

Spatial-Temporal Analysis of Surface Water Coverage from 1984 to 2021 in Rohtak District Applying Geoinformatics Tools.

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Abstract

This study examined the surface water cover of the Rohtak district in Haryana from 1984 to 2021. Geoinformatics and remote sensing techniques have been used for the spatial-temporal analysis of surface water coverage. The study area is in the central region of the state of Haryana, and the climate is subtropical and subarid, with a monsoon pattern of precipitation. There have rainy sessions from last June to September. The Global Surface Water-Data Users Guide (v4) database have been used for this study. QGIS software has been applied to analyse the satellite imagery collected for the study area. Surface water extent, transition, and surface water area seasonality for 2021, major surface water classes, and occurrence of surface water have been obtained from the QGIS software. The study revealed that there are spatial-temporal variations in surface water coverage in the district. Tehsil Mehem has the highest maximum water coverage in the district. Three clear trends can be identified from the results about surface water coverage: the area shown as "not water" is decreasing; the area shown as "seasonal water" is increasing; and "permanent water" has noticed but in very few places. The surface water occurrence in the study area drastically decreased as the number of months in years increased. After the threshold reaches 50%, of surface water occurrence, Mehem Tehsil has no record, but Rohtak and Sampla record marginal areas.

Keywords: Surface Water Coverage, Surface water Extent, Water Transition, Water Seasonality, Water Occurrence, QGIS, Geoinformatics Tools

Introduction

Surface water availability is often influenced by a variety of factors, including climate change, urbanisation, land use practices, and human activities, all of which have the potential to drastically modify surface water coverage across time and place. Because of the rapid urbanisation, intense agricultural, and infrastructure development that has occurred in the Rohtak district of Haryana, India, surface water patterns in this area may change differently. Geospatial technologies, such as remote sensing and geographic

information systems (GIS), provide an effective and precise way for monitoring, analysing, and visualising spatiotemporal changes in surface water coverage. The results from this paper are expected to give import information on the dynamics of water bodies, provide for more better-informed based decisions on surface water management in the Rohtak district, which is facing increased demand for its surface water. This spatial-temporal approach provides the groundwork for others researches in other places where aquatic ecosystems facing pressures from environmental and developmental factors. This research is also focussing the need of utility of GIS technology for monitoring and planning water resources in the Rohtak district at both the local and regional levels.

Surface water is categorised primarily into two broad classifications: permanent and seasonal. Precipitation is the main contributor to surface water. About 20% of the total surface water available undergoes evaporation into the atmosphere. A substantial percentage of surface water can be detected in lakes, rivers, streams, ponds, and lowland areas.[1] The limitations on the availability and accessibility of surface water in India are significant. Moreover, the geographical distribution indicates significant irregularity in surface water cover.[4] The continuous decrease in water quality has become a critical concern for everyone. The availability of fresh water and the relationship between human water consumption and surface water availability pose significant global environmental challenges. Geoinformatics technology plays a crucial role in addressing these challenges.[6]The surface water cover is a crucial natural resource for human survival and ecological sustainability. [9] Various studies revealed that the management of surface water coverage can be integrated with ecosystems, particularly those that are subject to intense human activity and it requires more in-depth research.[10]Urbanisation, land use, land cover change, changing agricultural practices, and development plans all play a critical role in determining water extent or reduction in any given area. Quality of surface water cover is also important because degradation of surface water quality in developing countries has severe environmental consequences. [11][2]Water shortage remains a prevalent problem in the dry and semi dried area are and this phenomenon is very much correlated to weather conditions particularly precipitation and temperature.[7][3]Surface water dynamics, quality, and extent have had an impact on local ecology and the lives of dependent living beings. Geoinformatics technology is highly needed for better and more frequent monitoring of surface water processes.[4]Scholars emphasize the association between permanent, sessional changes, and the extension of available agricultural land irrigated with surface water as another aspect of the study of surface water cover. The

study area, located in the southern part of Haryana state, experiences significant seasonal variations in surface water availability.[13]

Objectives

- To evaluate the spatial and temporal variations in surface water coverage in Rohtak District from 1984 to 2021.
- To evaluate the patterns and trends of surface water cover in District and identify significant tehsil wise growth of water cover.
- To use the geoinformatics technology, GIS, and remote sensing, in monitoring tehsil level surface water cover in the district.

Methodology

This study is a spatial-temporal analysis of surface water coverage in Rohtak District from 1984 to 2021, using data from the Global Surface Water-Data Users Guide (v4), a comprehensive database that offers near-contemporaneous data on global water bodies. [8] Geoinformatics data associated with the study area was collected and analysed using QGIS software. The maximum surface water extent, surface water transition, surface water area seasonality for 2021, major surface water classes, and water occurrence have been obtained using QGIS software. The seasonal changes in surface water in 2021 in surface water coverage were also to be determined by the examination of data from the data source. The surface water areas were categorised into two classifications: permanent and seasonal. The analysis examined the frequency of water presence in the study area throughout the study period. The QGIS raster calculator and associated tools facilitated the calculation and visualisation of water occurrence in Rohtak District, yielding significant insights into long-term changes in surface water presence. The methodology included geoinformatics techniques and remote sensing data to provide a precise characterisation of surface water bodies in Rohtak District from 1984 to 2021.

Water Occurrence; $SWO \text{ month} = \Sigma W D \text{ month} / \Sigma V O \text{ month}$ Averaging

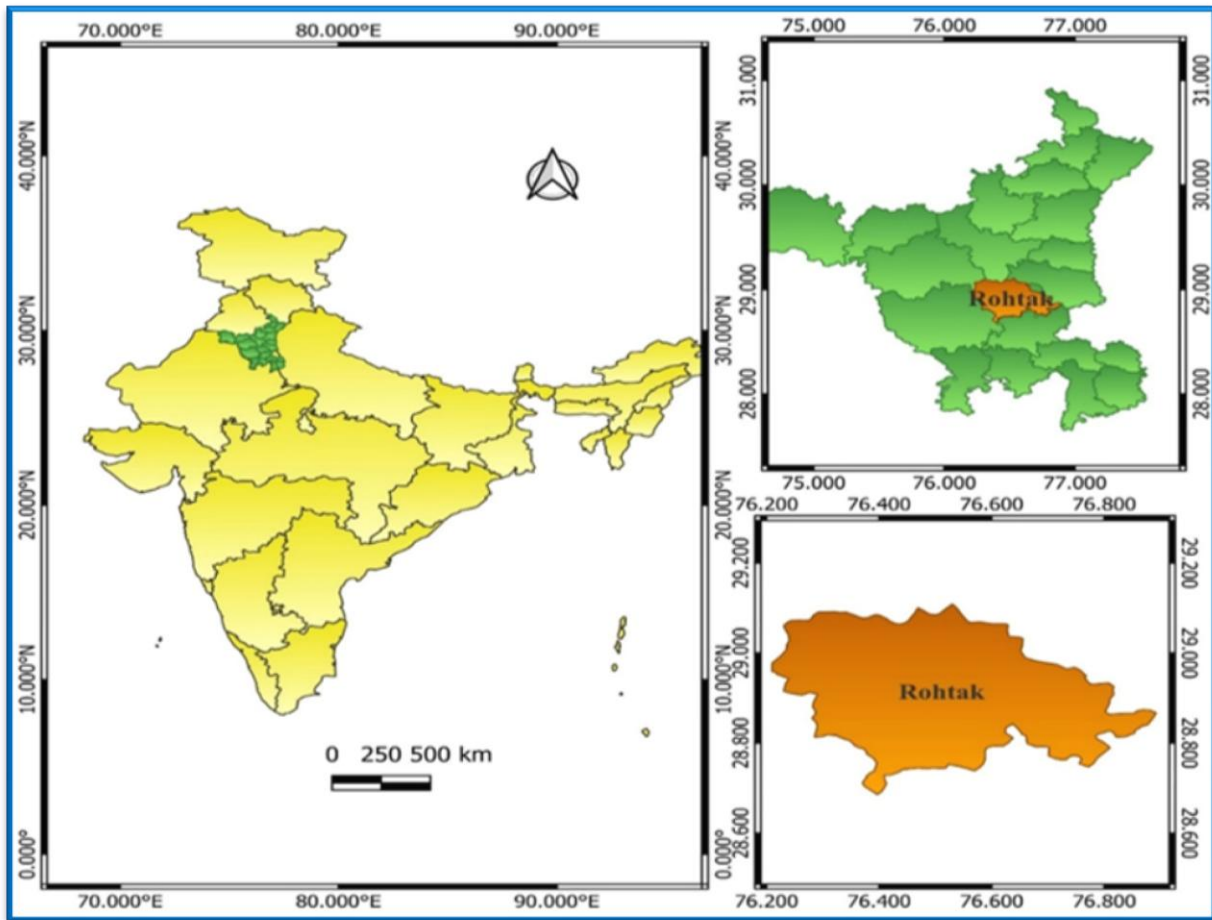
Where: *SWO (surface water occurrence) *WWD (valid direction) *VO (valid observations)

*Surface water transition classes; first- and last-year sample observations.

*Water Seasonality; *permanent water - availability for all 12 months, *seasonal water - availability for less than 12 months.

Study Area

Figure no.1: Map Study Area



The Rohtak district, the study area, is in the central region of Haryana state. The region is bordered by Jind and Sonapat districts to the north and east, Jhajjar district to the south, and Bhiwani and Hisar districts to the west. The total land area of the study area is documented to be 1682.83 square kilometres, based on village records. The district is situated at a latitude ranging from 28° 40' 58" North to 29° 06' 13" North, and its longitude extends from 76° 12' 47" East to 76° 51' 43" East. The district measures 62.5 kilometres in length and 44.0 kilometres in breadth, covering a total area of 1668 square kilometres. This district, located within the Great Northern Plain, has an average elevation of 220 meters above sea level. The northern section of the district has a gradual incline from north to south, measuring 19 centimetres per kilometre until it arrives at Jhajjar. Additionally, there exists a significant incline extending from the west to the east over a considerable distance. Rohtak district, characterised by its different land uses that include urban and rural areas along with agricultural land, gives a great opportunity for investigating the interactions and dynamics within a landscape developed by different activities. Significant changes to the

land use have been brought about by the rapid expansion of urbanisation and intensive agricultural practices.

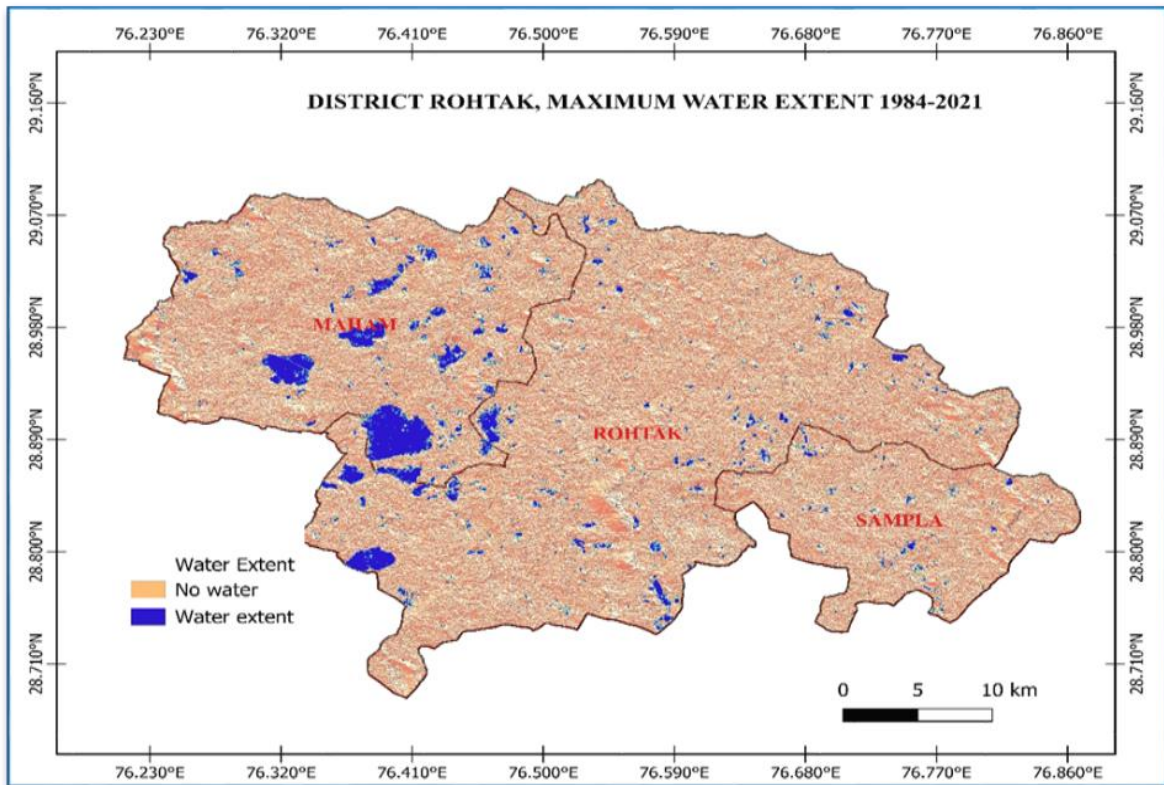
The study area's climate is subtropical and sub-arid, with a monsoon pattern of precipitation. In the study area, there are two distinct rainy seasons: the monsoon season from last June to the next three most significant months from July to September. For a long time, the district has recorded large amounts of annual precipitation. The annual average is around 400 mm. The flow of precipitation generally increases from west to east. The state receives about 72 percent of its average annual rainfall during the brief southeast monsoon season between July and September, with peak rainfall occurring in July and August. Precipitation is also heavy in June, with thunderstorms occurring the most frequently. The remaining months have very low precipitation.

Data Analysis, Discussion and Result

Table 1: The Maximum Water Extent in Rohtak District 1984 to 2021

<i>Tehsil</i>	<i>Total area (acres)</i>	<i>Total Area under water (acres)</i>	<i>Water area in %</i>
Mehem	122845.93	9751.54	7.94
Rohtak	220446.99	6277.72	2.85
Sampla	56084.93	773.76	1.38

Table No. 1 delineates the surface water extent in Rohtak District from 1984 to 2021. Maham tehsil has the highest percentage of its total area reported to be watered, covering 7.94% of its 122,845.93 acres. The surface water in this tehsil covers 9,751.54 acres, showing a substantial water cover relative to other tehsils in the district. Rohtak Tehsil, the biggest in the district, with an area of 220,446.99 acres, of which 6,277.72 acres, having 2.85%, is surface water cover. Despite having the highest geographical area, its water coverage percentage is much lower than that of Maham Tehsil. Sampla tehsil is the smallest tehsil in the district, with a total area of 56,084.93 acres and exhibiting small surface water coverage. Only 1.38% of the total area has surface water, which is equivalent to 773.76 acres. This signifies a markedly reduced occurrence of surface water cover compared to Maham and Rohtak tehsil.

Figure 1: Maximum Water Extent in Rohtak District 1984 to 2021**Table 2: Surface Water Transition in Rohtak District from 1984 to 2021**

	Water	Mehem	Rohtak	Sampla
		Surface Water in Acres 1984 - 2021		
1	Permanent	0.00	1.34	0.00
2	New permanent	0.00	8.70	0.00
4	Seasonal	115.22	356.53	87.29
5	New seasonal	1285.31	965.57	316.39
6	Lost seasonal	48.50	206.69	39.47
7	Seasonal to permanent	0.00	2.17	0.00
8	Permanent to seasonal	0.00	0.17	0.00
9	Ephemeral permanent	203.68	0.17	0.00
10	Ephemeral seasonal	7913.71	4475.85	279.10

Table No. 2 shows surface water data trends and patterns for the Rohtak district from 1984 to 2021. Permanent water bodies are the minimum in the district, with Rohtak tehsil showing a mere 1.34 acres of permanent water, while the tehsils of Mehem and Sampla

show an absence of permanent water. There were just new permanent water bodies that emerged in the Rohtak tehsil, and they covered an area of 8.70 acres. Mehem recorded 1,285.31 acres of seasonal water, Rohtak recorded 965.57 acres, and Sampla recorded 316.39 acres. This indicates that the district's seasonal water presence has significantly increased, particularly in newly developed seasonal water bodies. The district reported seasonal water loss, with Rohtak noticing the most loss at 206.69 acres, followed by Mehem at 48.50 acres and Sampla at 39.47 acres. The change of seasonal water into permanent bodies is a modest occurrence, seen only in Rohtak (2.17 acres), whereas transitory water forms are more widespread. Ephemeral seasonal water covers 7,913.71 acres in Mehem, 4,475.85 acres in Rohtak, and 279.10 acres in Sampla. Ephemeral permanent water in the district occurs only in Mehem, covering an area of 203.68 acres. This table indicates that while permanent water bodies are relatively rare, there has been considerable variation in seasonal and transitory water bodies, especially in Mehem and Rohtak.

Figure 2: Surface Water Transitions in Rohtak District 1984 to 2021

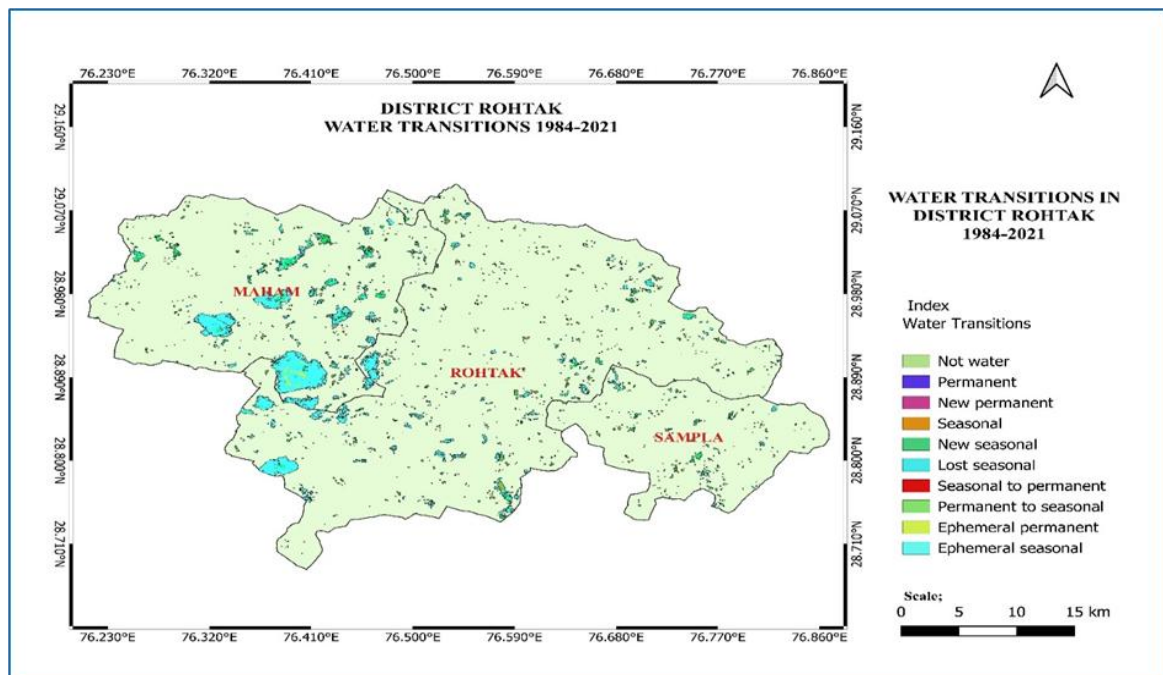
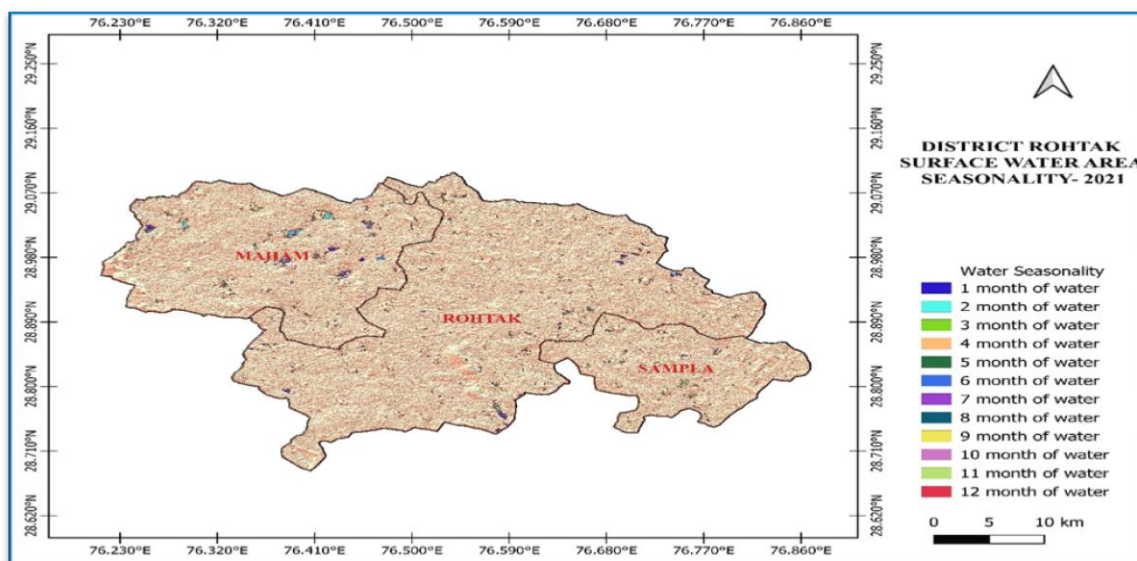


Table 3: Surface water Area Seasonality in 2021 in District Rohtak

	Water	Surface Water Area in Acres		
		Rohtak	Mehem	Sampla
1	1 month of water	8643.32	7714.90	1361.13
2	2 months of water	7925.78	3423.37	1695.25
3	3 months of water	2410.05	3595.90	1544.62
4	4 months of water	1580.23	2245.73	1065.35
5	5 months of water	1185.85	1714.42	553.22
6	6 months of water	761.36	1276.23	230.05
7	7 months of water	276.61	816.13	106.81
8	8 months of water	109.55	512.14	43.82
9	9 months of water	38.34	287.56	10.95
10	10 months of water	5.48	60.25	0.00
11	11 months of water	0.00	8.22	0.00
12	12 months of water	0.00	8.22	0.00

Table 3 presents the seasonality data for surface water area in 2021 for the District of Rohtak, highlighting significant variations in water availability among the tehsils of Rohtak district, including Rohtak, Mehem, and Sampla. All tehsils in the Rohtak district have witnessed a notable decline in the surface water area. The surface water cover area for one month was recorded as 8,643.32 acres in Rohtak, 7,714.90 acres in Mehem, and 1,361.13 acres in Sampla. As the number of months increased, there was a significant reduction in the surface water cover area, with Rohtak recording only 276.61 acres, Mehem at 816.13 acres, and Sampla at 106.81 acres. After a period of 9 months, the surface coverage of water areas decreased to less than 100 acres across all tehsils. After a period of 10 months, Sampla reported no surface water area, while Rohtak had 5.48 acres, and Mehem Tehsil indicated 60.25 acres. Mehem tehsil recorded only 8 acres of surface water cover during the 11th and 12th months. The figure no.3 reveals that water availability in the district indicates significant seasonality, with most areas experiencing brief intervals of surface water, particularly in Rohtak and Sampla. The district's Mehem tehsil had marginally higher surface water retention than the other tehsils.

Figure 3: Surface Water Seasonality in Rohtak District 2021**Table 4: Area of Major Surface water Classes in Rohtak District 1984-2018**

Sr.No.	Years	Tehsil	Water Classes and Area (Acres)	
			Seasonal water	Permanent water
1	2000	Mehem	2785.99	0
		Rohtak	5708.91	12.73
		Sampla	1413.69	0
2	2004	Mehem	4206.17	0
		Rohtak	6995.43	0
		Sampla	1872.24	0
3	2007	Mehem	4355.82	0
		Rohtak	7361.60	12.73
		Sampla	1799.00	0
4	2011	Mehem	5992.44	0
		Rohtak	11567.77	50.94
		Sampla	2910.25	0
5	2014	Mehem	7444.38	0
		Rohtak	13373.15	22.28
		Sampla	5559.40	0
6	2018	Mehem	18375.34	0
		Rohtak	27682.42	191.04
		Sampla	3725.377	0

Table 4 shows the shifts in Rohtak district's surface coverages water from 2000 to 2018, separating the water as 'not water, seasonal water, or permanent water.' Statistics reveal a three-main trend. It shows that areas covered with "not water" are reducing; those under "seasonal water" increased; and "permanent water" emerged, however it is restricted to only a few areas. Seasonal surface water areas have expanded. The seasonal area of surface water in Mehem Tehsil increased from 2,785.99 acres in the year 2000 to 18,375.34 acres in the year 2018, which was a significant growth of surface water area coverage in the season. The surface seasonal water area under Rohtak Tehsil has increased from 5,708.91 acres to 27,682.42 acres as of the year 2011. Sampla partly followed the pattern, showing an increase of its seasonal water area from 1,413.69 acres in 2000 to 3,725.38 acres in 2018. Permanent surface water increased only in Rohtak Tehsil from 12.73 in the year 2000 to 191.04 acres in the year 2018 while the records show that none of the two tehsils, Mehem and Sampla, had permanent surface water.

Table 5: Surface Water Occurrence in Percentage in Rohtak District 1984-2021

Sr.No.	Tehsil	Water Occurrence Area in Acres			
		Mehem	Rohtak	Sampla	Area in %
1	Water Occurrence 1%	79917.81	47812.11	1944.472	53.9
2	Water Occurrence 10%	369.72	859.95	312.21	0.62
3	Water Occurrence 20%	216.36	457.36	87.64	0.36
4	Water Occurrence 30%	172.54	325.90	60.25	0.18
5	Water Occurrence 40%	41.08	142.41	19.17	0.11
6	Water Occurrence 50%	0.00	13.69	2.74	0.01
7	Water Occurrence 60%	0.00	30.13	0.00	0.01
8	Water Occurrence 77%	0.00	2.74	0.00	0.00

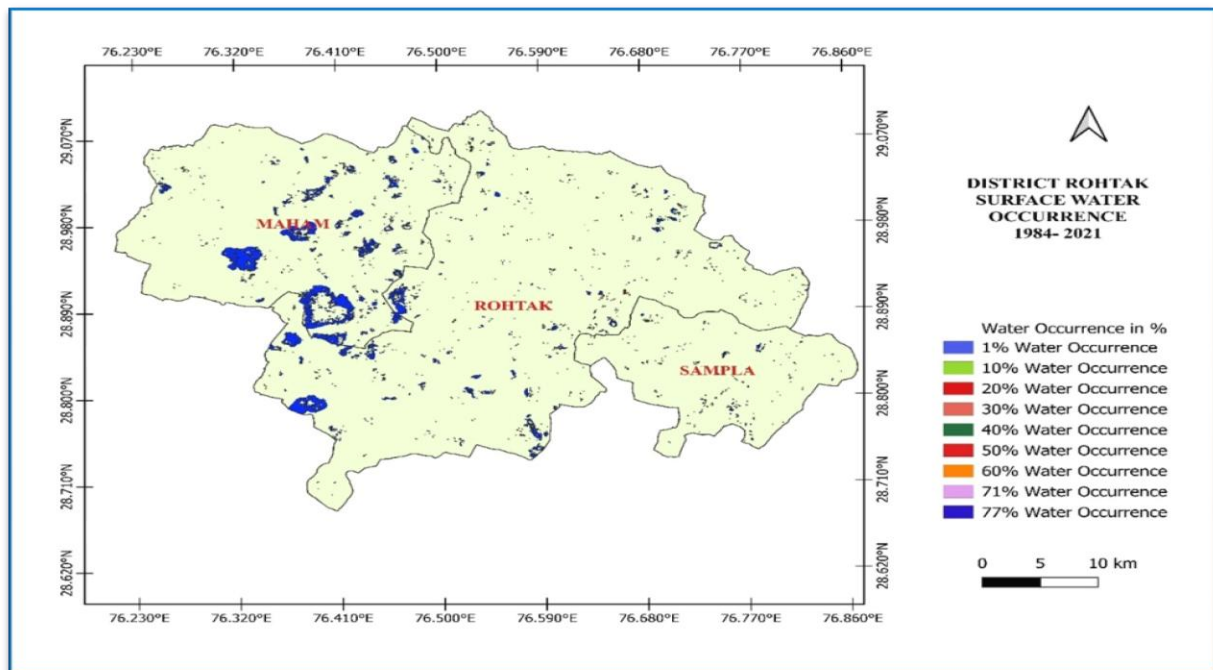
Figure 4: Surface Water Occurrence in Rohtak District 20211

Table no. 5 indicates that in Rohtak district, the area of surface water decreased as the proportion of water occurrence rose. All the tehsils of the districts possess a substantial region with less than 1% surface water presence. The Tehsil, including 79717.81 acres, ranks most, while Sampla, with 1944.472 acres, ranks lowest. However, when the threshold increased to 10%, the water occurrence coverage decreased significantly. Rohtak has the most surface water at 859.95 acres; however, Mehem and Sampla tehsils reported 369.72 acres and 312.21 acres, respectively. The pattern of decreasing surface water area continues at occurrence levels of 20% and 30%, with Rohtak continuously at the top (457.36 acres at 20% and 325.90 acres at 30%), followed by Mehem and Sampla tehsils. A 40% water occurrence significantly reduces the areas, with Rohtak covering 142.41 acres, Mehem covering 41.08 acres, and Sampla covering just 19.17 acres. After the threshold reaches 50%, Mehem Tehsil has no surface water to record, but Rohtak and Sampla record marginal areas of 13.69 acres and 2.74 acres, respectively. The area with surface water occurrence at 60% shows a slight rise to 30.13 acres in the tehsils of Rohtak, while Mehem and Sampla do not have any records. Only Rohtak tehsil recorded a 77% water occurrence, spanning a mere 2.74 acres, demonstrating the rarity of significant and consistent water occurrence across all tehsils.

Conclusion

Surface water coverage in Rohtak District from 1984 to 2021 has noticed tehsils wise spatial-temporal variations. Although Mehem is a small tehsil in terms of size, it records the highest surface water coverage, while the biggest tehsil, Rohtak, shows only moderate coverage. Sampla, the smallest tehsil, has the lowest surface water cover. The district lacks permanent water bodies throughout the study period, with only Rohtak tehsil exhibiting some seasonal persistence. The district's water coverage changes due to the increase in seasonal water, primarily in Rohtak and Mehem tehsils, but Rohtak experiences a significant decrease in seasonal water. By the tenth month of the year, surface water in all tehsils had receded below 100 acres; occasionally, it had completely dried up Sampla tehsil. Mehem had slightly more surface water. Overall, there is a very dramatic trend in the downward decline of surface water cover, with higher thresholds of water occurrence further reducing the occurrence of water. Although Rohtak has a better overall seasonal surface water coverage at higher levels than Mehem and Sampla tehsils, the overall findings seem to highlight the district's limited and irregular surface water cover. The study suggested the importance of effective and sustainable surface water management in the district.

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