणांना प्राधान्य दिले जात असल्याने मोठ्या प्रमाणात रोजगार निर्मिती झालेली आहे. .

## इतर सौर ऊर्जा सुविधा

जामखेड तालुक्यात मुख्यमंत्री सौर कृषी वाहिनी योजनेच्या माध्यमातून शेतकऱ्यांना दिवसा वीज उपलब्ध करून देण्यासाठी तालुक्यातील रिकाम्या शासकीय जमिनींवर सौर संच बसवले जात आहेत. यामुळे शेतीपंपांना रात्रीच्या ऐवजी दिवसा वीज मिळण्यास मदत होत होते. या व्यतिरिक्त

कुसुम योजनेच्या माध्यमातून (PM-KUSUM): तालुक्यातील वैयक्तिक शेतकऱ्यांना शेतपंपांसाठी सौर पंप (Solar Pumps) मोठ्या प्रमाणावर वितरित करण्यात आले आहेत त्यामुळेही मोठ्या प्रमाणात शेतकऱ्यांनी सौर पंप वापरण्यास सुरुवात केलेली आहे. रहिवासी आणि व्यावसायिक इमारतींवरतीच्या छतावरील सौर ऊर्जा यंत्रणा (Rooftop Solar) बसवण्याकडे शासनाने विशेष लक्ष दिल्याने पीएम सूर्य घर (रूटॉप सोलर योजनेच्या माध्यमातूनही असंख्य लोकांनी जामखेड तालुक्यात सौर ऊर्जा यंत्रणा (Rooftop Solar) बसवलेली आहे.

## निष्कर्ष

वरील प्रकारच्या अभ्यासातून असे निदर्शनात येते की, संशोधनांती असे सिद्ध जामखेड तालुक्यात पवन व सौर ऊर्जा निर्मितीस अत्यंत पोषक वातावरण असून या भागातून मोठ्या प्रमाणात नूतनीकरणक्षम ऊर्जा निर्मितीची क्षमता अधिक आहे असल्याने या भागात नवनवीन ऊर्जा निर्मिती प्रकल्प उभारले जात आहेत त्यामुळे हा तालुका ऊर्जा क्षेत्रात स्वयंपूर्ण होण्याच्या मार्गावर आहे. भौगोलिक अनुकूलता आणि शासकीय पाठबळ यांच्या जोडीला जर आधुनिक 'एनर्जी स्टोरेज' तंत्रज्ञान वापरले, तर हा तालुका 'नेट-झिरो' (Net-Zero) होणारा पहिला तालुका ठरू शकतो.

शासनाने खुल्या प्रवेशाद्वारे (Open Access) वीज विक्रीची परवानगी दिल्याने मोठ्या खासगी कंपन्या (उदा. सुझलॉन, टाटा पॉवर) जामखेडकडे वळल्या आहेत. नूतनीकरणक्षम ऊर्जेमुळे पर्यावरणाचा न्हास न होता विकास साध्य होत असल्याने तालुक्यात जरी सुरुवातीची गुंतवणूक कमी असली, तरी दीर्घकालीन विचार करता ही ऊर्जा अत्यंत स्वस्त आणि प्रदूषणमुक्त असल्याने तालुक्यातील शाश्वत विकासासाठी हे क्षेत्र महत्वाचा आर्थिक कणा ठरणार आहे.

मुख्यमंत्री सौर कृषी वाहिनी या योजनेमुळे महावितरणच्या उपकेंद्रांजवळील पडीक जमिनीवर सौर प्रकल्प उभारले जात आहेत. यामुळे शेतकऱ्यांना दिवसा वीज मिळणे सुलभ झाले आहे. या प्रकल्पांमुळे स्थानिकांना सुरक्षा रक्षक, तांत्रिक सहाय्यक आणि देखभाल कामात स्थानिक लोकांना रोजगार मिळाला आहे तर कांही शेतकऱ्यांच्या जमिनीला चांगले भाडे मिळत असल्याने शेतकऱ्यांचे उत्पन्न वाढले आहे.

## उपाययोजना

- तालुक्यातील संभाव्य ऊर्जा निर्मिती क्षमता पाहता या भागात आणखीन नवनवीन व्यावसायिकांना प्रकल्प उभारण्यास प्रोत्साहन द्यावे.

- शेतकऱ्यांना शेतीद्वारे सामूहिक सौर प्रकल्प उभारण्यास प्रोत्साहन द्यावे.
- 'एनर्जी स्टोरेज सिस्टम' (Batteries) वर अधिक गुंतवणूक करावी जेणेकरून रात्रीही सौर ऊर्जेचा वापर करता येईल.
- स्थानिक युवकांसाठी 'सोलर आणि विंड टेक्नोलॉजी' कोर्सेस तालुक्यात सुरु करावेत.

### संदर्भ

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