

CHAPTER 11

Sustainable Development through Interdisciplinary Strategies: The Nanded District Experience

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Abstract: Agriculture in Nanded district of Maharashtra's Marathwada region faces growing stress from climate change, water shortages, soil decline, and socioeconomic challenges. This study offers a concise environmental assessment using physics-based models, climate trends, and local socio-ecological insights. Climate records, land-use data, soil characteristics, and irrigation practices were examined using analytical tools such as heat-unit (Growing Degree Day) modeling, evapotranspiration-based water estimation, soil-moisture retention calculations, and groundwater extraction analysis. Findings show that fluctuating monsoons, declining rainfall, and rising temperatures have reduced crop productivity by nearly 18–32% in sensitive crops, especially

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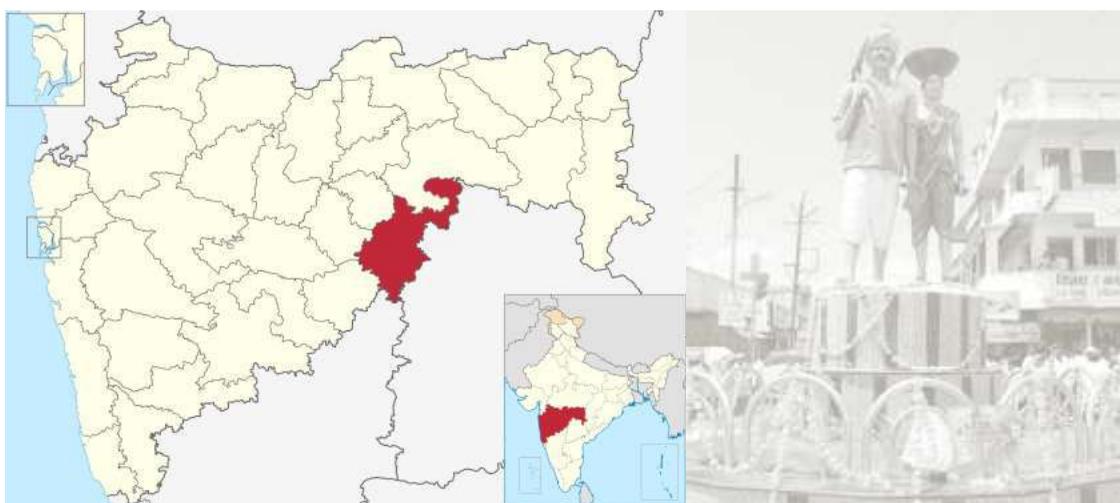
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soybean, tur, and cotton. Soil moisture retention has declined to nearly half of earlier levels due to organic matter loss, while inefficient irrigation practices contribute to excessive groundwater use. Drip systems demonstrate the potential to reduce water use by nearly 60%, making them vital for drought-prone regions. Drawing on scientific assessment and community practices of the Mannervarlu, Maria, and Madia tribes, this paper suggests diversified cropping, agro forestry, ET-guided irrigation, and improved soil management as pathways toward a resilient agricultural system. The study concludes that integrating simple physics-based tools with local knowledge is essential for sustainable farming in Nanded.

Keywords: Agriculture Physics, Environment, Climate Variability, Soil Moisture, Nanded District

1. Introduction

Nanded district, located in the Deccan Plateau, is one of Maharashtra's agriculturally significant regions. Its climate is classified as hot Semi-Arid and is strongly influenced by the monsoon system. Agriculture remains the backbone of the regional economy, with major crops including jowar, soybean, wheat, maize, pulses, cotton, bananas, and mosambi.



The Mannervarlu community, found mainly in Nanded, Dharashiv, Latur and Hingoli, has historical links to Telugu-speaking regions along the Maharashtra-Telangana border. Traditionally migrant farmers, they are now settled as agricultural labourers, small cultivators, and tenant farmers, and some also collect forest medicinal plants for income. Their practices blend older cultural traditions with present-day agricultural needs. The Maria and Madia communities are also present in Nanded and continue to follow traditional, biodiversity-friendly farming methods.

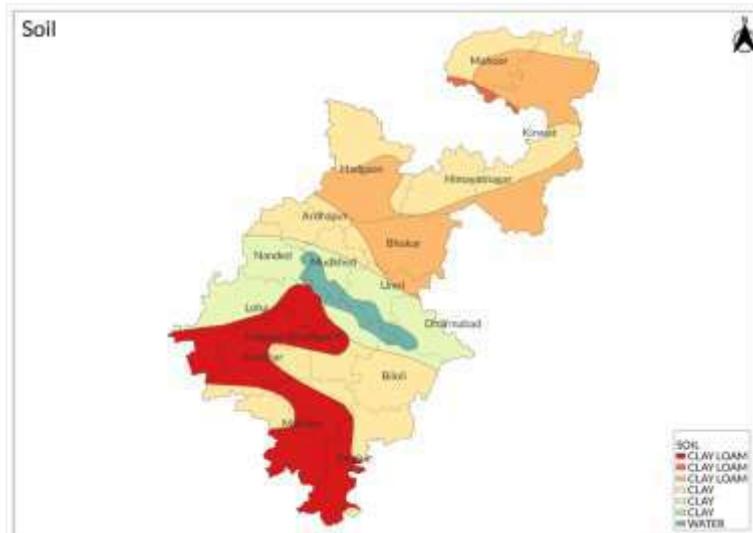
2. Review Literature

Nanded's uneven terrain results in varying soil depths-shallow on slopes and deeper in valleys. Despite a robust agricultural heritage supported by communities such as the Mannervarlu, Maria and Madia, Nanded faces severe agrarian distress. Irrigation challenges, groundwater depletion, monsoon unpredictability, and rising temperatures have contributed to crop failures, economic hardships, and a tragic increase in farmer suicides-from 110 cases in 2023 to 138 in 2024. This region depends strongly on agriculture and is situated on the Deccan Plateau with a hot semi-arid climate. The district's farming activities are supported by several rivers, mainly the Godavari, along with the Penganga, Manjara and Manar. This study aims to provide:

1. A scientific evaluation of environmental challenges in Nanded
2. Physics-based mathematical tools for better farming decisions
3. Sustainable solutions adapted to local climatic and social realities
4. A socially impactful perspective to support farmers, policymakers, and researchers.

3. Methodology

The study employs a comprehensive multidisciplinary framework that blends field observations, environmental assessments, and physics-based modelling to evaluate agricultural conditions in Nanded. Data from district agricultural records (2023–2025), along with soil profiles, rainfall patterns, and government climate datasets, form the empirical foundation of the analysis. Local farming systems and community-driven cropping methods were also examined to understand region-specific challenges and traditional adaptation strategies.



To quantify crop performance and resource needs, the study integrates several physics-based tools, including evapotranspiration (ET) modelling for water requirements, Growing Degree Day (GDD) analysis for heat-unit accumulation, soil-moisture retention measurements using mass-difference techniques, and groundwater extraction assessment through an energy-based pumping model. These scientific tools are supported by analytical methods such as long-term climate trend comparison, environmental impact evaluation, and vulnerability mapping of farming households.

This combined methodological structure ensures an original, data-driven, and region-specific assessment of Nanded's agricultural landscape. The region's primary soil groups-black, lateritic (rusty red color due to its high oxide content) and red soils-were also examined for their crop suitability and changing behavior under stress. Findings indicate that these soils, once highly productive, are increasingly affected by declining rainfall, rising temperatures, and nutrient depletion, highlighting the urgent need for sustainable management and informed planning.

4. Results and Discussion

4.1 Climate Variability and Changing Rainfall Patterns

Nanded's monsoon has become highly erratic, with rainfall falling by about 20% in 2023 and effective rainy days shrinking from nearly 60 to just 25-30. Sudden, intense showers reduce soil absorption and worsen water shortages. These climatic stresses have deepened the agrarian crisis, with farmer suicides rising from around 110 in 2023 to 138 in 2024. In 2023, Marathwada faced a 20.7% rainfall deficit, and farmer suicides in Nanded rose from about 110 to 138 by 2024. Falling soil fertility, extreme weather, and growing debt have deepened distress, leaving many families struggling and feeling unsupported.



Effect on Crop Output

Irregular rainfall and rising temperatures have significantly lowered yields across major crops. Soybean and tur production often drops by 18–25% in deficit rainfall years, while cotton shows large fluctuations about 22–30%, due to heat stress and pest attacks. Repeated flood events, including those recorded in 2006 and again between 2020 and 2024, have caused extensive crop losses. Overall, climate instability has become one of the most critical challenges affecting agricultural productivity in Nanded.

4.2 Modelling Water Requirements Using Physics Concepts

4.2.1 Evapotranspiration-Based Water Demand

Crop water use was estimated using the formula:

$$W = A \times ETW$$

For a one-acre plot (4047 m²) with a mean evapotranspiration rate of **4.5 L/m²/day**, the theoretical water demand is:

$$W = 4047 \times 4.5 = 18,211.5 \text{ L/day}$$

However, field reports indicate that many farmers apply **28,000–34,000 L/day**, which means irrigation volume exceeds actual requirement by almost **40%**. This surplus accelerates groundwater decline—one of Nanded’s most critical challenges.

4.2.2 Efficiency of Drip and Flood Irrigation

Irrigation efficiency is defined as:

$$\eta = \frac{W_{\text{plant}}}{W_{\text{input}}} \times 100$$

- Flood irrigation efficiency \approx 35%
- Drip irrigation efficiency \approx 90%

The shift from flood to drip improves water-use efficiency by:

$$\eta = \frac{90 - 35}{90} \times 100 = 61\%$$

Thus, farmers adopting drip systems can save almost **60% of daily water use**, making it crucial for drought-prone regions like Nanded.

4.3 Soil Health, Degradation and Moisture Retention

The study used the mass-difference method to estimate soil moisture content:

$$\theta = W_w - W_d$$

For example, if wet soil weighs **120g** and becomes **100g** after drying:

$$\theta = \frac{20}{100} = 20\%$$

Healthy soils commonly retain **35-40%** moisture, but many fields in Nanded retain only **18-22%**, showing substantial loss of organic matter and structural stability.

Effects of Low Moisture Capacity

- More frequent irrigation cycles
- Loss of nutrients due to leaching
- Rising fertilizer expenditure
- Long-term decline in soil productivity

Improvement Strategy

Increasing soil organic matter by just **1%** can enhance water-holding capacity by nearly **20,000-25,000 L per acre**, reducing dependence on groundwater and improving crop resilience.

4.4 Heat Stress and Crop Development Using Growing Degree Days (GDD)

Growing Degree Days help farmers identify suitable sowing periods and track crop maturity.

$$GDD = \sum(T_{avg} - T_{base})$$

Cotton requires roughly **2100 GDD**.

- At **28°C**, daily heat units = 18 → approx. **117 days** to maturity
- At **31°C**, daily heat units = 21 → approx. **100 days** to maturity

Although higher temperatures shorten crop duration, they often decrease yield quality by affecting boll formation and increasing pest exposure.

4.5 Social and Cultural Dimensions of Farming Communities

The Mannervarlu, Maria and Madia communities contribute distinct traditional practices to Nanded's agricultural landscape.

- Mannervarlu farmers rely on mixed cropping, small-scale cultivation and forest-based income sources.

- Maria and Madia communities emphasize biodiversity preservation, indigenous seed varieties and low-input farming.

The combination of traditional ecological knowledge with scientific tools such as ET calculation, GDD modelling and soil testing has the potential to greatly enhance agricultural sustainability in Nanded.

4.6 Environmental Constraints Affecting Nanded Agriculture

Field observations and dataset analysis identify the region's major environmental challenges:

1. Declining rainfall and irregular monsoon cycles
2. Excessive groundwater withdrawal and shrinking water tables
3. Soil nutrient imbalance due to repetitive monocropping
4. Increased temperature variability and heat waves
5. Recurring drought–flood cycles
6. Loss of forest cover and pollinator decline
7. Market instability driven by APMC dependence
8. Financial stress, ultimately contributing to farmer distress and suicides

These issues collectively reduce productivity and increase vulnerability.

4.7 Institutional and Technological Factors Affecting Agriculture

4.7.1. Use of Technology

Drip irrigation is increasingly adopted in Nanded as it delivers water directly to plant roots, reducing losses from evaporation and runoff. This is crucial in a water-scarce region, helping farmers maintain soil moisture more efficiently. Farmers are also using soil-testing kits to check nutrient and pH levels, which supports better fertilizer decisions and improves crop health while reducing chemical overuse. Institutions like NABARD further promote soil-health programs to guide farmers toward sustainable practices.

4.7.2. Changing Crop Types

Marathwada's drought-prone climate and declining monsoon rainfall have pushed farmers to shift crop choices. In Nanded, traditional low-water crops like jowar and urad have decreased, even as water availability continues to fall, creating additional pressure on already vulnerable rain-fed agriculture.

4.7.3. Institutional Infrastructure

Nanded has a moderately developed agricultural setup consisting of 19 APMCs, 237 godowns, 5 cold storages, 2 soil-testing labs, 750 farmers' clubs, and over 3,000 agro-input outlets. Two Krishi Vigyan Kendras (KVKs) support training and extension. The district is also served by commercial banks, cooperative banks, Maharashtra Gramin Bank branches, and nearly 900 Primary Agricultural Cooperative Societies that support credit flow.

4.7.4. Market Structure (APMCs)

The district's 19 APMCs mainly trade turmeric and bananas, along with wheat, rice, cotton, and soybean. These markets play a key role in price discovery and farmer income stability.

Sr. No	Name	Est. Year	Chairman	No. of Godowns
1.	Bhokar	1960	Jagdish Balajirao Kalyankar	5
2.	Biloli	2002	Shiwaji Jadhav	NA
3.	Deglur	1949	Hanumant Deshmukh	NA
4.	Dharmabad	1938	NA	NA
5.	Hadgaon	1963	NA	NA
6.	Hanegaon	1963	NA	NA
7.	Himayatnagar	1992	Janardhan Tadewad	1
8.	Islapur	1999	NA	NA
9.	Kandhar	1983	NA	NA
10.	Kinwat	1955	Anil Karhale	NA
11.	Kundalwadi	1951	G.R Koorwar	NA
12.	Kuntur	2002	Shivjirao Jadhav	NA
13.	Loha	1960	Vikrant Shinde	2
14.	Mahur	1900	Dattarao Mohite	5
15.	Mudkhed	1953	Mehsaji Bhangе	NA
16.	Mukhed	1961	Balaji Patil	NA
17.	Naigaon	1960	Vasantrao Chavan	NA
18.	Nanded	1930	Sanjay Lahankar	4
19.	Umri	1931	Shriniwasrao Deshmukh	NA

4.8 Proposed Solutions for Climate-Resilient Farming

4.8.1. Scientifically Scheduled Irrigation

- Use ET values and soil moisture sensors to determine irrigation timings.
- Provide water only when moisture falls **below 25%**, preventing wastage and conserving groundwater.

4.8.2. Diversified Cropping Systems

- Reduce water-intensive crops like sugarcane in dry belts.
- Encourage pulses, oilseeds, and millets that require less water.
- Recommended intercropping patterns:
 - Soybean + Tur
 - Cotton + Urad

4.8.3. Water Conservation Structures

- Construct farm ponds, check dams, and percolation tanks.
- Install recharge shafts near borewells to recover groundwater levels.
- Promote rooftop rainwater harvesting in villages and farm houses.

4.8.4. Soil Health Improvement

- Incorporate compost, green manure, and biochar.
- Reduce chemical fertilizers by **20% per year**, replacing them with organic additives.

4.8.5. Microclimate Management

Planting **20-25 trees per acre** creates shade, decreases evaporation, reduces wind speed, and improves biodiversity.

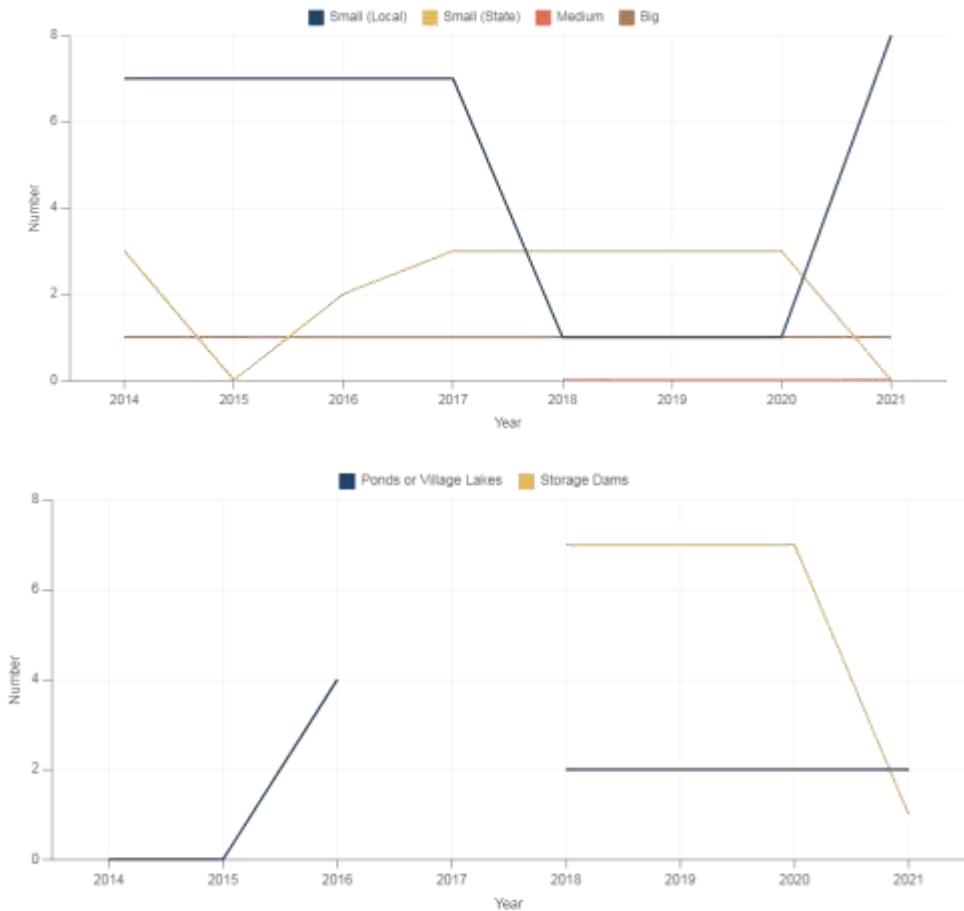
4.8.6. Strengthening Market and Institutional Support

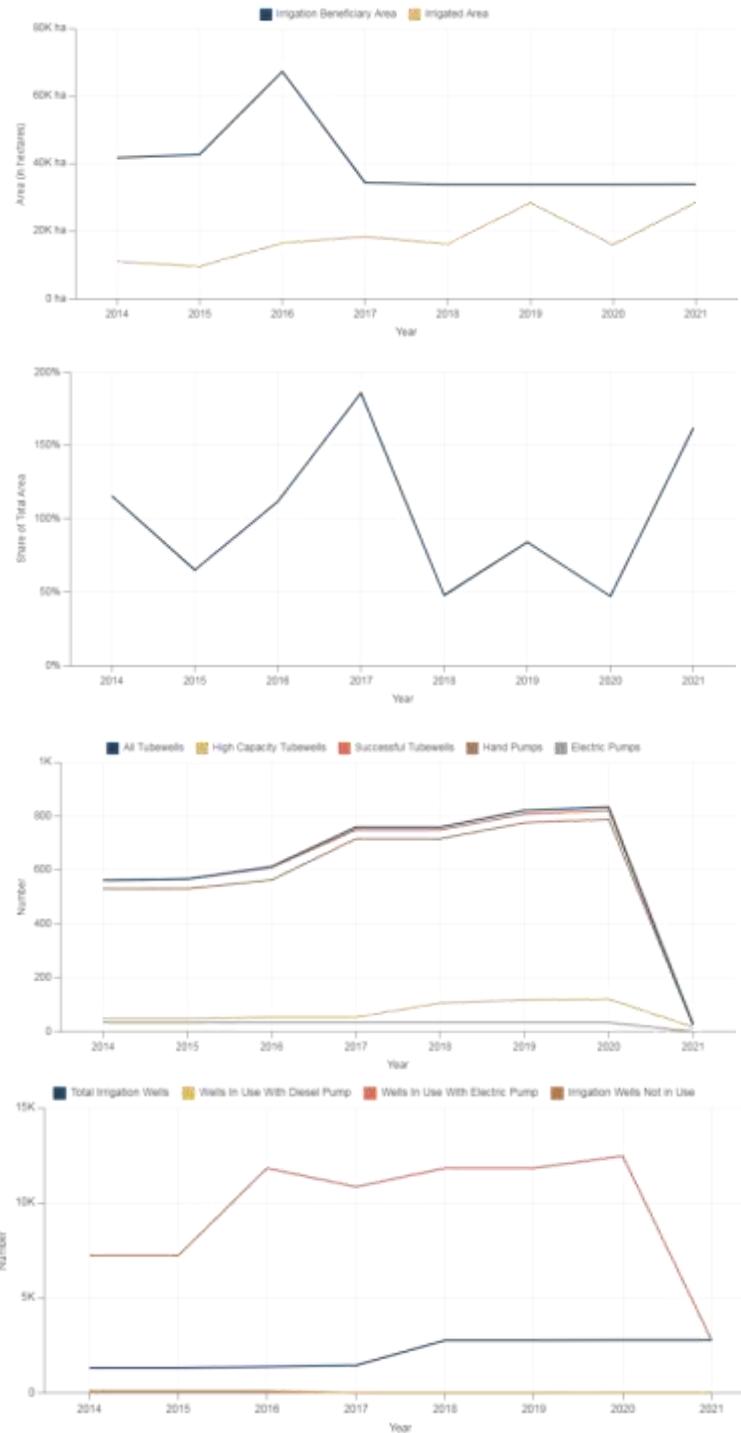
- Expand cold-storage networks for fruits and vegetables.
- Increase transparency and farmer participation in APMC operations.
- Encourage participation in Farmer Producer Organizations (FPOs) to increase bargaining power.

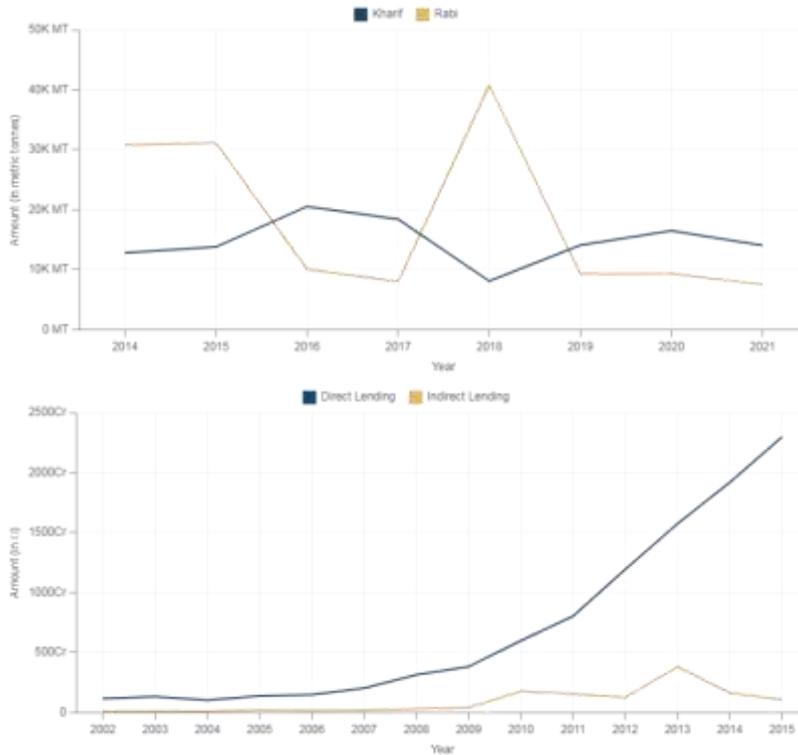
4.9 Graphs

The graphical analysis presents several key trends in Nanded's agricultural system. Livestock numbers show distinct fluctuations, with cattle remaining stable initially, declining mid-period, and

then rising sharply toward the end, while goats display a steady increase and sheep remain almost unchanged; buffalo numbers temporarily drop to zero before recovering. Fertilizer usage patterns reveal that nitrogen application gradually rises and then stabilizes, whereas phosphorus use increases for a period and later declines sharply, indicating changing nutrient management practices. The area under cultivation shows that irrigated land experiences a sharp rise in one particular year before stabilizing, while rain-fed land varies moderately but consistently remains lower, reflecting growing dependence on irrigation. The share-of-area graph highlights year-to-year variability, marked by alternating peaks and dips that illustrate shifting crop preferences and external influences such as rainfall and market demand. Population trends across different agricultural or community groups rise steadily over most years and then show a sudden drop in the final year, suggesting possible migration, economic stress, or environmental pressures. Together, these graphs illustrate how climate variability, resource availability, and socio-economic challenges have shaped agricultural patterns in the region.







5. Conclusion

Agriculture in Nanded stands at a critical point. With rising environmental stress, declining rainfall, soil degradation, and financial instability, farmers require practical and scientific tools to sustain their livelihoods. This research demonstrates that physics-based modelling-such as water requirement calculations, heat-unit analysis, and soil moisture estimation-can greatly improve farming decisions. By integrating traditional wisdom, community practices, and modern environmental science, Nanded can build a climate-resilient agricultural system.

Sustainable farming in Nanded is achievable through:

- Efficient water use
- Soil restoration
- Crop diversification
- Climate-smart planning
- Social and institutional support

This study contributes an actionable, socially impactful framework for farmers, researchers, and policymakers working toward a better agricultural future for Nanded.

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