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Original Article

Temporal Analysis of Water Resources and Command Area of Satara District

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Abstract

Water resources play a crucial role in sustaining agriculture, livelihoods, and regional development in semi-arid regions. Satara District, Maharashtra, has experienced increasing pressure on its water resources due to fluctuating rainfall patterns, expanding irrigation demands, and growing dependence on both surface and groundwater sources. This study presents a temporal analysis of water resources and irrigation command areas in Satara District for the period 2022–23 to 2024–25. The research examines variations in irrigation infrastructure, net irrigated area, cultivated area, and the distribution of irrigation facilities across different tehsils. Secondary data obtained from official district reports were analyzed using comparative statistical methods and Spearman's Rank Correlation technique. The findings reveal significant spatial disparities in irrigation resources, with Phaltan, Man, and Karad emerging as highly irrigated tehsils, while Mahabaleshwar, Jaoli, and Patan exhibit relatively lower irrigation development. The correlation analysis indicates a moderate positive relationship (R = 0.5) between geographical area and net irrigated area, and a strong positive relationship (R = 0.75) between geographical area and cultivated area. The study highlights that irrigation development depends not only on land area but also on factors such as water availability, infrastructure, rainfall variability, and government interventions. The research emphasizes the need for equitable distribution of irrigation facilities, efficient water management practices, and sustainable planning to strengthen agricultural productivity and resilience in Satara District.

Keywords: *Water Resources, Irrigation Facilities, Command Area, Satara District, Temporal Analysis, Groundwater Resources, Irrigated Agriculture, Spearman's Rank Correlation, Water Management, Sustainable Agriculture.*

Introduction

Water is a critical but finite resource that governs agricultural productivity, rural livelihoods, and ecosystem health in semi-arid regions such as Satara District in Maharashtra. In recent years, this district has witnessed growing pressure on its water resources due to variable rainfall, expanding irrigated areas, and increasing dependence on both surface-water reservoirs and groundwater. The years 2022–23, 2023–24, and 2024–25 represent a particularly significant period, marked by moderate drought-like conditions, lower reservoir storages, and heightened competition for water between irrigation command areas and domestic supply. Satara is drained by the Krishna River and its tributaries such as the Warna, which host several dams and canals that form the backbone of irrigation command areas. These systems, however, are sensitive to monsoon variability and long-term groundwater-level trends, making temporal analysis of water-resource availability and command-area performance essential for sustainable planning. The present research aims to carry out a temporal analysis of water resources and the command area of Satara District over the three-year period 2022–23, 2023–24, and 2024–25.

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It focuses on assessing changes in surface-water storage in key reservoirs, groundwater-availability indicators, gross irrigated area under major crops, cropping intensity, and the extent of command areas served by canal and lift-irrigation systems. By examining these parameters year-wise, the study seeks to highlight inter-annual variability in water-resource availability, identify stress zones in the command area, and provide an evidence base for improving irrigation scheduling, water-use efficiency, and drought-resilient agrarian strategies in Satara.

Objectives:

1. To analyze the spatial distribution of irrigation facilities at the tehsil level in the study area for the year 2024-25.
2. To assess the relationship between total geographical area, net area under irrigation, and total area under cultivation in the study region using Spearman's Rank Correlation method.

Study Area

The present study focuses on Satara District, located in the western part of Maharashtra between 17°05′ to 18°11′ North latitudes and 73°33′ to 74°54′ East longitudes. The district is bounded by Pune District to the north, Solapur District to the east, Sangli District to the south, and Ratnagiri District to the west, forming a transitional zone between the humid Western Ghats and the semi-arid Deccan plateau. Physiographically, the western part of the district is dominated by the Western Ghats (Sahyadris), characterized by rugged terrain, steep slopes, and dense vegetation, while the eastern region consists of undulating plateaus and plains. The average elevation of the district is about 600–700 meters above mean sea level, although elevations are much higher in the western hilly areas such as Mahabaleshwar.

The climate is tropical monsoonal with significant spatial variation in rainfall; the western region receives heavy rainfall exceeding 2000 mm annually, whereas the eastern rain-shadow areas receive around 500–800 mm, leading to uneven water availability across the district. The drainage system is primarily governed by the Krishna River and its tributaries such as the Koyna River, Warna River, and Yerla River, which support several reservoirs and irrigation systems.

Administratively, the district comprises tahsils including Satara, Karad, Wai, Mahabaleshwar, Koregaon, Khatav, Phaltan, Patan, Jaoli, and Man, each showing variations in topography and water resource availability. According to the Census of India 2011, Satara District has a population of about 3 million with a population density of approximately 286 persons per square kilometer. The population is predominantly rural and largely dependent on agriculture, which includes crops such as sugarcane, jowar, wheat, and rice, making the district highly sensitive to fluctuations in water availability and irrigation infrastructure.

Research Methodology

The study is based on secondary data collected from official Agriculture Department reports for the years 2022–23 to 2024–25 in Satara District. Data related to crop patterns, gross irrigated area, and command area were compiled and organized using Microsoft Excel. The analysis is primarily focused on temporal (year-wise) comparison to understand changes over the three-year period, along with tahsil-wise comparison to capture spatial variations within the district. Simple statistical techniques such as percentage change and comparative analysis were used to identify trends, increases, or declines in irrigation and cropping patterns.

The findings are presented using tables, charts, and graphs to clearly illustrate variations across different years and tahsils.

The collected data has been systematically processed and interpreted for analysis. To examine the relationship between total geographical area, net irrigated area, and total cultivated area within the study region, the Spearman's Rank Correlation method has been applied for the only year of 2024-25.

The formula used for calculating Spearman's Rank Correlation is:

$$R = 1 - \frac{6\sum D^2}{N\,(N^2 - 1)}$$

Where:

- R : The rank correlation coefficient,
- D : The difference between the ranks of the two variables for each observation, and
- N : The total number of observations.

Database And Analysis -

Table 1.1 Satara district: Tehsil wise Irrigation Facility,2022 – 2023

Tahsils	Major Project	Medium Project	Minor irrigation Project		Percolati on Tank	KT Weir	Storage Pond	Lift Irrigation Scheme	Well	Total Irrigation Resources
			State Level	Local Level						
Mahabaleshwar	0	0	0	5	8	11	35	27	286	372
Wai	2	2	1	1	34	67	6	36	8050	8199
Khandala	1	0	1	2	99	78	4	13	2702	2900
Phaltan	1	0	2	7	181	123	5	1	12948	13268
Man	0	3	3	8	299	166	0	18	12393	12890
Khatav	0	2	0	7	217	303	1	21	6637	7188
Koregaon	1	2	3	7	159	93	13	13	2695	2986
Satara	2	0	8	6	28	119	12	8	6973	7156
Jaoli	0	1	0	6	29	41	2	4	3600	3683
Patan	2	3	6	2	40	30	3	11	1180	1277
Karad	2	4	7	7	85	131	16	0	11716	11968
Total	11	17	31	58	1179	1162	97	152	69180	**71887**

Source: Socio-Economic Review and Statistical Abstract of Satara District: 2022

Table 1.2Satara district: Tehsil wise Irrigation Facility, 2023 – 2024

Tahsils	Major Project	Medium Project	Minor irrigation Project		Percolati on Tank	KT Weir	Storage Pond	Lift Irrigation Scheme	Well	Total Irrigation Resources
			State Level	Local Level						
Mahabale	0	0	0	5	2	3	35	27	286	358
Wai	2	2	1	1	1	0	6	36	8050	8099
Khandala	1	0	1	1	0	1	4	13	2702	2723
Phaltan	1	0	2	7	7	0	5	1	12948	12971
Man	0	3	3	12	6	4	0	18	12393	12439
Khatav	0	2	0	7	2	5	1	21	6637	6675
Koregaon	1	2	3	7	1	6	13	13	2695	2741
Satara	2	0	8	7	1	5	12	8	6973	7016
Jaoli	0	1	0	6	1	5	2	4	3600	3619
Patan	2	3	6	2	1	1	3	11	1180	1209
Karad	2	4	7	7	1	2	16	0	11716	11755
Total	11	17	31	62	23	32	97	152	69180	**69605**

Source: Socio-Economic Review and Statistical Abstract of Satara District: 2023

Table 1.3 Satara district: Tehsil wise Irrigation Facility, 2024 – 2025

Tahsils	Major Project	Medium Project	Minor irrigation Project		Percolation Tank	KT Weir	Storage Pond	Lift Irrigation Scheme	Well	Total Irrigation Resources
			State Level	Local Level						
Mahabale	0	0	0	5	10	8	34	27	286	370
Wai	2	2	1	2	35	28	13	36	8050	8169
Khandala	1	0	0	1	120	41	15	13	2702	2893
Phaltan	1	0	0	7	247	50	6	1	12948	13260
Man	0	3	8	12	515	101	13	18	12393	13063
Khatav	0	2	8	7	274	210	6	21	6637	7165
Koregaon	1	2	5	7	150	52	2	13	2695	2927
Satara	2	0	8	7	30	56	13	8	6973	7097
Jaoli	0	2	0	6	31	21	2	4	3600	3666
Patan	2	3	13	2	68	15	6	11	1180	1300
Karad	2	4	0	7	90	74	12	0	11716	11905
Total	11	18	43	63	1570	656	122	152	69180	**71815**

Source: Socio-Economic Review and Statistical Abstract of Satara District: 2024 Irrigation Recourses in the study area –

Satara district shows diversity in the irrigation facilities available in the different tahsils. By observing the data tabulated for three consecutive years we can simply conclude that Satara district has very good irrigation resources. Major and minor irrigation projects, KT bandh, percolation tanks, lift irrigation schemes, storage ponds play an important role in the irrigation infrastructure of the district. It is observed from the data that the distribution of irrigation facilities over the district is uneven.

Highly Irrigated Tahsil (Above 10000)

Phaltan, Man and Karad are the three major tahsils where high number of irrigation facilities are available. Phaltan tahsil records one major project, seven minor local level projects, more than two hundred percolation tanks and 12948 wells. In Man tahsil 3 medium projects are observed also state level 8 and local level 12 minor irrigation projects are there in Man tahsil. Highest number of percolation tanks in the district of Satara are in the tahsil of Man i.e. 515. 18 lift irrigation schemes are in operation and 13063 wells are utilized to irrigation in Man tahsil. With 11905 total irrigation resources Karad tahsil ranks in highly irrigated tahsils. Karad tahsil has the highest medium irrigation projects i.e. 4 in the Satara district.

Medium Irrigated Tahsils (5000 To 10000)

Wai, Khatav and Satara are the three tahsils having medium facilities of irrigation in the study area. Wai tahsil has 8169 total irrigation facilities including highest lift irrigation schemes in the district i.e. 36 with 8050 wells. Khatav tahsil has 2 medium projects, 274 percolation tanks, 210 KT weir, 6 storage ponds, 21 lift irrigation schemes and 6637 wells to irrigate the area for various cultivation. Satara tahsil is the third medium irrigated tahsil of the study area with 6973 wells, 30 percolation tanks, 56 KT weirs and 13 storage ponds.

Low Irrigated Tahsils (Below 5000)

Mahabaleshwar, Khandala, Koregaon, Jaoli and Patan are the five tahsils which comes under low irrigated tahsils of Satara district. Mahabaleshwar tahsil has lowest irrigation resources

i.e. 370 including 5 minor local level irrigation projects, 10 percolation tanks, 8 KT weirs, 34 storage tanks, 27 lift irrigation schemes and 286 wells all of these sources were used for various irrigation purposes. Jaoli tahsil has 3600 wells, 31 percolation tanks, 21 KT weirs and only 4 lift irrigation schemes. Patan tahsil counts total 1300 irrigation facilities, under which 68 percolation tanks, 15 KT weirs, 1180 wells are utilized for irrigation.

Correlation between Total Geographical Area to Net Area under Irrigation and Total Area under Cultivation:

The table no. 2 shows that tehsil wise geographic area, net area under irrigation andtotal area under cultivation in hectare of Satara district.

Table: 2
Satara District: Correlation between Total Geographical Area and Net Area under Irrigation and Total Area under Cultivation, 2024-25

Tahsils	Geographic Area of Tehsil (Hectare)	Net Area Under Irrigation (Hectare)	Total Area Under Cultivation (Hectare)
Mahabaleshwar	65537	3186	4899
Wai	71499	7899	39659
Khandala	52106	9330	35665
Phaltan	125061	29309	70277
Man	154314	21866	91267
Khatav	145283	14502	96392
Koregaon	95338	14881	61056
Satara	91536	26677	71996
Jaoli	59025	2759	39984
Patan	147826	9322	54903
Karad	114439	32725	77633
	Correlation	Correlation between total geographical area and net area under irrigation = 0.5	Correlation between total geographical area and net area under Cultivation = 0.75

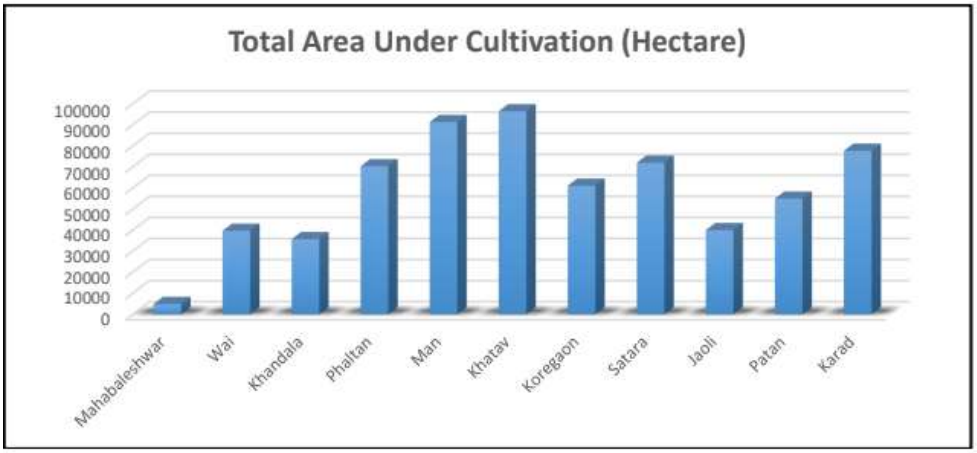
Source: Socio-Economic Review and Statistical Abstract of Satara District: 2024

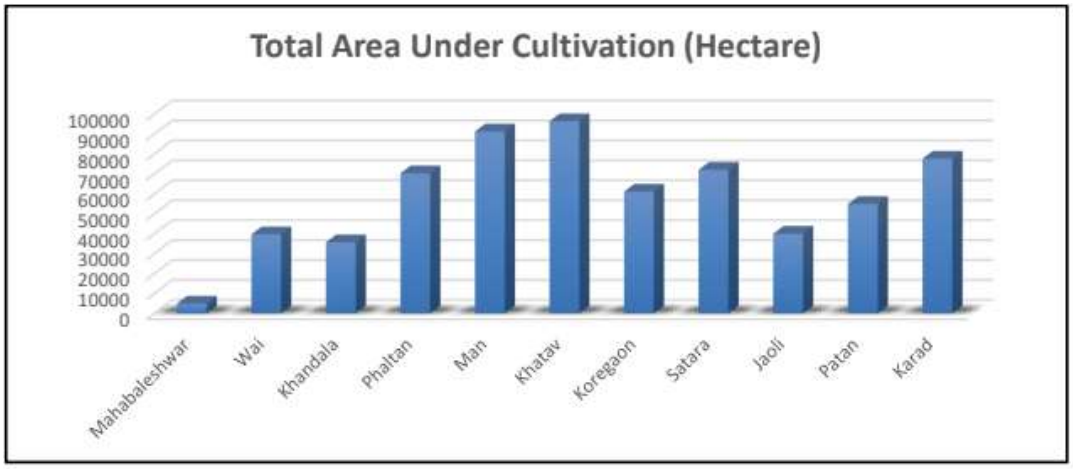
Karad tahsil shows highest net irrigated area in Satara district. Phaltan and Satara tahsils are ranked second and third respectively in net irrigated area. On the other hand, Jaoli Mahabaleshwar shows lowest net irrigated area to the geographical area.

Correlation between total geographical area and net area under irrigation is 0.5. The calculated Spearman's Rank Correlation value (R = 0.5) shows a moderate positive relationship between total geographical area and net irrigated area. This means that generally, bigger tehsils have more irrigated land. However, this relation is not very strong, which shows that irrigation is not equally available in all areas. Other factors like water availability, dams and canals, rainfall, and government facilities also affect irrigation, not just the size of the tehsil.

Khatabv and Man are the two respective tehsils that ranks first and second in the net cultivated area. Contrary to this Mahabaleshwar and Khandala are two least cultivated tahsils of Satara district. Correlation between total geographical area and net area under Cultivation is 0.75. The correlation between total geographical area and net area under cultivation (R = 0.75) shows a strong positive relationship. This means that bigger tehsils generally have more cultivated land. In other words, as the size of the tehsil increases, the area under farming also increases to a large extent.

This relationship is quite strong, which indicates that most of the land in larger tehsils is being used for agriculture. However, in some places, factors like hilly terrain, forests, or less fertile land can still reduce the cultivated area.





Conclusion –

The present study clearly shows the relationship between total geographical area, irrigation, and cultivation among different tehsils of the study region. Using Spearman's Rank Correlation method, it is found that the correlation between geographical area and net irrigated area (R = 0.5) is moderate positive, while the correlation between geographical area and total cultivated area (R = 0.75) is strong positive. In terms of geographical area, Man tehsil ranks first, followed by Patan and Khatav, which means these are the largest tehsils. On the other side, Khandala, Jaoli, and Mahabaleshwar are smaller in size. When we look at irrigation, Karad ranks first with the highest irrigated area, followed by Phaltan and Satara. In contrast, Jaoli and Mahabaleshwar have very low irrigation, showing lack of proper irrigation facilities. The difference in ranks between geographical area and irrigation explains why the correlation is only moderate. Even though larger tehsils like Man and Patan have good irrigation, it is not the same everywhere. For example, Khatav is large in size but has comparatively less irrigation. This shows that irrigation does not depend only on area, but also on factors like water availability, dams, canals, rainfall, and government schemes. When we study cultivation, the relationship is stronger. Khatav ranks first in cultivated area, followed by Man and Karad, which shows these tehsils have more farming activities. Smaller and hilly areas like Mahabaleshwar and Jaoli have less cultivation. Since the cultivation ranks are quite similar to geographical area ranks, the correlation becomes strong. However, some differences are still there due to physical conditions like hilly terrain, forest area, and soil quality. Also, uneven distribution of irrigation affects agriculture in some regions. Overall, it can be said that cultivation mainly depends on the size of the tehsil, but irrigation depends on many other factors. The results show that there is a need for better planning and equal distribution of irrigation facilities to improve agriculture in all tehsils.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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