GIS-Based Analysis of Soil Health: A Comparative Study of Maharashtra and Tamil Nadu

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Abstract

This research explores the application of **Geographic Information Systems** (GIS), particularly PostGIS and QGIS software for mapping and analyzing soil health. By utilizing spatial queries and datasets, we investigate soil health parameters, including contamination levels and erosion risks, to support sustainable agricultural practices. The study integrates tools like **RUSLE** (Revised Universal Soil Loss Equation) to assess factors such as slope steepness (LS), soil erodibility (K), rainfall erosivity (R), and crop management (C). Incorporating GIS-based spatial analysis provides actionable insights into contamination hotspots, land-use optimization, and conservation strategies, enabling data-driven solutions to promote long-term agricultural sustainability. Additionally, this paper includes a **comparative study of agricultural practices in Maharashtra and Tamil Nadu**, using GIS data, crop patterns, and government-sourced queries to support the analysis.

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1. Introduction

1.1 Background

Soil health is the cornerstone of agricultural productivity and environmental sustainability. However, soil degradation from erosion, contamination by industrial pollutants, and intensive agricultural practices poses a significant threat to global food security. Soil erosion leads to the loss of fertile topsoil, reduces land productivity, and disrupts ecosystems, while contamination compromises the safety and nutritional value of crops. Addressing these challenges requires precise, location-specific insights into soil health dynamics. Geographic Information Systems (GIS) provide an innovative platform for understanding and mitigating these issues, enabling sustainable agricultural practices to thrive despite environmental and human pressures.

1.2 Importance of GIS in Soil Analysis

GIS has revolutionized environmental and agricultural research by providing tools for spatial analysis and visualization. It enables the mapping of soil properties, identification of vulnerable regions, and prediction of contamination or erosion trends. GIS tools like QGIS and integration with databases (e.g., PostGIS) allow researchers to overlay spatial layers, analyze patterns, and make data-driven decisions. For soil analysis, GIS facilitates real-time monitoring of soil health parameters, supports predictive modeling using erosion factors such as RUSLE, and helps design conservation strategies tailored to local conditions. By adopting GIS, researchers and policymakers can enhance sustainable agriculture, optimize land use, and protect natural resources.

2. Related Work

2.1 GIS in Agriculture and Soil Mapping

Over the years, GIS has proven invaluable in agricultural planning. It has been used to map soil fertility, analyze contamination levels, and evaluate erosion risks. Research shows GIS applications have helped farmers identify optimal land use patterns, select appropriate crops, and adopt conservation techniques like contour farming and crop rotation. However, studies often focus on either soil erosion or contamination, rarely integrating both into a unified framework. Recent developments, such as QGIS and open-source geospatial databases, offer opportunities to bridge these gaps and develop comprehensive soil management systems.

2.2 Advances in Soil Erosion and Contamination Models

Models like RUSLE have long been used to quantify soil erosion by considering factors such as slope, rainfall, and land cover. Advances in remote sensing and GIS integration have improved the accuracy and scalability of these models. Meanwhile, studies on soil contamination have shifted from localized assessments to broader spatial analyses using GIS, enabling researchers to track pollutants and identify hotspots. However, integrating erosion and contamination models remains a challenge. This research leverages RUSLE and contamination mapping in a GIS framework to provide actionable insights into sustainable land management.

3. Methodology

3.1 Data Sources

The data for this research was primarily sourced from the following two reputable platforms:

- Bhuvan Indian Geo Platform of ISRO: This platform provided high-resolution **Digital Elevation Models (DEM)**, essential for slope analysis and the calculation of the LS factor. It also offered valuable **land use/cover data**, which was crucial for analyzing the C factor and understanding land management practices in the target regions.
- Directorate of Economics and Statistics (DES): This resource provided critical datasets, including **rainfall data** for calculating the R factor, and **soil data** related to texture, structure, and organic matter content, which were needed for the K factor calculation and for soil contamination mapping. The

platform also offered comprehensive agricultural datasets that helped in understanding crop patterns and land utilization trends.

These two sources formed the foundation of the data analysis, allowing us to conduct a thorough spatial analysis of soil health in the study regions.

3.2 RUSLE Factor Analysis

3.2.1 LS Factor

The LS factor quantifies the influence of slope length and steepness on erosion. Using DEMs, slope gradients were calculated, and formulas were applied to estimate erosion risk. Raster layers were generated in QGIS to map high-risk areas, emphasizing steep and long slopes.

Key Insights: Maharashtra's hilly regions pose a greater risk for maize-growing areas compared to Tamil Nadu's largely flat rice fields.

3.2.2 K Factor

The K factor represents soil erodibility, which varies based on texture, structure, and organic matter. Soil sample data was processed to assign K values to different soil types. These values were mapped to visualize erodible zones, helping target areas with high erosion potential.

Key Insights: Soil type in Tamil Nadu's rice cultivation is less erodible than Maharashtra's maize-growing zones.

3.2.3 R Factor

Rainfall erosivity was computed using historical rainfall intensity and duration data. Spatial distribution maps of R factors were created in QGIS, identifying regions prone to soil detachment during storms.

Key Insights: Both states have rainfall erosivity challenges, but Tamil Nadu's rice paddies manage it better due to controlled water regimes.

3.2.4 C Factor

The C factor measures the impact of vegetation and land management on soil erosion. Using land cover data, values were assigned to different crop types and ground covers. Maps were produced to highlight areas where vegetation provides minimal protection against erosion.

Key Insights: Rice cultivation inherently mitigates erosion due to water management, while maize fields in Maharashtra face erosion risks post-harvest.

Below table shows a comparative study between Maharashtra and Tamil Nadu.

RUSLE Factor	Maharashtra (Maize Crop)	Tamil Nadu (Rice Crop)
LS Factor	- Slopes are generally moderate in maize-growing areas.	- Rice cultivation often occurs in low-lying, flat terrains.
	- High LS values observed in hilly regions like Western Ghats, leading to erosion.	- Minimal LS factor influence due to lack of significant slope gradients.
K Factor	- Maize is grown in soils with moderate to high erodibility (loamy soils).	- Rice is grown in low erodibility soils like clayey soils with good structure.
	- Soil with higher sand content increases erosion risks.	- Clayey soil resists detachment, reducing overall erosion vulnerability.
R Factor	- Maharashtra receives moderate to heavy rainfall, with high seasonal variability.	- Tamil Nadu experiences variable rainfall, with northeast monsoon contributing significantly.
	- Rainfall erosivity is higher in monsoon months, increasing erosion risk.	- Rainfall intensity during monsoons affects erosion in upland rice areas.
C Factor	- Maize provides moderate soil cover, but post-harvest periods expose soil to erosion.	- Paddy fields are flooded during cultivation, significantly reducing erosion risk.
	- Poor land management practices, like stubble burning, can elevate erosion.	- Land management for rice (terracing, bunding) offers strong erosion control.

4. Results and Analysis

4.1 Comparative Study of Maharashtra and Tamil Nadu

This section presents a detailed comparative analysis of agricultural patterns in Tamil Nadu and Maharashtra, conducted through extensive web scraping and data extraction from government websites. The findings were further substantiated using GIS-based spatial queries, providing concrete visualizations and insights. Below is a summary of our key observations:

Soil Types

- Tamil Nadu features diverse soil types, including red, laterite, black, alluvial, and saline soils, making it suitable for a variety of crops but also prone to salinity issues.
- Maharashtra predominantly consists of black cotton soil, ideal for water-retentive crops like cotton and soybeans.

Crop Patterns

- Tamil Nadu prioritizes water-intensive crops like paddy and sugarcane, whereas Maharashtra has shifted toward pulses and oilseeds, reflecting irrigation development.

Land Utilization and Urbanization

- Tamil Nadu has seen a significant shift toward non-food crop cultivation (29% by 2021), driven by urbanization and industrial expansion.
- Maharashtra, though urbanized, retains higher agricultural coverage, with a marked rise in cash crop cultivation (e.g., soybeans and cotton).

Comparative Table: Tamil Nadu vs Maharashtra Agriculture

Parameter	Tamil Nadu (2010-2021)	Maharashtra (1960-2011)	Differences/Key Points
Types of Soils	Red, laterite, black, alluvial, saline	Black cotton soil, laterite, sandy, alluvial	Tamil Nadu has more salinity in soils; Maharashtra's black soil is dominant.
Crops Grown in Summer	Paddy, sugarcane, groundnuts, pulses	Soybean, cotton, sugarcane, cereals (wheat, jowar)	Tamil Nadu focuses more on water-intensive crops. Maharashtra leans on pulses and oilseeds.
Land Utilization	71% under food crops, shift to non-food (29% by 2021)	41.53% cereals (decline), 23.04% cash crops (growth)	Maharashtra has shifted more to commercial cropping due to irrigation.
Area Under Cultivation (%)	Declined by 3.49% (food crops); minor increase in non-food	Decline in cereals (19%), rise in cash crops (8%)	Both states see declining food crop areas, driven by urbanization and irrigation factors.
Non-Agricultural Use	Increased urbanization and industry expansion	Gradual but lesser compared to Tamil Nadu	Tamil Nadu faces higher pressure from urban expansion.
Economic Development Scope	Diversification into high-value crops, agribusiness hubs	Expansion in agro-based industries, cash crops	Tamil Nadu focuses on exports; Maharashtra on processing.
Use of GIS Technology	Soil mapping, crop monitoring, irrigation planning	Cropping pattern analysis, irrigation efficiency mapping	Both utilize GIS heavily, but Tamil Nadu applies it more for sustainability.

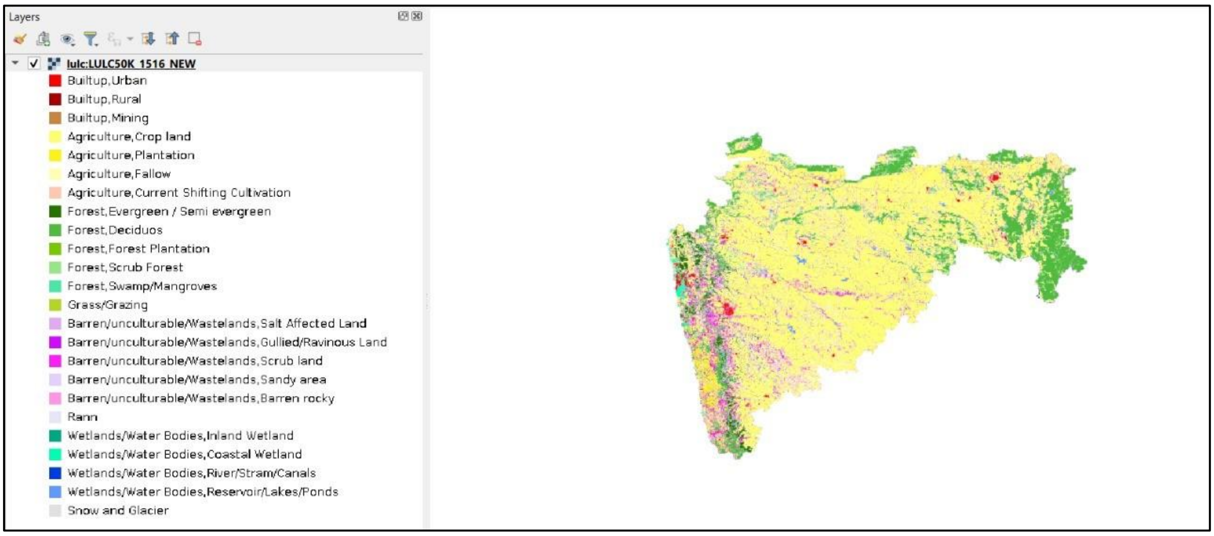
Key Insights from Comparative Study:

- Irrigation: Maharashtra’s irrigation development enabled a significant shift towards cash crops.
- Urbanization: Tamil Nadu faces greater land-use pressures from urban sprawl, leading to intensive agricultural practices.
- GIS Usage: Both states extensively use GIS for agriculture, but Tamil Nadu applies it more for sustainability.

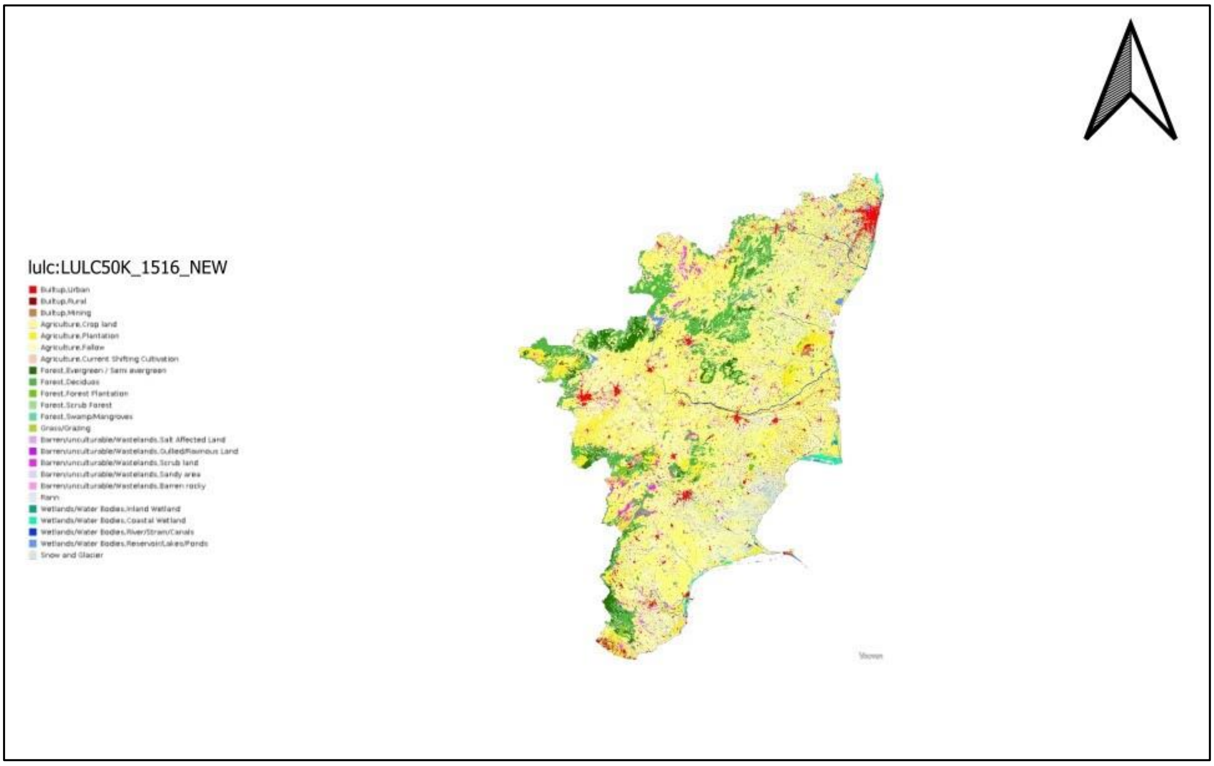
4.2 GIS Application

Spatial queries were executed to map the distribution of crop patterns, irrigation coverage, and urbanization effects. The GIS results validated the shifts in cropping patterns and highlighted areas of stress due to urban sprawl in Tamil Nadu. Screenshots of these GIS outputs will be included to showcase key findings.

QGIS:

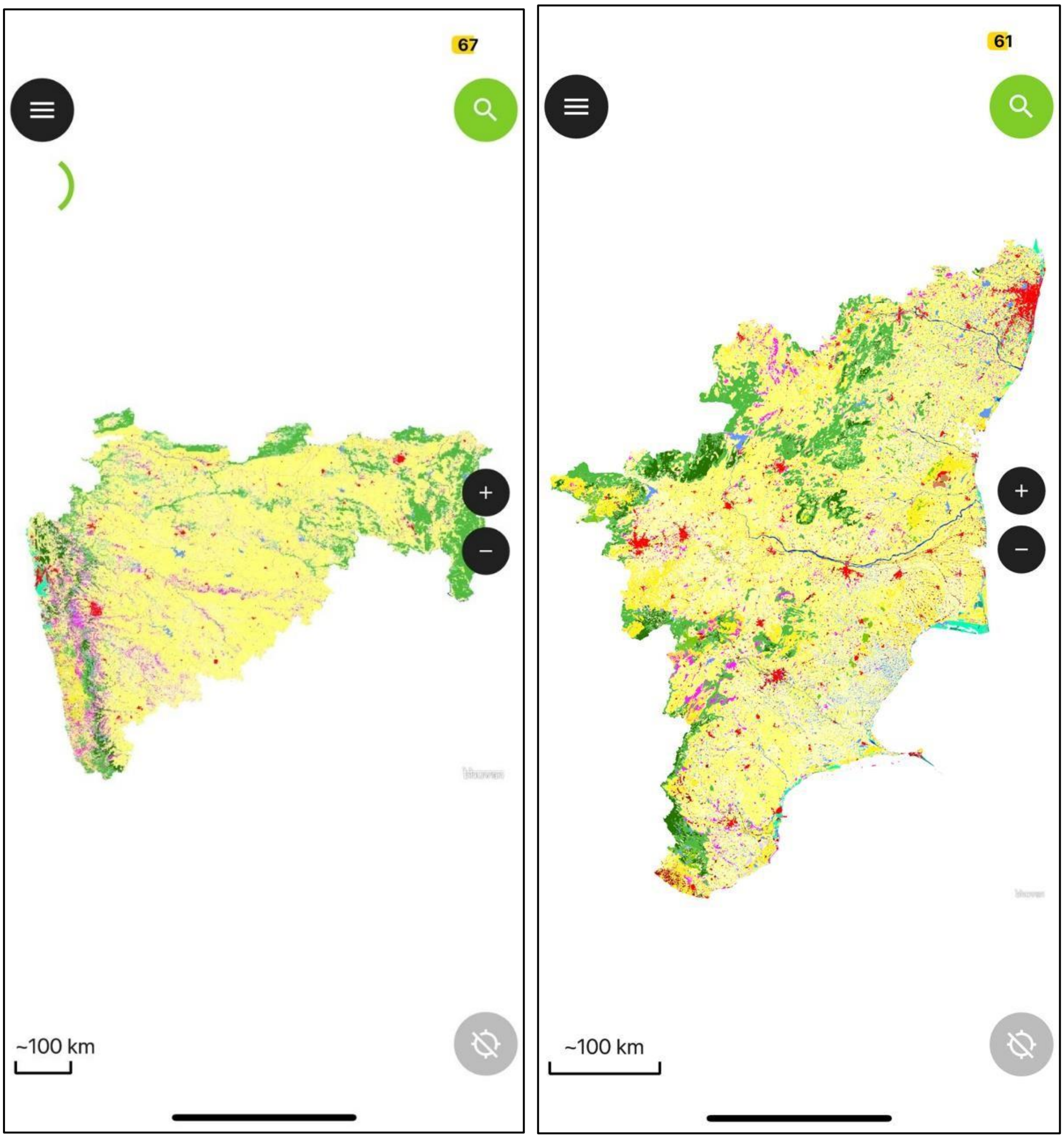


Maharashtra Map: as seen in the QGIS software



Tamil Nadu Map: After Using the "Print Layout" feature and adding the legend and compass before saving.

QField:



Maharashtra and Tamil Nadu maps as seen on the QField mobile app.

4.3 Data Query and Analysis

As part of this study, we leveraged various data queries to extract meaningful insights from crop production data. The data was sourced from an official government database that provides detailed information on crop yields, land area, and production across districts. The following SQL queries were executed to support the research on agricultural productivity, land use trends, and regional performance in both Maharashtra and Tamil Nadu.

1. Average Yield Per Hectare for Each District

This query calculates the average yield per hectare for each district. By grouping the data by district and calculating the average yield, this analysis provides insight into regional productivity levels. The query also orders the results in descending order to highlight the districts with the highest yield.

Results:

	district character varying (100)	avg_yield numeric
1	Sangli	2.8200000000000000
2	Kolhapur	2.5500000000000000
3	Jalgaon	2.3800000000000000
4	Thane	2.3300000000000000
5	Nashik	2.3300000000000000
6	Sindhudurg	2.3300000000000000
7	Dhule	2.2000000000000000
8	Satara	2.1000000000000000
9	Ahmednagar	1.90000000000000000000
10	Nandurbar	1.90000000000000000000
11	Buldhana	1.80000000000000000000
12	Pune	1.75000000000000000000
13	Amravati	1.71000000000000000000
14	Akola	1.67000000000000000000
15	Solapur	1.61000000000000000000
16	Gadchiroli	1.55000000000000000000
17	Beed	1.53000000000000000000

Total rows: 31 of 31 Query complete 00:00:00.133

	district character varying (100)	avg_yield numeric
1	Dindigul	4.8700000000000000
2	Tirupathur	4.6000000000000000
3	Dharmapuri	4.5800000000000000
4	Tirunelveli	4.3700000000000000
5	Thoothukudi	4.3000000000000000
6	Chengalpattu	4.2300000000000000
7	Tiruvannamalai	4.2200000000000000
8	Ranipet	4.2100000000000000
9	Chennai	4.1500000000000000
10	Kanchipuram	4.1200000000000000
11	Krishnagiri	4.1000000000000000
12	Cuddalore	4.0700000000000000
13	Tiruppur	3.9800000000000000
14	Erode	3.9800000000000000
15	Sivaganga	3.9800000000000000
16	Thiruvallur	3.9800000000000000
17	Nagapattinam	3.9800000000000000

Total rows: 35 of 35 Query complete 00:00:00.115

Maharashtra and Tamil Nadu results.

Analysis: The results of this query reveal which districts are performing best in terms of crop yield efficiency. Higher average yields often correlate with regions that have favorable agricultural conditions, advanced farming techniques, or better irrigation facilities. This analysis also helps identify districts where productivity may need improvement, signaling a need for better agricultural practices or resource management. TN is doing better than MH.

2. Total Production by District

This query aggregates total crop production (in tonnes) by district, providing a comprehensive view of production levels across regions. The query groups the data by district and orders it in descending order to showcase the highest production regions.

Results:

	district character varying (100)	total_production numeric
1	Jalgaon	33917.30
2	Solapur	15537.46
3	Aurangabad	11462.49
4	Ahmednagar	11032.75
5	Pune	9624.17

Maharashtra.

Data Output Messages Notifications

SQL

	district character varying (100)	total_production numeric
1	Tiruvannamalai	254210.00
2	Chengalpattu	132103.00
3	Kanchipuram	115789.00
4	Thiruvallur	99578.00
5	Ranipet	70889.00

Tamil Nadu.

Analysis: This query is useful in identifying the top-producing districts in terms of total crop output. By examining these districts, we can assess the scale of agricultural activities and determine which areas contribute most to the overall agricultural output. Such data is crucial for identifying areas that may require infrastructural support, such as storage facilities or improved transportation networks, to better handle high production volumes. In MH we have Jalgaon, Solapur, etc and in TN we have Tiruvannamalai, Chengalpattu, etc. But even then comparatively TN is doing better.

3. Productivity Calculation (Production per Area)

Here, we calculate the productivity of each district by dividing total crop production by the cultivated area in hectares. This productivity metric gives a clearer picture of how efficiently land is being used for crop production. The query also limits the results to the top 10 districts by productivity.

Results:

	district character varying (100)	year character varying (20)	productivity numeric
1	Sangli	2022-2023	2.8179995454250276
2	Kolhapur	2022-2023	2.5500066622251832
3	Jalgaon	2022-2023	2.3820001404593019
4	Sindhudurg	2022-2023	2.3282822085889571
5	Nashik	2022-2023	2.3282782680073876
6	Thane	2022-2023	2.3282666666666667
7	Dhule	2022-2023	2.1999987013071344
8	Satara	2022-2023	2.1000018579072533
9	Ahmednagar	2022-2023	1.9049999395662932
10	Nandurbar	2022-2023	1.9022819677714626

Maharashtra.

	district character varying (100)	year character varying (20)	productivity numeric
1	Dindigul	2022-2023	4.8712947026200038
2	Tirupathur	2022-2023	4.6030481468652581
3	Dharmapuri	2022-2023	4.5777703043551370
4	Tirunelveli	2022-2023	4.3738157629510179
5	Thoothukudi	2022-2023	4.2957414179544650
6	Chengalpattu	2022-2023	4.2252678714217176
7	Tiruvannamalai	2022-2023	4.2175730829213259
8	Ranipet	2022-2023	4.2080612608334323
9	Chennai	2022-2023	4.1538461538461538
10	Kanchipuram	2022-2023	4.1214850145938635

Tamil Nadu.

Analysis: The productivity data helps us understand how effectively the land is being utilized. High productivity can indicate efficient farming practices, good soil health, and favorable climatic conditions. On the other hand, low productivity may suggest challenges such as soil erosion, poor crop management, or inadequate irrigation. This analysis is vital for identifying best practices and areas needing attention to optimize land use. TN was more productive as compared to MH.

4. Districts with High Total Production (Threshold)

This query identifies districts where total production exceeds a certain threshold, in this case, 10,000 tonnes. The results can be used to identify key production areas that might benefit from targeted policies or interventions to maintain or increase their agricultural output.

Results:

	district character varying (100)	total_production numeric
1	Tiruvannamalai	254210.00
2	Chengalpattu	132103.00
3	Kanchipuram	115789.00
4	Thiruvallur	99578.00
5	Ranipet	70889.00
6	Villupuram	65408.00
7	Thanjavur	54972.00
8	Tirunelveli	43397.00
9	Krishnagiri	42727.00
10	Cuddalore	41863.00
11	Kallakurichi	40301.00
12	Thoothukudi	36415.00
13	Thenkasi	35679.00
14	Madurai	33252.00
15	Dharmapuri	27224.00

Total rows: 25 of 25 Query complete 00:00:00.144 Ln 6, Col 1

Tamil Nadu.

	district character varying (100)	total_production numeric
1	Jalgaon	33917.30
2	Solapur	15537.46
3	Aurangabad	11462.49
4	Ahmednagar	11032.75

Maharashtra.

Analysis: This query helps to identify districts that are not just producing high volumes of crops, but those where production levels are significantly higher than average. These regions may have more advanced farming techniques or access to better resources. The findings could be used to develop region-specific policies aimed at sustaining or expanding agricultural output, or they could help pinpoint areas where infrastructure improvements are needed. TN has 15 out of 35 districts that are above the mark but MH only has 4.

5. Districts with Below-Average Area under Cultivation

This query identifies districts where the total cultivated area in a given year is below the district's average over time. It could help pinpoint regions where farming activities are declining or where agricultural expansion might be constrained.

Results:

	district character varying (100)	year character varying (20)	total_area numeric
1	Ariyalur	2022-2023	682.00
2	Chennai	2022-2023	13.00
3	Coimbatore	2022-2023	220.00
4	Dharmapuri	2022-2023	5947.00
5	Dindigul	2022-2023	5229.00
6	Erode	2022-2023	3701.00
7	Karur	2022-2023	703.00
8	Madurai	2022-2023	9076.00
9	Mayiladuthurai	2022-2023	127.00
10	Nagapattinam	2022-2023	623.00
11	Namakkal	2022-2023	880.00
12	Perambalur	2022-2023	2198.00
13	Pudukkottai	2022-2023	4511.00
14	Salem	2022-2023	6072.00
15	Sivaganga	2022-2023	991.00
16	Theni	2022-2023	3570.00
17	Thiruvarur	2022-2023	8202.00
18	Thoothukudi	2022-2023	8477.00
19	Tiruchirappalli	2022-2023	5663.00
20	Tirupathur	2022-2023	2887.00
21	Tiruppur	2022-2023	652.00

Total rows: 23 of 23 Query complete 00:00:00.106 Ln 12, Col 1

	district character varying (100)	year character varying (20)	total_area numeric
1	Akola	2022-2023	315.20
2	Amravati	2022-2023	565.50
3	Beed	2022-2023	1544.00
4	Bhandara	2022-2023	500.50
5	Chandrapur	2022-2023	36.47
6	Dhule	2022-2023	1540.01
7	Gadchiroli	2022-2023	1111.48
8	Gondia	2022-2023	556.12
9	Hingoli	2022-2023	822.68
10	Kolhapur	2022-2023	750.50
11	Latur	2022-2023	366.39
12	Nagpur	2022-2023	167.20
13	Nandurbar	2022-2023	939.54
14	Parbhani	2022-2023	871.90
15	Sangli	2022-2023	1231.92
16	Satara	2022-2023	1076.48
17	Sindhudurg	2022-2023	163.00
18	Thane	2022-2023	75.00
19	Wardha	2022-2023	37.81
20	Washim	2022-2023	192.18
21	Yavatmal	2022-2023	671.30

Total rows: 21 of 21 Query complete 00:00:00.121 Ln 4, Col 18

Tamil Nadu and Maharashtra results.

Analysis: This query reveals districts that may be experiencing a reduction in cultivated land, possibly due to urbanization, land degradation, or changes in crop patterns. Understanding such trends is crucial for addressing the broader issues of land use and ensuring that agricultural areas are protected from encroaching urban development or environmental degradation.

6. Average Production and Area by District

This query calculates the average production and average cultivated area for each district, which helps assess the overall scale of agricultural activities in a region.

Results:

	district character varying (100)	avg_production numeric	avg_area numeric
1	Latur	469.7100000000000000	366.3900000000000000
2	Jalgaon	33917.300000000000	14239.0000000000000000
3	Sangli	3471.5500000000000000	1231.9200000000000000
4	Parbhani	894.7000000000000000	871.9000000000000000
5	Wardha	25.4900000000000000	37.8100000000000000
6	Sindhudurg	379.5100000000000000	163.0000000000000000
7	Bhandara	485.2400000000000000	500.5000000000000000
8	Washim	252.1400000000000000	192.1800000000000000
9	Ahmednagar	11032.7500000000000000	5791.4700000000000000
10	Thane	174.6200000000000000	75.0000000000000000
11	Nandurbar	1787.2700000000000000	939.5400000000000000
12	Gondia	530.8400000000000000	556.1200000000000000
13	Satara	2260.6100000000000000	1076.4800000000000000
14	Kolhapur	1913.7800000000000000	750.5000000000000000
15	Beed	2367.4700000000000000	1544.0000000000000000
16	Gadchiroli	1722.0800000000000000	1111.4800000000000000

Total rows: 31 of 31 Query complete 00:00:00.108 Ln 4, Col 18

Maharashtra.

	district character varying (100)	avg_production numeric	avg_area numeric
1	Kallakurichi	40301.000000000000	10619.0000000000000000
2	Mayiladuthurai	504.0000000000000000	127.0000000000000000
3	Chengalpattu	132103.000000000000	31265.000000000000
4	Dindigul	25472.000000000000	5229.0000000000000000
5	Kanchipuram	115789.000000000000	28094.000000000000
6	Theni	14190.0000000000000000	3570.0000000000000000
7	Ariyalur	2710.0000000000000000	682.0000000000000000
8	Krishnagiri	42727.000000000000	10416.0000000000000000
9	Villupuram	65408.000000000000	20813.000000000000
10	Thiruvarur	26747.000000000000	8202.0000000000000000
11	Thanjavur	54972.000000000000	16975.0000000000000000
12	Tiruppur	2592.0000000000000000	652.0000000000000000
13	Thenkasi	35679.000000000000	9653.0000000000000000
14	Cuddalore	41863.000000000000	10275.0000000000000000
15	Tiruvannamalai	254210.000000000000	60274.000000000000
16	Thiruvallur	99578.000000000000	25017.000000000000

Total rows: 35 of 35 Query complete 00:00:00.127 Ln 6, Col 1

Tamil Nadu.

Analysis: By examining both the average production and the average area, this query provides a balanced view of agricultural performance. Districts with high average production and area are likely to be the major agricultural hubs, while those with lower averages might need more focused interventions to improve both yield and land usage.

7. Districts with the Largest Area under Cultivation

This query identifies the top 5 districts with the largest total area under cultivation, highlighting regions with significant agricultural activity.

Results:

	district character varying (100)	total_area numeric
1	Jalgaon	14239.00
2	Aurangabad	9847.50
3	Solapur	9667.41
4	Ahmednagar	5791.47
5	Pune	5505.82

Maharashtra.

	district character varying (100)	total_area numeric
1	Tiruvannamalai	60274.00
2	Chengalpattu	31265.00
3	Kanchipuram	28094.00
4	Thiruvallur	25017.00
5	Villupuram	20813.00

Tamil Nadu.

Analysis: Identifying districts with the largest cultivation areas is important for policy planning, as these regions may have more complex agricultural landscapes that require comprehensive support. These areas are also likely to face challenges related to land management, soil conservation, and irrigation.

8. Districts with the Smallest Average Yield

This query identifies the districts with the lowest average yield per hectare, which can indicate regions facing challenges such as poor soil quality, lack of irrigation, or insufficient crop management techniques.

Results:

	district character varying (100)	avg_yield numeric
1	Yavatmal	0.53000000000000000000
2	Wardha	0.67000000000000000000
3	Chandrapur	0.68000000000000000000
4	Nagpur	0.86000000000000000000
5	Gondia	0.95000000000000000000

Maharashtra.

	district character varying (100)	avg_yield numeric
1	Villupuram	3.1400000000000000
2	Thanjavur	3.2400000000000000
3	Thiruvarur	3.2600000000000000
4	Tiruchirappalli	3.5500000000000000
5	Virudhunagar	3.5700000000000000

Tamil Nadu.

Analysis: Low yield districts are of particular interest for intervention. These regions may require further investigation to understand the causes of low productivity, whether due to soil health issues, pests, water scarcity, or poor crop management practices. Targeted interventions in these districts can significantly improve overall agricultural output.

9. Crop Production by Zone in Maharashtra

This query examines crop production across different zones within Maharashtra by joining the crop data with district zones. It highlights which zones contribute most to the total crop production in the state.

Results:

	zone character varying (50)	total_production numeric
1	Coastal	174.62
2	Eastern	3287.45
3	Western	23322.47
4	North	5175.29
5	Central	98544.23

Maharashtra.

	zone character varying (50)	total_production numeric
1	Southern	191902.00
2	Coastal	231470.00
3	Western	21676.00
4	Northern	40301.00
5	Central	414034.00

Tamil Nadu.

Analysis: By aggregating production data by zone, this query helps identify the most productive zones within Maharashtra. It provides insights into regional agricultural strengths, which can guide policy decisions or resource allocation to further enhance productivity in these key areas.

5. Discussion

5.1 Impacts on Sustainable Agriculture

This study demonstrates how GIS and RUSLE-based analysis can improve soil health management, mitigate contamination risks, and optimize land use for sustainable agriculture. By integrating spatial data, the research provides actionable insights into erosion and contamination hotspots, facilitating informed decision-making for agricultural policy and practice.

5.2 Challenges and Limitations

Challenges encountered included the limited availability and resolution of some datasets and high computational requirements for large-scale spatial analysis. Additionally, field validation of model outputs is needed to improve the reliability of predictions.

5.3 Future Enhancement

Future research could explore AI-driven predictive models to enhance risk forecasting, as well as the integration of real-time sensor data for dynamic updates. Expanding the study area to incorporate diverse ecosystems and climate zones could also yield valuable insights.

6. Conclusion and Future Work

In conclusion, this study has examined the impact of soil contamination and agricultural practices in Maharashtra and Tamil Nadu, using GIS-based mapping to highlight critical issues related to soil health and erosion. The comparison of agricultural development between the two states revealed differences in cropping patterns, crop productivity, and contamination risks. Through QGIS and QField, we identified areas vulnerable to soil degradation, providing valuable insights for future agricultural policies and interventions.

The findings emphasize the importance of sustainable farming practices and continuous monitoring to mitigate soil erosion and contamination. GIS technologies, such as remote sensing and precision agriculture techniques, offer great potential in improving soil health management and agricultural productivity. Adopting environmentally sustainable practices can support long-term agricultural development and resilience.

Future Work

1. **Enhanced Data Integration**: Future studies can incorporate real-time data from IoT-based soil sensors and satellite imagery for dynamic and more accurate soil health monitoring.
2. **Climate Impact Analysis**: Include climate variability and its influence on soil erosion and contamination, providing insights into adaptation strategies for climate-resilient agriculture.
3. **Crop-Specific Models**: Develop GIS-based models tailored for specific crops to analyse their unique impact on soil health and erosion patterns under varying agricultural practices.
4. **Economic Viability Studies**: Assess the cost-effectiveness of sustainable farming practices and propose actionable policy recommendations for large-scale adoption.
5. **Spatial-Temporal Analysis**: Extend the study by conducting long-term spatial-temporal analysis of soil erosion trends to evaluate the effectiveness of implemented soil conservation measures.
6. **AI-Powered Predictive Tools**: Integrate AI and machine learning to create predictive models for soil erosion and contamination risks, aiding proactive decision-making.
7. **Cross-Regional Comparisons**: Expand the study to include other states or countries, enabling a comparative understanding of soil health challenges under diverse agricultural practices.

By addressing these areas, future research can be built on the current findings, leveraging advanced technologies and participatory approaches to drive sustainable agricultural growth and effective soil management.

7. Acknowledgements

We would like to express our sincere gratitude to the following individuals and institutions for their support and contributions throughout this research:

1. Institutional Support

We extend our deepest thanks to the Department of Information Technology at Veermata Jijabai Technological Institute (VJTI) for providing access to essential tools, including PostGIS, QGIS, and PostgreSQL, along with the necessary computational resources to conduct the experiments and validate the system.

2. Mentorship and Guidance

Special thanks to our faculty advisor, Prof. Vedashree Awati, for her invaluable guidance, insightful feedback, and unwavering support throughout the course of this project. Her expertise in spatial databases and geospatial analysis was instrumental in shaping the research methodology and analysis.

3. Research Contributions

We would also like to acknowledge the authors and researchers whose works have provided the theoretical and practical foundations for this project. Their insights in spatial databases, GIS technology, and agricultural studies were essential in framing the research and contributing to its success.

8. References

Main References:

1. Pagar, S. D. (Year). *Geographical Analysis of Cropping Pattern in Maharashtra State, India*. Department of Geography, MVP Samaj's K.T.H.M. College Nashik-422002, Maharashtra State.
2. Yoganandham, Dr. G. (2021). *An Overview of the Agricultural Development in Tamil Nadu From 2010 to 2021, Focusing on the Area and Production of Major Crops*. Department of Economics, Thiruvalluvar University, Tamil Nadu, India.

Additional References:

3. Kale, P., & Patil, S. (2012). Impact of Ujjani Irrigation project on Agricultural Development of Solapur District. *Maharashtra Bhugolshastra Sanshodhan Patrika*, Vol. 29, No. 1, Jan-June 2012, pp. 111-116.

4. Khullar, D. R. (2014). *India-A Comprehensive Geography*. Kalyani Publishers, New Delhi, pp. 695-702.

5. Kuppan, M., & Yoganandham, G. (2016). A Study on Agricultural Development on Post Reforms Period in India. *International Journal of Business and Administration Research Review*, Vol. 1, No. 1, E-ISSN: 2347-856X, ISSN: 2348-0653.

6. Yoganandham, G., & Babitha, K. (2019). Usage of Drones in Precision Agriculture and Challenges in Introducing Drone Technology for Local Farmers in India. *Journal of Emerging and Innovative Research*, Vol. 6, Issue 3, ISSN: 2349-5162.