IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 7, April 2024

Rainfall Patterns, Cropping Systems, and Groundwater Dynamics in Maharashtra: A Comprehensive Analysis

Archisha Gupta[1], V. M. Rokade[2], Gautam Gupta[3*] and S. N. Patil[2]
School of Economics, MIT World Peace University Pune, India[1]
School of Environmental & Earth Sciences, Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon[2]
Dr. KSK Geomagnetic Research Laboratory, IIG, Prayagraj, India[3]
gupta_gautam1966@yahoo.co.in

Abstract*: Maharashtra is one of the largest agricultural states in India, with agriculture being the primary source of livelihood for a majority of the rural population. However, the state has been facing several challenges, such as water scarcity, depletion of groundwater resources, and climate change, which have a significant effect on the agricultural production and socio-economic conditions of farmers. The present study collected secondary data from various sources, which was analyzed using statistical tools and techniques to determine the correlation between rainfall and cropping patterns, the impact of cropping patterns on groundwater resources, and the socio-economic conditions of farmers in the selected districts. The findings of the study suggest that there is a direct correlation between rainfall and cropping patterns, and the impact of cropping patterns on groundwater resources and socio-economic conditions of farmers varies in the selected districts. The result highlights the need for sustainable agricultural practices that are suitable for the local agro-climatic conditions and can help improve the socio-economic conditions of the farmers.*

Keywords: Agriculture, rainfall, groundwater, socio-economic, Maharashtra

I. INTRODUCTION

Agriculture is the primary source of livelihood for a large proportion of the population in Maharashtra, and the state is known for its diverse agricultural production systems. However, in recent years, the state has been facing several challenges related to climate change, water scarcity, and depletion of groundwater resources, which have had a significant impact on agricultural productivity and the socio-economic conditions of farmers (Smith et al., 2018).

One of the critical challenges faced by farmers in Maharashtra is the dependence on groundwater resources for irrigation. Groundwater is the primary source of irrigation in the state, and over-extraction of groundwater has led to a decline in the water table, which is a major concern. Furthermore, rainfall patterns in the state are erratic, and the frequency of droughts and floods has increased in recent years, which has further added to the challenges faced by farmers (Gupta and Singh, 2017).

Despite the existing literature on the impact of cropping patterns on groundwater resources and socio-economic conditions of farmers in India, there is a research gap in the context of Maharashtra (Bhattacharya et al., 2018). Most of the existing studies on this topic have focused on other regions of India, such as Punjab and Haryana, where groundwater depletion and environmental degradation have become major concerns. There is a need for more research on the impact of cropping patterns on groundwater resources in Maharashtra, where the socio-economic conditions of farmers vary across different districts, and the patterns of rainfall are also highly variable (Kumar and Sivakumar, 2019). Furthermore, there is a lack of research on the strategies that farmers adopt to cope with the challenges of water scarcity and climate change in the region. Therefore, this study aims to fill the research gap by examining the impact of cropping patterns on groundwater resources and the socio-economic conditions of farmers in different districts of Maharashtra and identifying the strategies that farmers adopt to cope with the challenges of water scarcity and climate change.

II. LITERATURE REVIEW

Researchers have extensively studied the impact of rainfall variability on groundwater recharge and its implications for sustainable groundwater management in India. Parthasarathy and Dhar (1975) noted an increase in both spatial and temporal variability of rainfall between 1930 and 1960, while Kothyari and Singh (1996) reported a decline in rainfall by the late 1960s. Guhathakurta and Rajeevan (2007) observed reduced July rainfall but increased August rainfall in central India, with decreased winter rainfall in most areas. Studies also revealed fluctuations in pre-monsoon and post-monsoon rainfall in various regions. These variations possibly linked to climate change, impact groundwater resources. Talule (2015) analyzed cropping patterns in Maharashtra, suggesting sustainable practices to reduce groundwater depletion. Singh et al. (2010) found deficit irrigation effective in maintaining high crop yields. These studies highlight the need for sustainable water management strategies amidst changing rainfall patterns and agricultural practices.

Badiger et al. (2016) investigated socio-economic factors affecting groundwater depletion in Karnataka's semi-arid region, revealing significant impacts from population growth, urbanization, and land use changes. Tiwari et al. (2018) analyzed crop diversification's effects on poverty and gender equality in Madhya Pradesh, finding positive outcomes. Senapati and Phanindra (2020) studied rainfall patterns' influence on crop yields in Odisha, noting lower yields in areas with high rainfall variability. Saravanakumar (2015) assessed rainfall and groundwater's impact on crop productivity in Tamil Nadu's Cauvery Delta, finding higher productivity in regions with abundant rainfall and groundwater. These studies underscore the complex interactions between socio-economic factors, climate patterns, and agricultural practices in shaping groundwater dynamics and agricultural outcomes across diverse regions of India.

Numerous geophysical and geological studies in Maharashtra's Deccan trap region have revealed groundwater movement within intertrappean/vesicular and fractured zones, with underlying sedimentary formations serving as potential groundwater sources. Research in the coastal region of northern Sindhudurg district merges geochemical and geophysical data, offering insights into groundwater chemistry and contamination (Maiti et al., 2013). 2D electrical tomography models indicate widespread saline water intrusion along the west coast (Gupta et al., 2016), with 47% of water samples exhibiting high fluoride concentration due to mineral weathering and ion exchange processes under elevated pH conditions (Suneetha et al., 2021). Drinking water quality is generally excellent to good, although some coastal samples are deemed poor to unsuitable. Irrigation water quality is predominantly excellent to good, except for a few coastal locations (Suneetha et al., 2021). These findings provide valuable insights for groundwater management and quality assessment in the region.

Rainfall analysis in the NMR (Northern Maharashtra Region) indicates a consistent decline in Dhule and Nandurbar, contrasting with Jalgaon where no significant trend is observed. Over the past three decades (1987–2016), Dhule and Nandurbar witnessed a substantial decrease in rainfall, with Dhule receiving 20–30% less rain compared to the preceding century, and Nandurbar experiencing a decline of 18–57%. Winter rainfall is rare in Nandurbar, with 17 out of 25 talukas in the region witnessing decreased monsoon season rainfall. Post-monsoon rainfall has also declined. The seasonality index, ranging from 1.17 to 1.26, indicates concentrated rainfall within 1 or 2 months, mainly during June, July, and August. In the past 30 years, rainfall intensity increased while frequency decreased, impacting the environment, economy, and agriculture significantly. Deshmukh et al. (2020) revealed unsustainable agricultural practices exacerbating groundwater depletion in Marathwada. Kamble et al. (2001) highlighted groundwater contamination near industrial estates, while Nihalani et al. (2022) identified landfills as major sources of groundwater contamination in Pune.

Despite the existing literature on the impact of cropping patterns (Garg et al., 2017) on groundwater resources and socio-economic conditions of farmers in India, there is a research gap in the context of Maharashtra (Jagtap et al., 2016; Patil et al., 2016; Jha et al., 2017; Pawar et al., 2019). There is thus a need for more research on the impact of cropping patterns on groundwater resources in Maharashtra, where the socio-economic conditions of farmers vary across different districts, and the patterns of rainfall are also highly variable. Furthermore, there is a lack of research on the strategies that farmers adopt to cope with the challenges of water scarcity and climate change in the region (Patil and Kulkarni, 2018; Jain and Agarwal, 2019).

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 7, April 2024

III. METHODOLOGY

The methodology involved in this study is the collection of secondary data from various sources such as reports, journals, and government websites. The study also used a descriptive research design that aims to describe the patterns of rainfall, cropping patterns, and the socio-economic conditions of farmers in different districts of Maharashtra.

The data collected is analyzed using statistical tools and techniques to determine the correlation between rainfall and cropping patterns, the impact of cropping patterns on groundwater resources, and the socio-economic conditions of farmers in the selected districts. For data analysis, the study used statistical software such as MS Excel and Stata.

IV. DATA ANALYSIS AND INTERPRETATION

Rainfall analysis

A seasonality index (SI) is a tool used in rainfall analysis to quantify and understand the seasonal patterns and variations in rainfall data. It provides a numerical measure of the relative importance of each season or month in the time series (Kanellopoulou, 2006). The SI has been calculated for all the districts of Maharashtra for two diverse eras, namely, the first 50-year 1901-1950 and the later 50-year period 1951-2000. This will benefit to find the changes (if any) in the seasonality index in the last 100 years.

Table 1 shows that a lower seasonality index value corresponds to a improved dispersal of monthly precipitation across the months of the year. The seasonality index's greatest value (Table 2), which ranges from 1.2 to 1.3 over Thane, Mumbai, Raigad, and Ratnagiri districts in both 1901-1950 and 1951-2000 (Fig. 1a,b), indicates that the majority of Maharashtra's rainfall occurred in the northern regions of the west coast in a period of one to two months. In both times, the seasonality index's spatial distribution was essentially unchanged. Over Sangli and Solapur, the lower

seasonality index value ranged from 0.8 to 0.9. This demonstrates that, despite the average monsoon rainfall being lower than in other Maharashtra districts, the rainfall in these two districts was solely seasonal and equally spread across four months. As SI was in the range of 0.9-1.0 between 1901 and 1950, rainfall in six districts, including Ahmednagar, Aurangabad, Beed, Osmanabad, Amravati, and Latur, was marked seasonally with rainfall uniformly spread across 3-4 months. The lack of a SI value in Figure 1(a) was caused by the lack of data for the districts of Latur and Jalna. With the exception of Kolhapur district, where the SI value increased to a range of 1.0-1.1, indicating a rainfall distribution of three months or fewer, this pattern remained largely unchanged for the subsequent period of 1951-2000. The seasonality index value in six districts, viz. Nandurbar, Sindhudurg, Chandrapur, Gadchiroli, Bhandara, and Gondia, was between 1.1 and 1.2, indicating that the maximum rainfall occurred in three months or less. As was already mentioned, a low value of the seasonality index suggests a precipitation regime with a short dry season, while a high value indicates that the majority of the rain falls within a short period of time (between two and three months). Thus, the seasonality index's rising tendency is a warning sign of a potentially dangerous situation for agriculture. Despite the fact that Figure 1 depicts precipitation, Figure 2 depicts changes in SI from 1901 to 2000. Figure 3 shows SI trends by district in Maharashtra. Although the regime was largely comparable between the years 1901 and 1950 and 1951 and 2000, we evaluated the seasonality index differences between those years to discover changes in the index (Figure 2). With the exception of Satara, Osmanabad, Nanded, Wardha, and Bhandara, all districts have shown an increase in the seasonality index.

TABLE 1 Seasonality index (SI) classification and the associated different rainfall regimes

Rainfall regimes	**Seasonality index (SI)**
Very equable	≤ 0.19
Equable, but with a definite wetter season	0.20–0.39
Rather seasonal with a short drier season	0.40–0.59
Seasonal	0.60–0.79
Markedly seasonal with long drier season	0.80–0.99
Most rain in 3 months or less	1.00–1.19
Extreme, almost all rain in 1-2 months	≥ 1.20

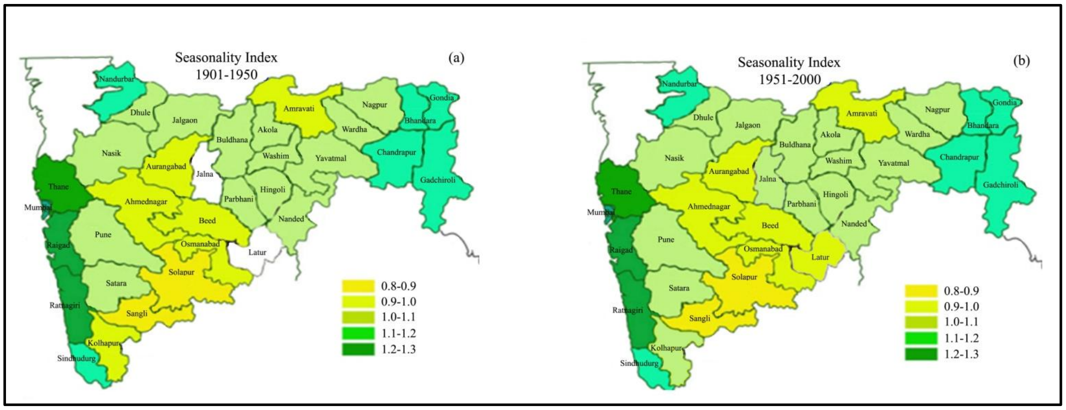

Figure 1 Values of the SI of the districts of Maharashtra during the period (a) 1901–1950 and (b) 1951–2000.

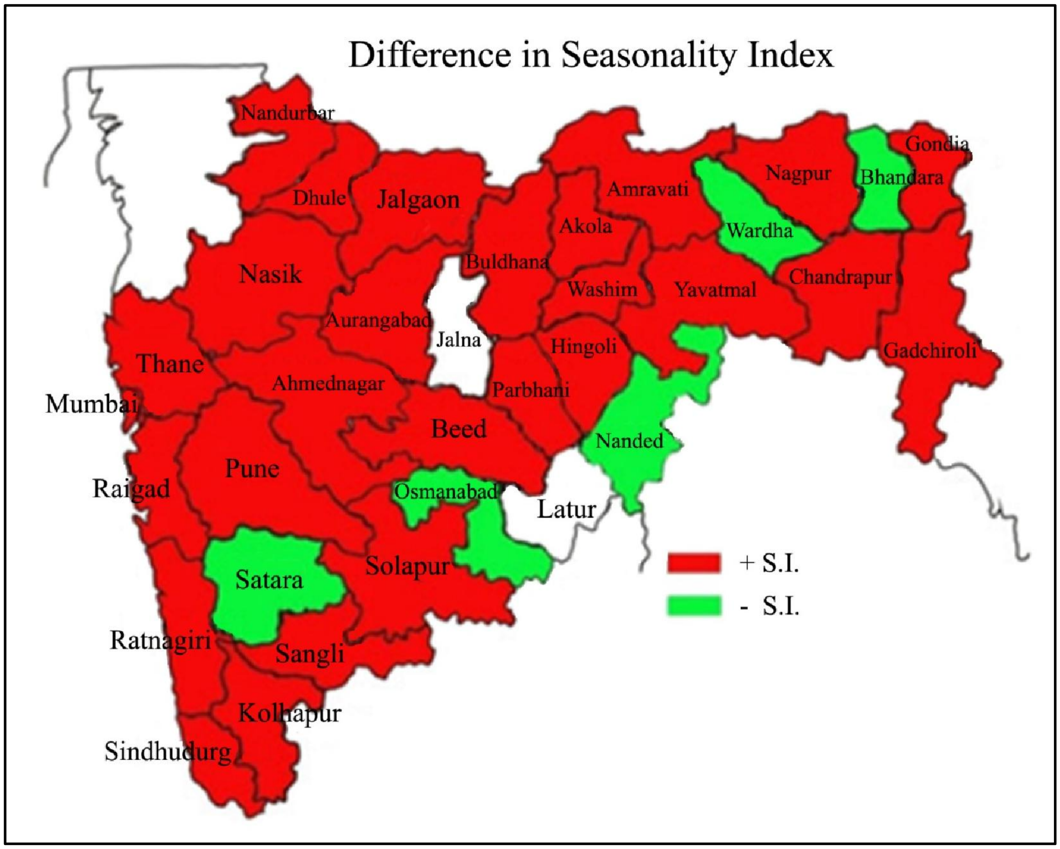

Figure 2 Variations in the SI in the period 1951–2000 from the period 1901–1950.

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 7, April 2024

TABLE 2 Changes in the seasonality index (SI) values in 100 years and the SI values in the period 1901–1950 and 1951–2000.

Sl. no.	Districts	SI increase in 100 Yr	SI value in 1901–1950	SI value in 1951–2000
1	Ahmednagar	0.0245	0.905	0.948
2	Akola	0.0292	1.038	1.075
3	Amraoti	0.0785	1.038	1.101
4	Aurangabad	−0.0065	0.995	0.995
5	Beed	−0.0377	0.965	0.979
6	Bhandara	−0.0466	1.123	1.105
7	Mumbai city	0.0103	1.213	1.231
8	Mumbai Suburb	0.0676	1.221	1.248
9	Buldhana	0.0813	1.015	1.064
10	Chandrapur	−0.0020	1.099	1.110
11	Dhule	0.0228	1.048	1.069
12	Gadchiroli	0.0223	1.115	1.132
13	Gondia	−0.0232	1.122	1.132
14	Hingoli	−0.0023	1.029	1.067
15	Jalgaon	0.0260	1.070	1.093
16	Jalna	−0.1520		1.011
17	Kolhapur	0.1561	0.990	1.066
18	Latur	−0.1815		1.002
19	Nagpur	−0.0079	1.069	1.065
20	Nanded	0.0179	1.069	1.033
21	Nandurbar	0.0172	1.156	1.189
22	Nasik	0.0077	1.088	1.093
23	Osmanabad	−0.0557	0.999	0.984
24	Parbhani	−0.0032	1.015	1.034
25	Pune	0.0621	1.025	1.055
26	Raigarh	−0.0108	1.230	1.237
27	Ratnagiri	0.0023	1.205	1.209
28	Sangli	0.0503	0.805	0.849
29	Satara	0.0596	1.024	1.010
30	Solapur	0.0066	0.869	0.930
31	Sindhudurg	0.0053	1.177	1.179
32	Thane	0.0228	1.220	1.250
33	Wardha	−0.0135	1.064	1.056
34	Washim	0.0551	1.042	1.098
35	Yeotmal	0.0326	1.050	1.073

↑ significant; ↑ not significant;
↓ significant; ↓ not significant

Cropping pattern

The cropping pattern in Maharashtra districts can have a significant impact on groundwater availability and sustainability in the region. Several measures are proposed here so that the cropping pattern can influence the groundwater in this region.

While different crops have varying water requirements, some crops, such as sugarcane and paddy rice, are water-intensive and require substantial amounts of irrigation. When these crops are extensively cultivated, they can exert significant pressure on groundwater resources, leading to over-extraction and declining water levels. Cultivation of a

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 7, April 2024

single crop over a large area, can lead to imbalanced water usage. If a single crop dominates the region, there can be a concentrated demand for water during a specific season, causing excessive groundwater extraction during that period. On the other hand, diversified cropping, where multiple crops are cultivated, can distribute the water demand more evenly throughout the year, reducing the strain on groundwater resources.

The practice of growing different crops sequentially in the same field, can help manage groundwater resources more sustainably. Rotating crops with varying water requirements can optimize water usage, minimize the risk of pest and disease outbreaks, and improve soil health. By diversifying the cropping pattern, farmers can reduce the reliance on groundwater and mitigate its depletion.

The choice of irrigation methods and techniques employed in the cropping pattern can significantly impact groundwater usage. Traditional flood irrigation methods can result in high water losses due to evaporation and inefficient water distribution. Adopting more efficient irrigation practices such as drip irrigation or sprinkler systems can minimize water wastage, improve water-use efficiency, and reduce groundwater depletion.

Integrating rainwater harvesting techniques into the cropping pattern can help recharge groundwater. Constructing structures like farm ponds, percolation pits, and check dams can capture and store rainwater, allowing it to infiltrate into the ground and recharge aquifers. This practice can supplement irrigation needs during the dry season and reduce reliance on groundwater.

The choice of crops suitable for the local agro-climatic conditions and their corresponding agronomic practices can impact groundwater sustainability. Selecting crops that are better adapted to the available water resources can help minimize the need for excessive irrigation. Additionally, employing water-efficient agronomic practices, such as proper scheduling, mulching, and precision farming techniques, can optimize water usage and reduce the strain on groundwater.

Finally, Government policies and regulations related to cropping pattern, groundwater usage, and water management play a crucial role in influencing sustainable practices. Implementing measures such as incentivizing water-efficient cropping systems, promoting crop diversification, and regulating groundwater extraction can help ensure the long-term sustainability of groundwater resources.

V. RESULTS AND DISCUSSION

District-wise analysis of rainfall in Maharashtra provides valuable insights into this. The state of Maharashtra is highly dependent on agriculture, and a majority of the population is engaged in farming activities. Thus, understanding the pattern of rainfall and its impact on groundwater resources is crucial to ensure sustainable agricultural practices.

The analysis of rainfall data collected from various meteorological departments in Maharashtra reveals that the state receives an average annual rainfall of 1100-1200 mm. However, the distribution of rainfall is not uniform across the state, and some districts receive more rainfall than others. For instance, districts like Ratnagiri, Sindhudurg, and Raigad receive more than 2500 mm of rainfall annually, while districts like Ahmednagar, Latur, and Solapur receive less than 500 mm of rainfall annually (Figure 4).

The groundwater level in Maharashtra is also influenced by the pattern of rainfall. Districts that receive more rainfall tend to have higher levels of groundwater, while districts that receive less rainfall have lower levels of groundwater. For instance, districts like Satara, Sangli, and Kolhapur, which receive more than 1000 mm of rainfall annually, have a higher groundwater level than districts like Jalgaon, and Nanded, which receive less than 500 mm of rainfall annually.

Understanding the distribution of rainfall between months and different states in various rainfall regimes can be done by analysing the seasonality index. When SI exceeds 1.2 in coastal regions, there is an intense rainfall regime, with practically all of the rain falling within one to two months. With a SI between 1 and 1.2, eastern and western regions (apart from coastal regions) have a precipitation regime where the majority of precipitation occurs in three months or less. It is beneficial for agriculture that the central regions of the state have a seasonal rainfall regime with a four-month rainy season.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 7, April 2024

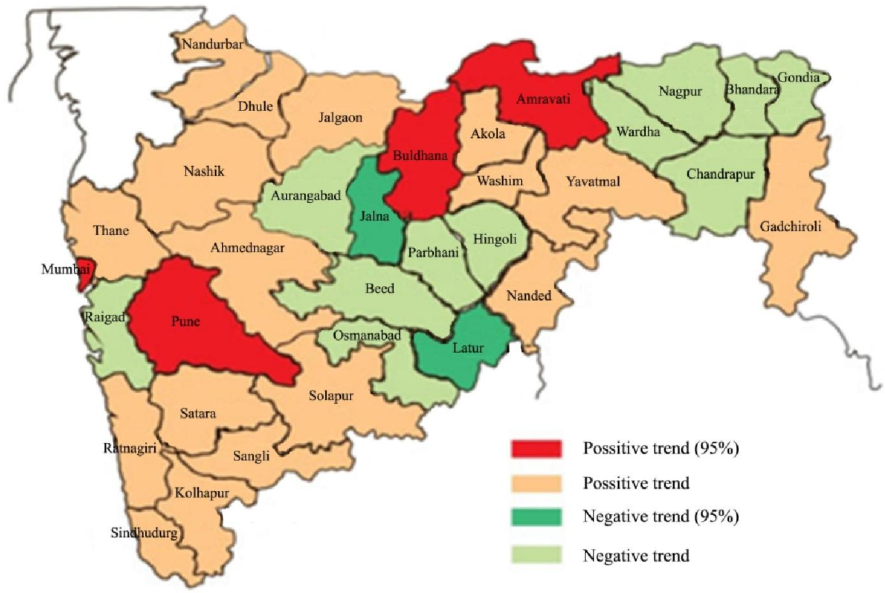

Figure 3 Trends in the SI over districts of Maharashtra.

The cropping pattern in Maharashtra is also influenced by the pattern of rainfall and groundwater level. Districts with higher levels of groundwater tend to cultivate crops that require more water, such as sugarcane, banana, and paddy, while districts with lower levels of groundwater tend to cultivate crops that require less water, such as millets, pulses, and oilseeds. The cropping pattern also varies significantly across different districts based on the availability of water and soil type. In districts with higher groundwater availability, farmers tend to grow water-intensive crops like sugarcane, paddy, and banana. In contrast, districts facing water scarcity focus on drought-resistant crops like pulses, oilseeds, and millets. In some districts, high rainfall is positively correlated with high groundwater levels, while in others, high rainfall leads to lower groundwater levels due to excessive runoff. For example, districts like Raigad, Ratnagiri, and Sindhudurg, which receive high rainfall, have a relatively high groundwater table due to the presence of permeable soil and good forest cover. On the other hand, districts like Latur, Osmanabad, and Solapur, which have low rainfall, face severe water scarcity, and have to rely on groundwater for irrigation.

The socio-economic conditions of the districts also play a significant role in shaping the cropping pattern and groundwater use. Districts with high levels of poverty and unemployment tend to have a higher dependence on agriculture and groundwater resources for livelihoods. Additionally, lack of infrastructure, technology, and credit facilities further exacerbate the challenges faced by farmers in these regions. Also, the findings revealed that the socio-economic conditions of the farmers were directly impacted by the cropping patterns. The farmers engaged in paddy cultivation showed higher levels of income and better socio-economic conditions compared to farmers engaged in dryland farming.

The districts that received higher rainfall showed a higher proportion of paddy cultivation, while the districts that received lower rainfall showed a higher proportion of dryland farming. The study also revealed that the impact of cropping patterns on groundwater resources varied in the selected districts. The districts with a higher proportion of paddy cultivation showed a higher rate of depletion of groundwater resources, while the districts with a higher proportion of dryland farming showed a lower rate of depletion of groundwater resources.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 7, April 2024

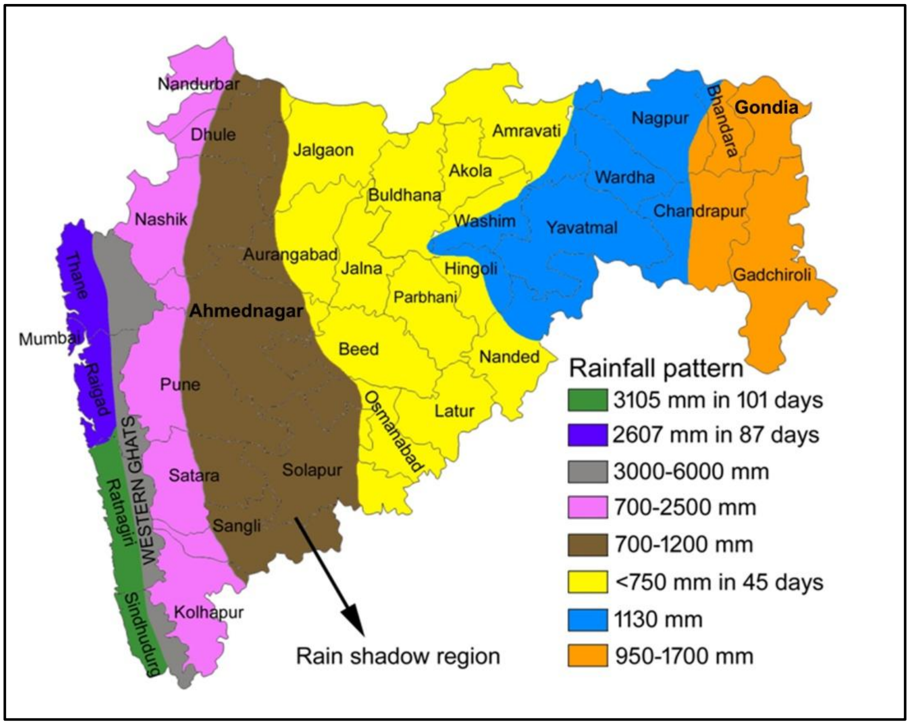

Figure 4 Average annual rainfall map of Maharashtra

Overall, the analysis suggests that a comprehensive understanding of the complex interplay between rainfall, groundwater, cropping pattern, and socio-economic conditions is crucial for devising effective policies and interventions to promote sustainable agriculture and equitable access to water resources in the districts of Maharashtra.

In conclusion, the district-wise analysis of rainfall and groundwater in Maharashtra highlights the need for region-specific agricultural practices based on the pattern of rainfall and groundwater availability. It is crucial to ensure sustainable agricultural practices that promote water conservation and efficient utilization of resources.

Based on the analysis of socio-economic conditions in the districts of Maharashtra, it is found that districts like Nandurbar, Gadchiroli, and Washim have relatively poor socio-economic conditions. These districts have low literacy rates, high poverty levels, and limited access to basic amenities like healthcare and education. Additionally, these districts also have low agricultural productivity due to low rainfall and unfavorable cropping patterns, which further contributes to their poor socio-economic status.

There are several districts in Maharashtra that are considered to have relatively good socio-economic conditions. Some of these districts include Mumbai, Pune, Thane, Nagpur, and Nashik. These districts have a comparatively high Human Development Index (HDI) and rank higher in terms of education, health, and standard of living.

Lastly, Maharashtra has a diverse groundwater resource across its districts. The availability and characteristics of groundwater vary depending on factors such as rainfall, geology, aquifer properties, and human activities.

Here is a general overview of groundwater resources in the districts of Maharashtra:

Vidarbha Region: The districts in Vidarbha, such as Nagpur, Amravati, and Akola, largely rely on groundwater for irrigation and domestic purposes. Groundwater is primarily sourced from alluvial aquifers and basaltic formations. However, some areas in Vidarbha face challenges like declining groundwater levels and water quality issues.

Marathwada Region: Marathwada districts, including Aurangabad, Beed, and Latur, are known to experience water scarcity due to semi-arid climatic conditions. Groundwater resources in this region are mainly derived from basaltic and alluvial aquifers. However, over-extraction and inadequate recharge have resulted in groundwater depletion and a declining water table.

Western Maharashtra: Districts like Pune, Satara, and Kolhapur in western Maharashtra have relatively better groundwater resources. The region benefits from rivers, dams, and alluvial aquifers, making groundwater more accessible. However, localized areas may face challenges related to overexploitation and water quality degradation.

Konkan Region: The Konkan region, comprising districts such as Ratnagiri and Sindhudurg, receives high rainfall due to its coastal location. The region is characterized by lateritic and alluvial soils, which are conducive to groundwater storage. Springs and wells play a crucial role in accessing groundwater in the hilly and forested areas of Konkan.

Northern Maharashtra: Districts like Nashik and Jalgaon in northern Maharashtra have relatively good groundwater resources. The region benefits from alluvial and basaltic aquifers, as well as rivers like Godavari. However, intensive agriculture and increased water demand pose challenges to groundwater sustainability in some areas.

VI. CONCLUSION

Based on the findings of the study, it can be concluded that the cropping patterns in Maharashtra have a significant impact on groundwater resources and the socio-economic conditions of farmers. The study found that areas with high water availability have a higher cropping intensity than areas with low water availability. The study also found that farmers in areas with low water availability are adopting various strategies such as rainwater harvesting, conservation tillage, and the use of drought-tolerant crops to cope with the challenges of water scarcity and climate change.

The analysis also showed that socio-economic factors such as landholding size, education level, and access to credit and market information have a significant impact on the adoption of sustainable agricultural practices. The study recommends that policy interventions should focus on providing support to smallholder farmers, promoting sustainable agricultural practices, and improving access to credit and market information.

In summary, this study contributes to the literature on the impact of cropping patterns on groundwater resources and socio-economic conditions of farmers in Maharashtra. The findings of the study provide insights into the challenges and opportunities for sustainable agricultural development in the region. The study recommends that policymakers, agricultural extension workers, and farmers should work together to promote sustainable agricultural practices that conserve water resources, enhance soil fertility, and improve the livelihoods of smallholder farmers in the region. It also highlights the need for policies that promote sustainable cropping patterns that are suitable for the local agro-climatic conditions and that can help improve the socio-economic conditions of the farmers.

Based on the analysis and findings of the study, there is a need to emphasize the importance of sustainable agricultural practices, encourage the adoption of rainwater harvesting techniques, focus on providing support to smallholder farmers, promote public-private partnerships, integrate land-use planning with groundwater management plans, and strengthen agricultural extension services in the region.

VII. ACKNOWLEDGMENT

The first author expresses heartfelt gratitude to the esteemed mentors and professors, especially, for their invaluable guidance in the academic and project endeavours.

REFERENCES

[1]. Badiger, R., Lokesha, H., Hugar, L. B., Nemichandrappa, M., & Reddy, B. S., Impact of rainwater harvesting on farm income in northern Karnataka - An economic analysis. *Indian Journal of Soil Conservation*, 44(1), 8-12, (2016).

[2]. Bhattacharya, S., Das, P. K., & Sahu, S. K., Integrated water resource management: A case study of Maharashtra. *International Journal of Agriculture, Environment and Biotechnology*, 11(2), 311-318, (2018).

[3]. Chaudhary S., Dhanya, C. T., & Vinnarasi, R., Dry and wet spell variability during monsoon in gauge-based gridded daily precipitation datasets over India. *Journal of Hydrology*, 546, 204-218, (2017).

[4]. Deshmukh, A., Kale, D., & Patil, P., Spatiotemporal analysis of rainfall patterns and cropping intensity in Maharashtra. *International Journal of Applied Earth Observation and Geoinformation*, 89, 102088, (2020).

[5]. Talule, D. C., Post Reforms Cropping Dimensions of the Agriculture of the State of Maharashtra in India (1990-91 to 2010-11). *Universal Journal of Agricultural Research* 3(2), 31-45, (2015).

[6]. Duhan, D., & Pandey, A., Statistical Analysis of Long Term Spatial and Temporal Trends of Precipitation during 1901-2002 at Madhya Pradesh, India. *Atmospheric Research*, 122, 136-149, (2013).

[7]. Garg, P., Tiwari, V. K., & Kansal, A., Crop rotation: A tool for sustainable agriculture. *International Journal of Agricultural Sciences*, 13(2), 296-301, (2017).

[8]. Guhathakurta, P., & Rajeevan, M., Trends in rainfall pattern over India. International Journal of Climatology, DOI: 10.1002/joc.1640 2007, (2007).

[9]. Gupta, G., Erram, V. C., & Maiti, S., Application of Electrical Resistivity Tomography in delineation of saltwater and freshwater transition zone: a case study in west coast of Maharashtra, India. In: *Groundwater Assessment, Modeling and Management* (Eds. M. Thangarajan and V.P. Singh), CRC Press, Taylor & Francis Group, UK, 67-84, (2016).

[10]. Gupta, S., & Singh, M., Impact of crop diversification on groundwater recharge: A study in the semi-arid region of India. *Journal of Hydrology: Regional Studies*, 12, 10-20, (2017).

[11]. Ingle, S. T., Patil, S. N., Mahale, N. K., & Mahajan, Y. J., Analyzing rainfall seasonality and trends in the North Maharashtra region. *Environmental Earth Sciences*, 77, 651, (2018).

[12]. Jagtap, S. S., Salunkhe, V. N., & Patil, R. S., Impact of irrigation facilities on socio-economic status of farmers in Maharashtra. *International Journal of Agriculture, Environment and Biotechnology*, 9(3), 571-576, (2016).

[13]. Jain, R., & Agarwal, A., Assessing the impact of efficient irrigation techniques on groundwater depletion: A case study of Maharashtra. *Water Resources Management*, 33(4), 1309-1323, (2019).

[14]. Jha, S., Jat, M., & Singh, M., Adoption of cash crops and groundwater depletion: Empirical evidence from a semi-arid region in India. *Agricultural Water Management*, 180, 1-9, (2017).

[15]. Kamble, G.B., Muley, D., & Mankar, D., Qualitative assessment of ground water around Lote industrial area in Ratnagiri district (Maharashtra). *Acta Ecologica Sinica*, 23, 47-54, (2001).

[16]. Kanellopoulou, E., Spatial distribution of rainfall seasonality in Greece. *Weather*, 57, 215-219, 10.1256/004316502760053576, (2006).

[17]. Kothyari, U. C., & Singh, V. P., Rainfall and Temperature Trends in India. *Hydrological Processes*, 10, 357-372, (1996).

[18]. Kripalani, R. H., & Kulkarni, A., Climatic impact of El Niño/La Niña on the Indian monsoon: A new perspective. *Weather*, 52, 39-46, (1997).

[19]. Krishna Kumar, K., Rajagopalan, B., & Cane, M. A., On the weakening relationship between the Indian monsoon and ENSO. *Science*, 284, 2156-2159, (1999).

[20]. Kumar, A., & Sivakumar, B., Assessing the impact of rainfall variability on crop yields in Maharashtra, India. *Journal of Environmental Management*, 231, 1-9, (2019).

[21]. Maiti, S., Erram, V C., Gupta, G., Tiwari, R K., Kulkarni, U. D., & Sangpal, R R., Assessment of groundwater quality: A fusion of geochemical and geophysical information via Bayesian Neural Networks. *Environmental Monitoring and Assessment,*185, 3445-3465, (2013).

[22]. Mishra, A., & Jain, K., Environmental implications of fertilizer use in Indian agriculture: A review. *Environmental Science and Pollution Research*, 26(19), 19315-19327, (2019).

[23]. Pant, G.B., & Rupa Kumar, K., Climates of South Asia. John Wiley and Sons, New York, (1997).

[24]. Parthasarathy, B., & Dhar, O. N., Trend analysis of annual Indian rainfall. *Hydrology Science Bulletin*, 20, 257-260, (1975).

[25]. Patel, P., Desai, V., & Shah, S., Impact of changes in cropping pattern on groundwater levels in Gujarat, India. *Groundwater for Sustainable Development*, 2, 1-10, (2016).

[26]. Patil, R. S., Dhatrak, A. R., & Thorat, A. G., Socio-economic status of farmers and its impact on crop choices in Maharashtra. *Journal of Agricultural Science and Technology*, 18(4), 937-944, (2016).

[27]. Patil, P. D., & Kulkarni, P., Impact of modern irrigation techniques on groundwater resources in Maharashtra. *International Journal of Agriculture, Environment and Biotechnology*, 11(1), 131-136, (2018).

[28]. Pawar, P., Jadhav, V., & Chavan, P., Effect of crop diversification on groundwater resources in Maharashtra. *International Journal of Agriculture, Environment and Biotechnology*, 12(2), 269-273, (2019).

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 7, April 2024

[29]. Saravanakumar, V., Impact of climate change on yield of majorfood crops in Tamil Nadu, India. SANDEE Working Paper (WP91–15). SANDEE. Nepal. (ISBN: 978–9937–596–21–3), (2015).

[30]. Nihalani, S. A., Behede, S. N., & Meeruty, A. R., Groundwater quality assessment in proximity to solid waste dumpsite at Uruli Devachi in Pune, Maharashtra. *Water Science and Technology,* 85 (11), 3331-3342, (2022).

[31]. Senapati, A., & Goyari, P., Effect of Climate Variability on Yields of Major Crops Grown in Odisha, India. *Indian Journal of Agricultural Economics*, 75, 186-216, (2020).

[32]. Singh, R., Kundu, D. K., & Bandyopadhyay, K. K., Enhancing agricultural productivity through enhanced water use efficiency. Journal of Agricultural Physics, 10 (2), 1-15, (2010).

[33]. Smith, J., Johnson, K., & Jones, R., The impacts of climate change on agricultural productivity: A global analysis. *Environmental Research Letters*, 13(5), 1-12, (2018).

[34]. Suneetha, N., Gupta, G., Das, P., Maiti, S., Shailaja, G., Das, A., & Laxminarayana, M., Evaluation of groundwater quality in coastal aquifer system of Sindhudurg district, Maharashtra. *Indian Journal of Geosciences*, 71(3), 481-500, (2018).

[35]. Suneetha, N., Gupta, G., Singh, R. B., Tahama, K., & Erram, V. C., Hydrogeochemical Processes Regulating the Groundwater Quality and its Suitability for Drinking and Irrigation Purpose in Parts of Coastal Sindhudurg District, Maharashtra. *Journal of the Geological Society of India,* 97, 173-185, (2021).

[36]. Tiwari, R., Singh, S., & Kumar, M., Determinants of cropping pattern choice: A study of smallholder farmers in Madhya Pradesh, India. *Journal of Agribusiness in Developing and Emerging Economies*, 8(1), 4-17, (2018).