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Spatial Distribution and Analysis of Farm Ponds in Jaipur District, Rajasthan

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Abstract - The primary challenge faced by farmers in the Jaipur district revolves around the scarcity of water for irrigation, exacerbated by the continuous decline in groundwater levels. This scarcity not only diminishes agricultural productivity but also hinders overall agricultural development. Consequently, rain becomes the sole recourse for irrigation. In response to this pressing issue, both the Central and State Governments have initiated various schemes, such as the National Horticulture Mission, Pradhan Mantri Krishi Sinchai Yojana, National Agricultural Development Scheme, and Atal Ground Water Scheme. These schemes aim to ensure water availability for irrigation, with a focus on constructing farm ponds subsidized under these programs. Rainwater harvesting from these ponds serves as a vital source for irrigation. Tools like GPS, Arc GIS, and Google Earth Pro have been utilized for this. The spatial distribution pattern of agricultural ponds has been ascertained using nearest neighbour analysis (NNA), special autocorrelation (Moran's' I index), and hotspot analysis for mapping and spatial analysis. Special Auto had a score of 0.156363, while the NNA Index received a score of 0.39 7477. As a result, the study's findings demonstrate that the district's farm pond distribution pattern is cluster-type. In addition, a hotspot study reveals that the Jhotwara, Sanganer, and Jalsu blocks have higher concentrations of form pond.

Keywords - Farm Pond, Spatial Distribution pattern, Nearest Neighbour Analysis, Special Auto Correlation, Hotspot Analysis, Jaipur.

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Author's contribution

Mamta Rolaniya: Data curation; Formal analysis; Investigation; Methodology; Software; Validation; Visualization; Roles/Writing - original draft

Ashutosh Sain: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Resources; Software; Supervision; Validation; Visualization; Roles/Writing - review & editing

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1. Introduction

1.1 Farm Pond

A farm pond is an earthen pit that is dug to collect rainwater for future use. It is usually square or rectangular (Jakkawad et al., 2020). A farm pond is a small water harvesting system that collects rainwater by digging a hole at the field's lowest point where water can collect and be used to store surplus water (Rao et al., n.d.; Reddy et al., 2020). During the delayed monsoon, this may result in irrigation that is life-saving or protective (Deshmukh et al., 2017; Jakkawad et al., 2020 ; Rao et al., n.d.). Due to its cost-effectiveness, the farm pound project has proven beneficial for marginal and small farmers (Rao et al., n.d.). Farm pond technology has the potential to boost crop yield and area, as well as increase water availability for supplemental irrigation, resulting in a net increase in net cultivated area (Kumar et al., 2016; Rao et al., 2017). Farm ponds necessitate lining to mitigate seepage in loose-textured soils like Alfisols, while clay soils such as Vertisols naturally exhibit low seepage, rendering lining unnecessary. Farm ponds are categorized into three types based on this: raw farm ponds, plastic-lined farm ponds, and cemented farm ponds (Rao et al., 2017; Reddy et al., n.d.). Some farm pond structures built in the Jaipur district is shown in Fig.1.

Farm pond provides a solution to address increasing frequencies of drought, especially mid-season and terminal drought under climate change scenarios. Farm Ponds intervention increases crop production by 25-30% as rainwater is available to provide one or two life-saving irrigations at critical growth stages of the crop during drought. Water harvesting structures like farm ponds have an important role to play in improving crop production and agriculture in rainfed areas under climate change conditions. Farmers can be given ongoing food and livelihood security with these water harvesting systems, in addition to mixed farming and crop diversification initiatives. To increase crop productivity and output, extra runoff water must be collected and used for preventive, life-saving irrigation (Dupdal & Ramesha, 2021).

Fig.1. Dugout farm pond in Jaipur district, Rajasthan, India

(a) & (b) Unlined (raw) farm ponds in clay soil, (c) & (d) Plastic-lined farm ponds in alluvial soil

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By minimizing the chance of crop failure in arid and semi-arid environments, these rain harvesting structures have the potential to raise agricultural yields and the amount of arable land available (Machiwal et al., 2004; Rao et al., n.d.). An analysis of the advantages of farm ponds has revealed that the installation of irrigation systems on arable, barren land has enhanced crop yield by providing supplemental irrigation (Shrivastava & Singh, n.d.). Rainfed crops will yield much higher yields if it is possible to collect rainwater and utilize it for agricultural irrigation. In India, rainwater collection and recycling are long-standing customs, particularly in semi-arid regions (Rao et al., n.d.)

Cropping intensity and crop production can both be greatly increased by the farm pound. Additionally, it aids in improving the farmers' financial situation. The irrigated area has increased as a result of the construction of the farm pond. It is a useful tool for raising revenue (Deshmukh et al., 2017; Rao et al., n.d.). The results of crop production through supplemental irrigation through farm ponds in the Jaipur district are shown in Fig. 2.

Through pound-on-farm runoff collection and additional irrigation, dugout farm ponds have been demonstrated by numerous researchers to both boost and stabilize crop productivity (Krishna et al., n.d.)

Farm ponds will help farmers manage water on the farm by using the stored water to combat drought Farm ponds play an important role in rain-fed areas (Reddy et al., n.d.).

Fig. 2. Crops with supplemental irrigation from farm ponds at Jaipur District

(a) & (b) Wheat cultivation by sprinkler, (c) Chilli cultivation in Notanal by drip system (d) Cucumber cultivation in poly house.

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In Jaipur district, the non-availability of water for irrigation due to falling groundwater levels and irregular rainfall is the main problem of agriculture. The groundwater level in the district is quite low. Here, seven blocks—Bassi, Shahpura, Govindgarh, Sanganer, Samar, Amer, and Jhotwara—are in the Over Exploited Notified Category, while five blocks—Dudu, Kotputli, Viratnagar, Jamaramgarh, and Chaksu—are in the Over Exploited Category. Phagi, one block, falls within the crucial category (Jaipur District Hydrological Atlas, 2003). Conversations with residents corroborated that the unavailability of irrigation water is the primary cause of declining agricultural productivity, significantly impacting their socio-economic well-being.

Implementing initiatives like Farm Pond schemes could significantly drive the district towards development. Technologies such as farm ponds have the potential to greatly reduce groundwater exploitation while ensuring a sustainable water supply for irrigation (Reddy et al., n.d.), which emphasizes the need to research their effectiveness in the area.

One of the main issues with agriculture in this area is the lack of water for irrigation. In this context, farm ponds are being built with subsidies in the Jaipur district. This work is being done through various schemes like National Horticulture Mission (2005-06), Pradhan Mantri Krishi Sinchai Yojana (2015), Rastriya Krishi Vikas Yojana (2007), Atal Ground Water Yojana (2019), etc., which will ensure the future of protective irrigation. It seems like a great option.

1.2 Spatial Distribution Pattern

Geographers and other scientists examine geographic or spatial patterns of various phenomena to gain insights into the processes that generate such patterns (Hamzah et al., 2020). Spatial statistics, the focal point of statistical methods, utilizes spatial relationships (such as distance, area, volume, length, and height) in mathematical computations. Spatial data aids in understanding the distribution pattern of features (Pimpler, E., 2017).

Numerous techniques exist for determining whether spatial patterns exist, including NNA and Moran's I statistic. Semivariogram, K function analysis, etc. It is frequently required in geographical data analysis to ascertain the existence of a detected spatial pattern (Ord & Getis, 1995).

1.3 Nearest neighbor analysis

NNA represents clustered, random, and regular point patterns (Bishop, 2010; Philo & Philo, 2022) and quantifies the separation between each centroid position and its nearest neighbor (Bishop, 2010). It was ecologists Clark and Evans who first used the NNA (1954). It has a value between 0 (completely random) and 2.5 (completely regular) (Philo & Philo, 2022). The distribution pattern will be clustered if the NNA index value is 0, random if it is 1, and even if it is 2.5(Philo & Philo, 2022; Uwala & Uwala, 2020).

1.4 Special Auto Correlation

This tool simultaneously measures attribute values and feature locations to calculate spatial autocorrelation. It is referred to as clustering when features that are near to one another have similar values. On the other hand, a diffuse pattern is formed when features that are near to one another have different values. This tool outputs Moran's I index value along with the z-score and p-value (Pimpler, E., 2017).

1.5 Hotspot Analysis

Mapping Cluster tools serve the purpose of identifying statistically significant hot and cold spots, spatial outliers, and similar features, as well as grouping features. They facilitate defining actions based on cluster locations. For instance, these tools can aid in pinpointing areas of high crime activity for strategic allocation of police resources. While these clusters typically do not explain why a phenomenon occurs, they often offer valuable clues. The toolset enables visualization of clustering patterns within datasets and provides a straightforward assessment of whether the dataset exhibits clustering or dispersion. Various tools available for mapping clusters include the Similarity Search tool, Grouping Analysis tool, Hot Spot Analysis tool, Optimized Hot Spot Analysis tool, and Cluster and Outlier Analysis tool (Pimpler, E., 2017).

1.6 Study Area

Rajasthan's eastern region contains the district of Jaipur. The districts of Sikar in Rajasthan and Mahendragarh in Haryana are located to the north; Tonk is located to the south; Alwar and Dausa are located to the east; Sawai Madhopur is located to the southeast; and Nagaur and Ajmer are located to the west. It spans 74°55' to 76° 54' east longitude and 26°23' to 27° 51' north latitude (Fig. 3). With a total area of 11,143 square kilometres, the Jaipur district makes up 3.3% of all of Rajasthan (Thukral, 2018).The district of Jaipur spans 180 km from east to west and around 110 km from north to south. Compared to other state districts, its area puts it in ninth place (Jaipur District, Rajasthan, n.d.)
To carry out plans and initiatives related to rural development under the Panchayati Raj system, the district is split up into 22 Panchayat Samitis (Blocks). which are: Dudu, Phagi, Madhorajpura, Chakshu Kotkhavda, Jobner, Mojmabad; and Kotphutli, Pavata, Viratnagar, Shahpura Govindgarh, Amer, Jalshu, Jamaramghar, Andhi, Bassi, Tunga, Jhotwada, Sanganer, Kishangarh Renwal.

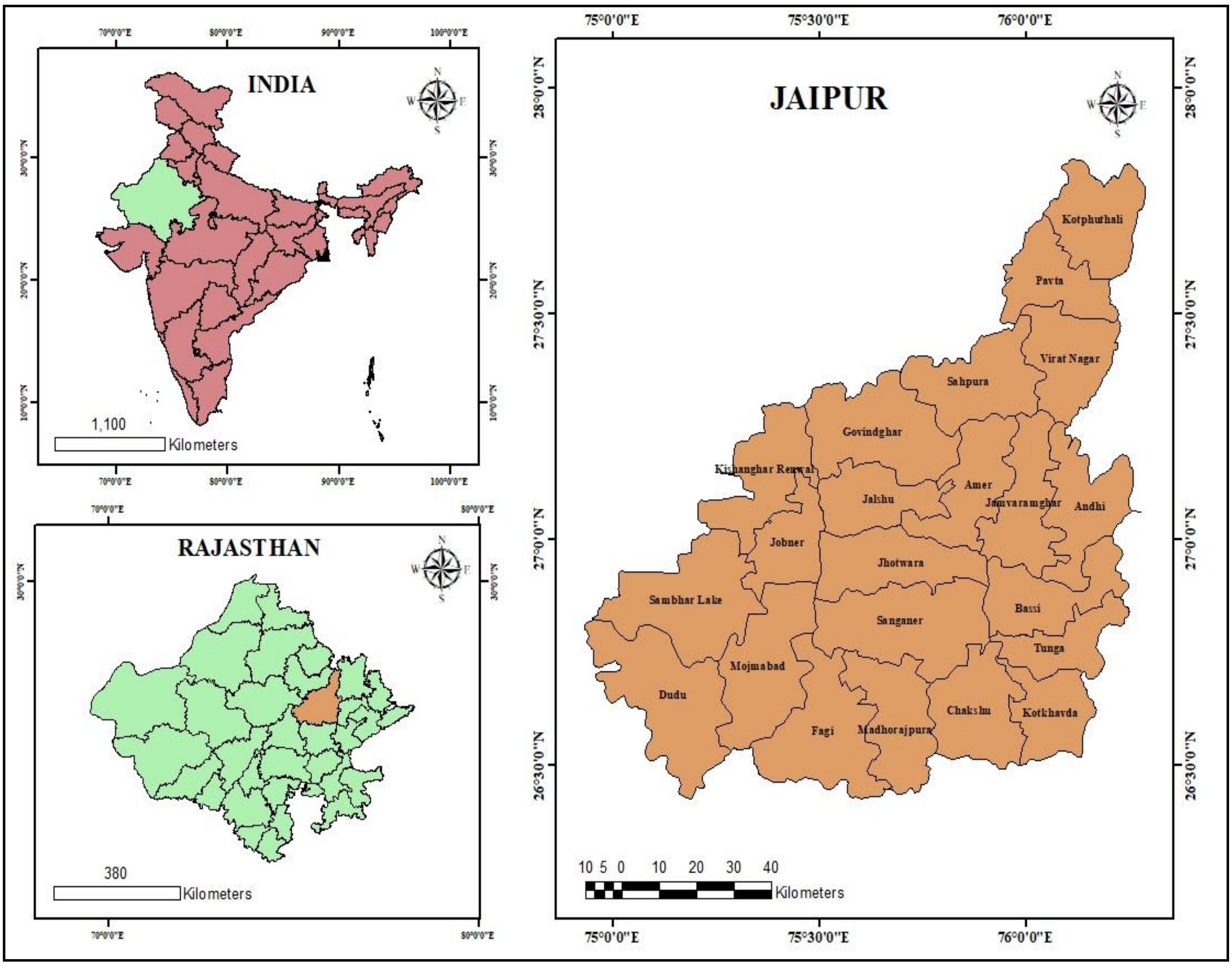

Fig. 3. Location map of Study area

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2. Material and methods

First, all of the district's farm ponds were located using Google Earth Pro, and their physical verification was done using GPS (JUNO - Trimble). Table 1 displays the farm pond distribution in the Jaipur district by block. After obtaining 12036 farm pond sites from Google Earth (Fig. 4 displays the farm pond point locations collected with the use of Google Earth Pro), the spatial distribution pattern was ascertained using NNA and Special Auto Correlation (Morris Index). The concentration of agricultural ponds in the research area has been determined by the application of hotspot analysis. Figure 5 displays a flowchart of the method being used.

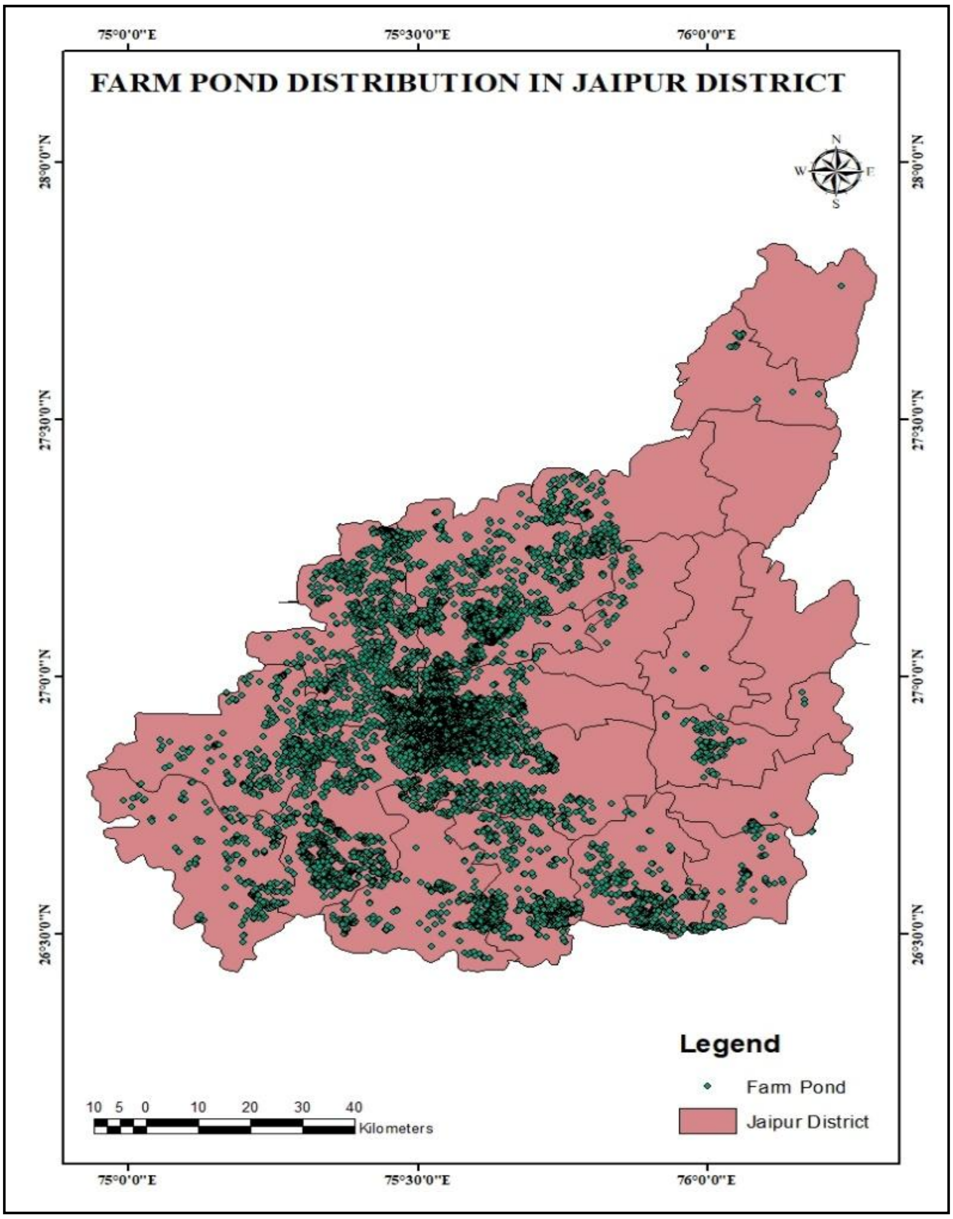

Fig. 4. Distribution of farm ponds in study area

COMMON GROUND

Table 1. Number of Farm Ponds in Jaipur district

S. No.	Name of Block	No. of Farm Pond	S. No.	Name of Block	No. of Farm Pond
1	Kotphutli	1	12	Jhotwada,	2829
2	Pavata	17	13	Sanganer	1777
3	Viratnagar	-	14	Kishangarh Renwal	543
4	Shahpura	392	15	Sambhar Lake	497
5	Govindgarh	663	16	Dudu	244
6	Amer	57	17	Phagi	485
7	Jalshu	1089	18	Madhorajpura	597
8	Jamaramghar	6	19	Chakshu	518
9	Andhi	-	20	Kotkhavda	112
10	Bassi	138	21	Jobner	918
11	Tunga	18	22	Mojmabad	510

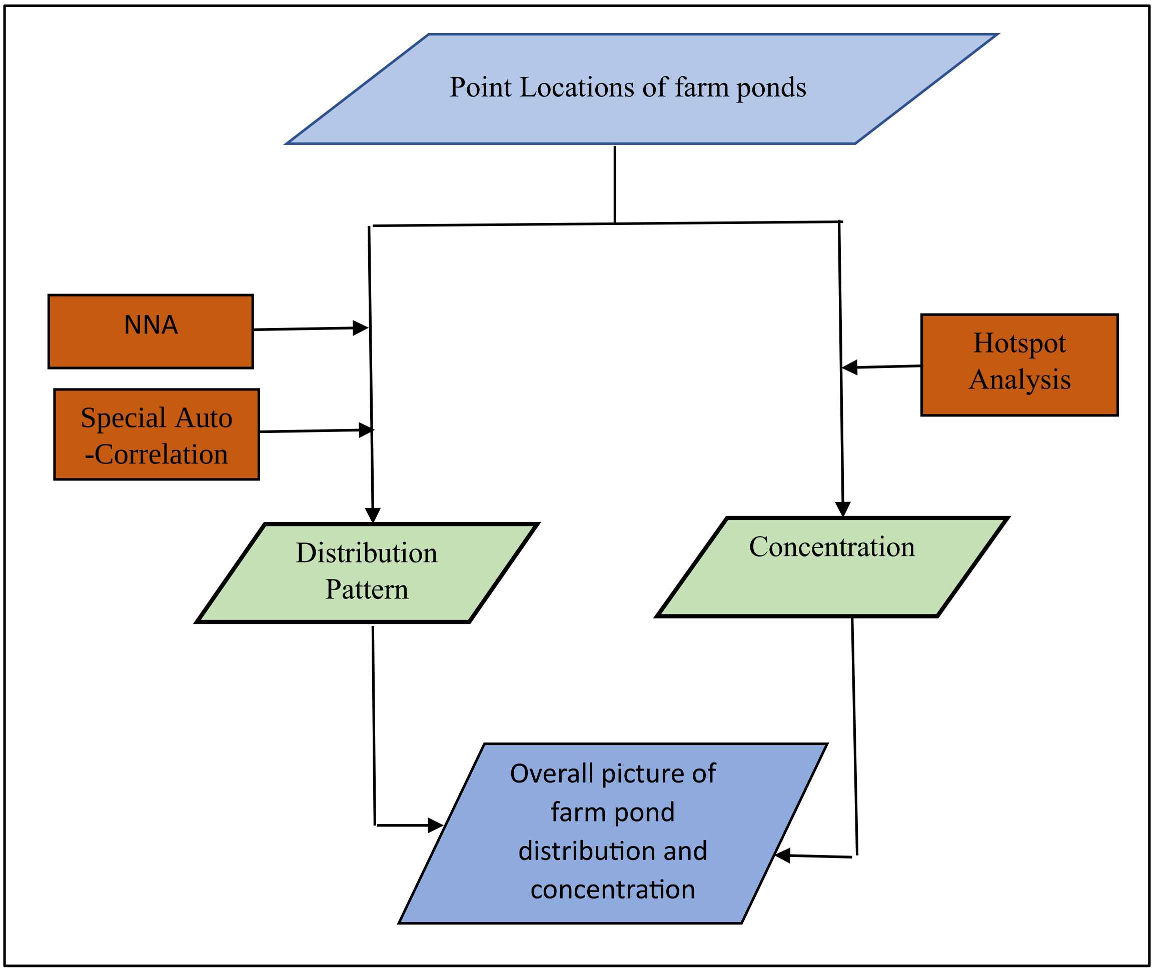

Fig. 5. Workflow of Methodology adopted to find out the distribution pattern and concentration of farm ponds.

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The three components of the NNA method's analysis of an area's distribution pattern are uniform, random, and clustered. This approach involves measuring the distance between each point and the closest nearby point and then calculating the mean of those distances. As a result, the NNA approach is concerned with calculating the distance without accounting for the direction between a point and its closest neighbour point. This approach represents the point or settlement distribution pattern in a regional distribution through quantitative analysis. This involves comparing the expected or expected distance (Expected Spacing) between various locations in a random distribution pattern with the observed distance (Observed Spacing) between them a result, the observed distance reveals the distance between each point or location, whereas the predicted distance provides information about the intensity of a random sample. The mean distance is ascertained in the analysis phase of this method by drawing a line linking the points or locations inside the area with their nearest points to one another (Sharma, P.M.,2021)

The acronyms R or Rn stand for the Index of Randomness in the NNA procedure. The ratio of the mean to the probability of the distances between the closest points in any distribution is expressed by this R (Sharma, P.M.,2021) Thus, the following procedure and formula can be used to determine the value of R:

$$R= \frac{\bar{D}O}{\bar{D}r}$$

R or Rn = irregularity index

$\bar{D}o$ = Mean of observed distance from nearest neighboring points.

$\bar{D}r$ = Mean of Expected Distance from nearest neighboring points.

(Expected mean of nearest neighbour distance for random point arrangement)

The approximate range of Moran's autocorrelation is -1 to +1. When spatial autocorrelation is positive, it is represented by a positive sign; when it is negative, the opposite is true. Spatiotemporal autocorrelation is zero. Determining if two places are neighbours is necessary to calculate the weight function. To define neighbours, this calls for criterion (Misra Sahoo, n.d.).

Moran (1950) proposed the following measure for calculating spatial autocorrelation (β):

$$\beta = \frac{N}{S} \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} wij(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i-1}^{N}(x_i - \bar{x})^2}$$

where xi is the observed value at location I,

N is the number of locations and

$S= \sum_{i=1}^{N}\sum_{j=1}^{N} wij$, i ≠j,

The weighting function wij is used to assign a weight to each pair of locations in the study area,

wij =1, if i and j are neighbours and = 0, otherwise.

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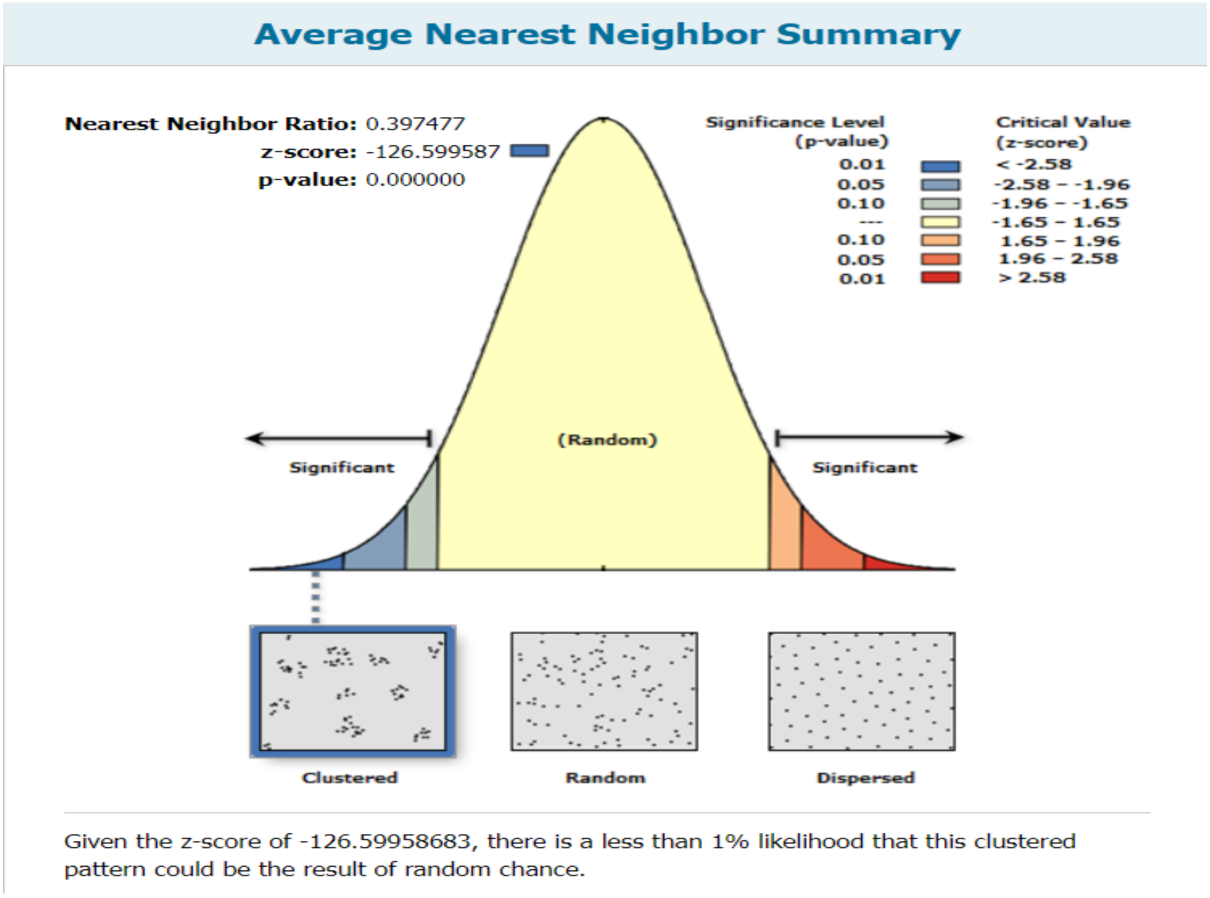
RESULTS AND DISCUSSION -

The distribution pattern has been examined using NNA, Hotspot Analysis, and Special Auto Correlation Morris Index. Special Auto had a score of 0.156363, while the NNA Index received a score of 0.39 7477. As a result, the study's findings demonstrate that the district's farm pond distribution pattern is cluster-type. The cluster distribution pattern of farm ponds, as indicated by the NNA yield of NNA ratio 0.397477 and Z score -126.599587, suggests that farm ponds are not dispersed equally throughout the research area, but rather are concentrated in some areas. The results for NNA are summarized in Fig.6. Moran's' I index of 0.156363, and z score of 204.182088, obtained through spatial autocorrelation, show the cluster pattern of farm ponds in the research area.
A summary of the results for Special Auto Correlation is shown in Fig. 7.



Average Nearest Neighbor Summary

Observed Mean Distance:	191.8150 Meters
Expected Mean Distance:	482.5815 Meters
Nearest Neighbor Ratio:	0.397477
z-score:	-126.599587
p-value:	0.000000

Fig. 6. Summary of Nearest Neighbour Analysis

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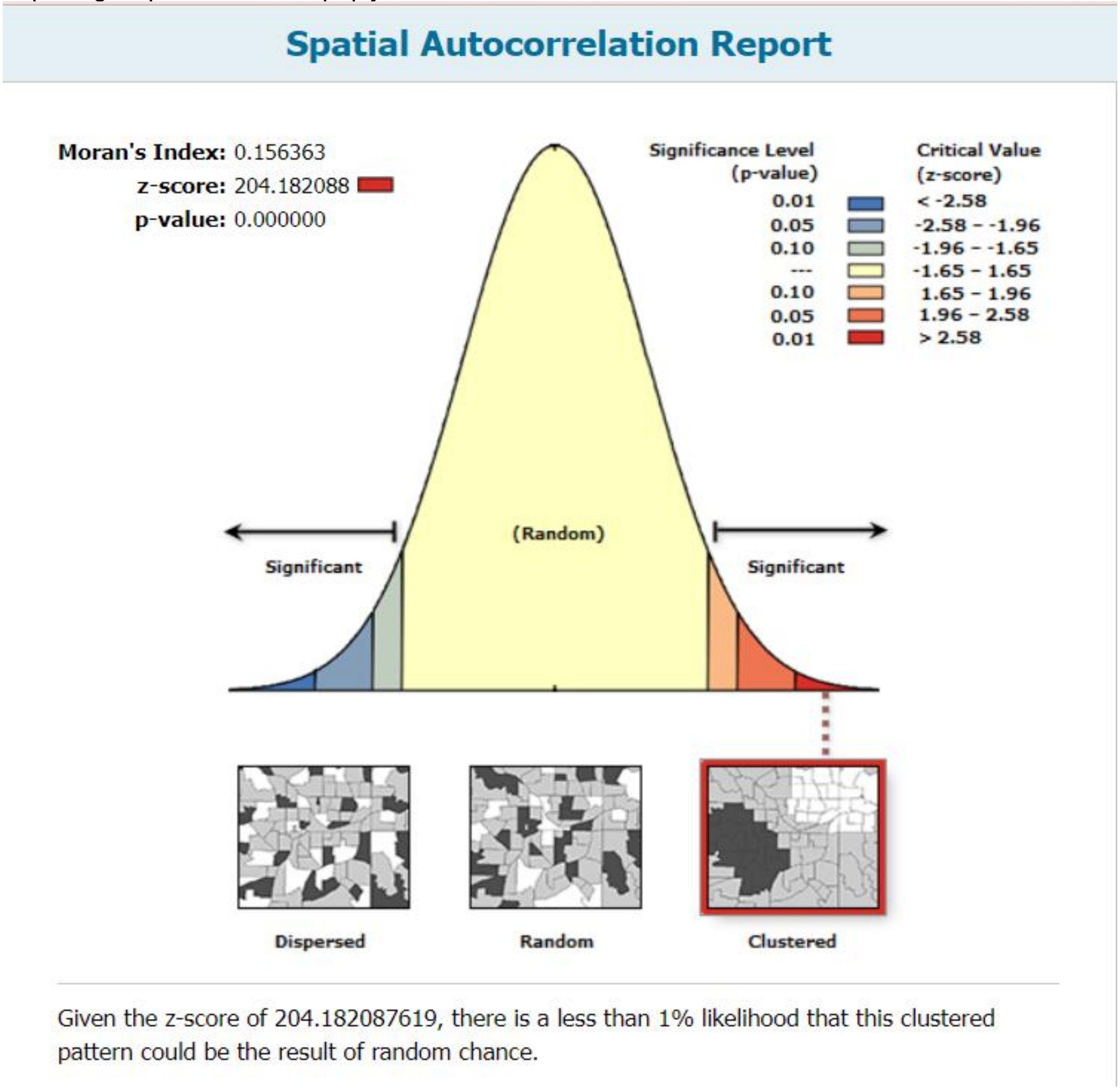

Global Moran's I Summary

Moran's Index:	0.156363
Expected Index:	-0.000168
Variance:	0.000001
z-score:	204.182088
p-value:	0.000000

Fig. 7. Summary of Special Auto Correlation

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The concentration of farm ponds in the research area has been examined using hotspot analysis; the outcome is displayed in Fig 8. According to hotspot analysis, Jhotwara, Sanganer, Jobner, south-western Jalshu and north Mojmabad, north-east Sambhar Lake, and north-east Kishanghar Renwal are among the areas where form ponds are concentrated.

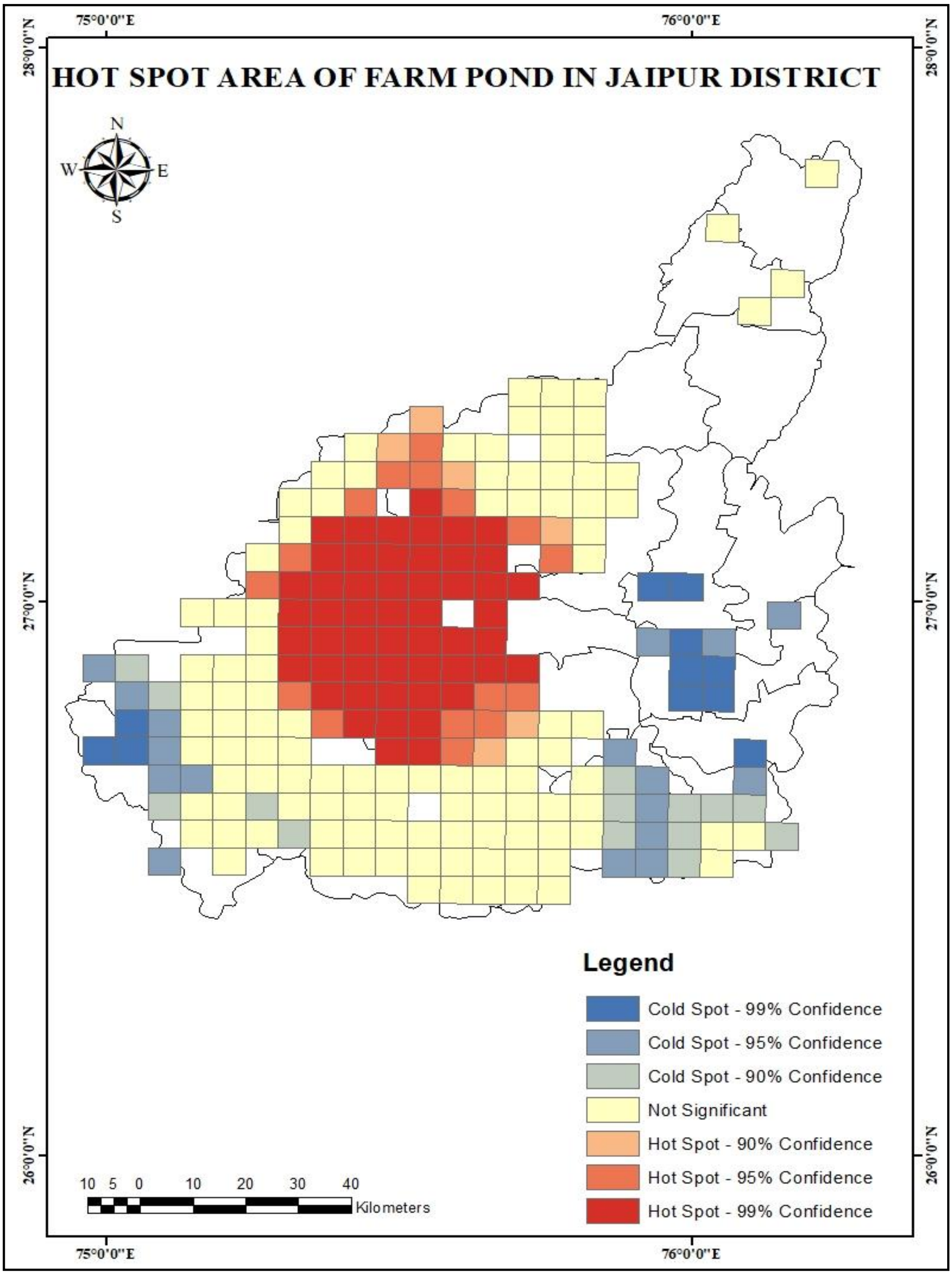

Fig. 8. Hot spot area of farm ponds in Jaipur district

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5. Conclusion

This research endeavours to uncover local disparities withın the distribution of farm ponds, focusing on identifying underserved or deprived areas lacking farm pond facilities. The findings highlight a concentration of farm ponds in the southwestern region of Jaipur district, with limited presence in the eastern and northern blocks. Such insights can aid the government in identifying optimal locations for future farm pond construction. Moreover, this research holds promise for informing future policy decisions aimed at addressing regional disparities and advancing the goal of equitable development in the region.

Research findings indicate a concentration of Farm Ponds in the southwestern region of Jaipur, with notably fewer in the north-eastern area. Insights from local farmers and agricultural experts attribute this imbalance to the ample availability of groundwater in the northeastern blocks, facilitating irrigation without the need for farm ponds. However, continuous groundwater exploitation for irrigation purposes raises concerns about future water scarcity, potentially leading to situations akin to those in the southwestern blocks. To pre-emptively address this issue and prevent future water shortages for irrigation, there is a pressing need to construct water harvesting structures such as farm ponds in the northeastern blocks as well.

In the Jaipur district, groundwater levels are steadily declining, which prevents farmers from having access to water for irrigation. It directly affects the development and productivity of agriculture. An effective watering alternative is a farm pond. Farm ponds can not only collect rainwater but can also harness groundwater. By using farm ponds as an alternative to irrigation, we can meet the needs of the present without compromising the needs of future generations and achieve the goal of sustainable development. Therefore the distribution pattern of farm ponds must be uniform in all the blocks of Jaipur district.

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