Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

INVESTIGATION ON SPATIAL ANALYSIS OF PRECIPITATION MAPPING USING GIS: A CASE STUDY OF NARUDAIYAR WATERSHED, TAMIL NADU, INDIA.

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Abstract

One of the climatic factors that varies the most throughout both time and space is rainfall. Since rainfall characteristics differ from region to region, it is crucial to analyze the distribution of rainfall over an area in order to comprehend the micro-level variability and plan future water management activities. Therefore, it is crucial to keep an eye on its nature and trend at any location to conserve land and water for the future. A powerful tool for creating a spatial distribution of rainfall utilizing a range of rainfall data attributes is geographical information system (GIS) software. For many simulation studies, especially runoff and hydrological modeling, this spatial rainfall data can be used as input. Consequently, the current study examines the Narudaiyar Vellar watershed's rainfall characteristics, including its spatial distribution and seasonal variations. The annual and seasonal rainfall patterns during a 30-year period, from 1991 to 2021, are spatially analyzed using statistical tools and GIS interpolation techniques. It rains heavily to extremely heavily in the research area's northwest and southwest regions. The monsoon season brings the most rain to the research region, and by 2016, the bulk of it had a high to extremely high rainfall distribution. The wettest years in the study region had average rainfall above 1000 mm in 1992, 1996, 1997, 1998, 1999, 2005, 2006, 2007, 2008, 2010, 2011, 2014, 2015, 2016, 2017,2019, 2020 and 2022. 3.66% of the annual average distribution of rainfall falls during the post-monsoon season, which is higher than winter-season rainfall but lower than pre-monsoon precipitation. The study's findings will shed insight into the Narudaiyar Watershed's geographical rainfall distribution, which can be useful for hydrological research, land use planning, and water management techniques.

Keywords: Rainfall, Spatial Analysis, Inverse Distance Weighting, GIS, Rainfall Variability

Introduction

India is a tropical country that depends on the monsoon rains for agricultural planning and water use. More than 75% of all rainfall occurs during this time. Since monsoon rainfall is unpredictable in terms of timing and location, it becomes a key factor as rainfall analysis progresses. The distribution of rainfall is the most important factor. It is required to assess data gathered over long time periods and from various sites in order to gain reliable information because rainfall happens in different places at different times. Since significant rainfall occurs mostly during the season of

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

monsoon and when rainfall is inconsistent in both regions and times, figuring out rainfall variance is critical (Sumedh R. et al., 2018). Although groundwater is a critical source of drinking water and is necessary for agriculture all over the world, among the most significant objectives of Integrated Water Resources Management (IWRM) is to gauge its availability and accessibility under changing boundary conditions. An unfavorable climate can have an impact on crop productivity at any stage, from planting through harvest. Even if there is adequate rain, erratic rainfall can diminish yields if it fails to arrive when the crops need it the most. (2002) Smith et al. The present research's major purpose is to better comprehend the Narudaiyar watershed's rainfall cycle. Multiple kinds of rain gauge stations established throughout the research region were employed to quantify seasonal and geographical changes in rainfall patterns. Rainfall plays a significant role in the flood. However, an effort had been made to understand that a number of earlier studies had used the IDW (Inverse Distance Weighting) interpolation method to estimate the distribution of rainfall before choosing which approach to use. Therefore, to assess the geographical variation of rainfall year and seasonally, this study used the IDW method in the software ArcGIS. Geographical information systems (GIS) and related technologies are being used extensively across many fields. The spatial interpolation technique known as Inverse Distance Weighting (IDW) interpolation method determines cell values by mixing the number of sample locations with linear weights. The interpolation is undertaken on the surface of a location-dependent variable, with the weight determined by inverse distance. Geostatistical interpolation techniques may be used to evaluate the various patterns and imply the degree of variability in precipitation rate changes.

Study Area

The study region is restricted to a river of a significant Cauvery carrier branch that branches off from the Cauvery in Trichy Districts of Upper Anicut. Through Trichy, Perambalur, Ariyalur, Thanjavur, Mayiladuthurai, and the Cuddalore District, it travels 100 miles before emptying into the Bay of Bengal. According to the Cauvery Water Dispute Tribunal, Lower Anicut is the final barrage across the Cauvery River system for sharing the river's water. According to Fig. 1, 10 thousand million cubic feet of water is designated for the minimal environmental flows downstream of the lower Anicut. The study region has a geospatial coverage of 1844 km^2. It Covers the longitude and latitude range from 79°08"08E to 79° 50"01E and 10°59" 27N to 11° 27" 05 N, respectively. Extreme weather conditions, particularly in coastal areas, such as flooding, have a frequent impact. Rainfall rises along the

coastline, when a low-pressure system emerges in the Bay of Bengal, with average coastal rainfall varying between 970 to 1500 mm. During the northeastern monsoon, nearly every one of these three coastal taluk’s experiences significant flooding. It also boasts a comfortable tropical climate all year, with mean summer temperatures roaming from 22 to 36 °C and mean winter temperatures roaming from 21 to 33 °C.

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

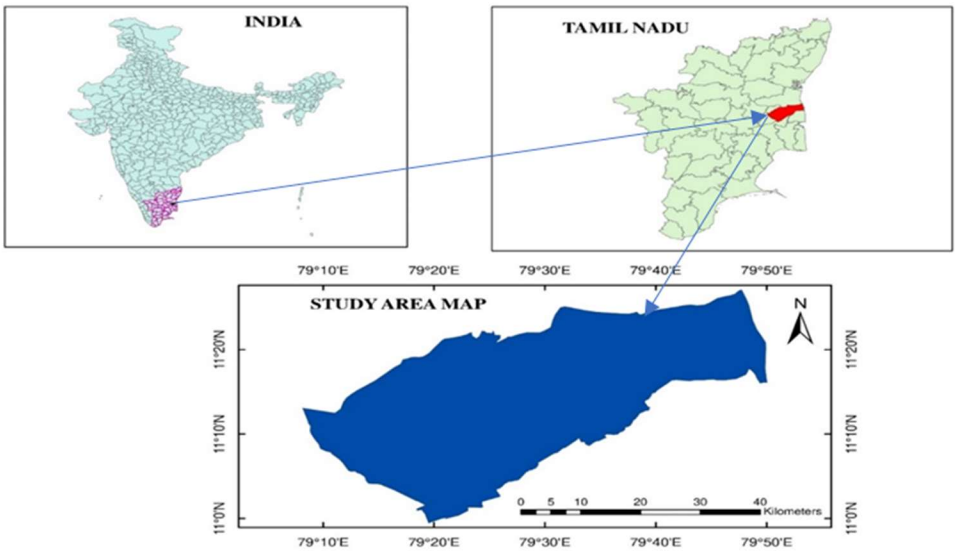

Figure 1. Study area map of Narudaiyar Watershed

Materials and Methods

Every day it rains, in accordance with the specifications for generating an interpretive area map, data for a 30-year period, from 1991 to 2021, of 4-gauge stations is gathered and processed on Excel sheets. The Arc GIS software version 10.8.1 was used for map generation.

Table (1) Datasets used in the study

S. no	Data sets	Description	Scale	Web Source
1	Boundary of Lower	Polygon	m	https://tngis.tn.gov.in/ (Tamil Nādu geographical information system)
2	Rainfall	Cuddalore District. Using the Inverse Distance Weight Tool	mm	Indian Meteorological Department (IMD) https://www.imdpune.gov.in/ & Institute of Water Studies (IWS), Tamil Nadu, Chennai.

Methods

In order to undertake the spatial analysis of rainfall using Geospatial methodologies, the daily point grid pattern of rainfall data from 1991 to 2021 was collected from the Indian Meteorological Department (IMD) and the Institute of Water Studies (IWS), Tamil Nadu, Chennai.

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

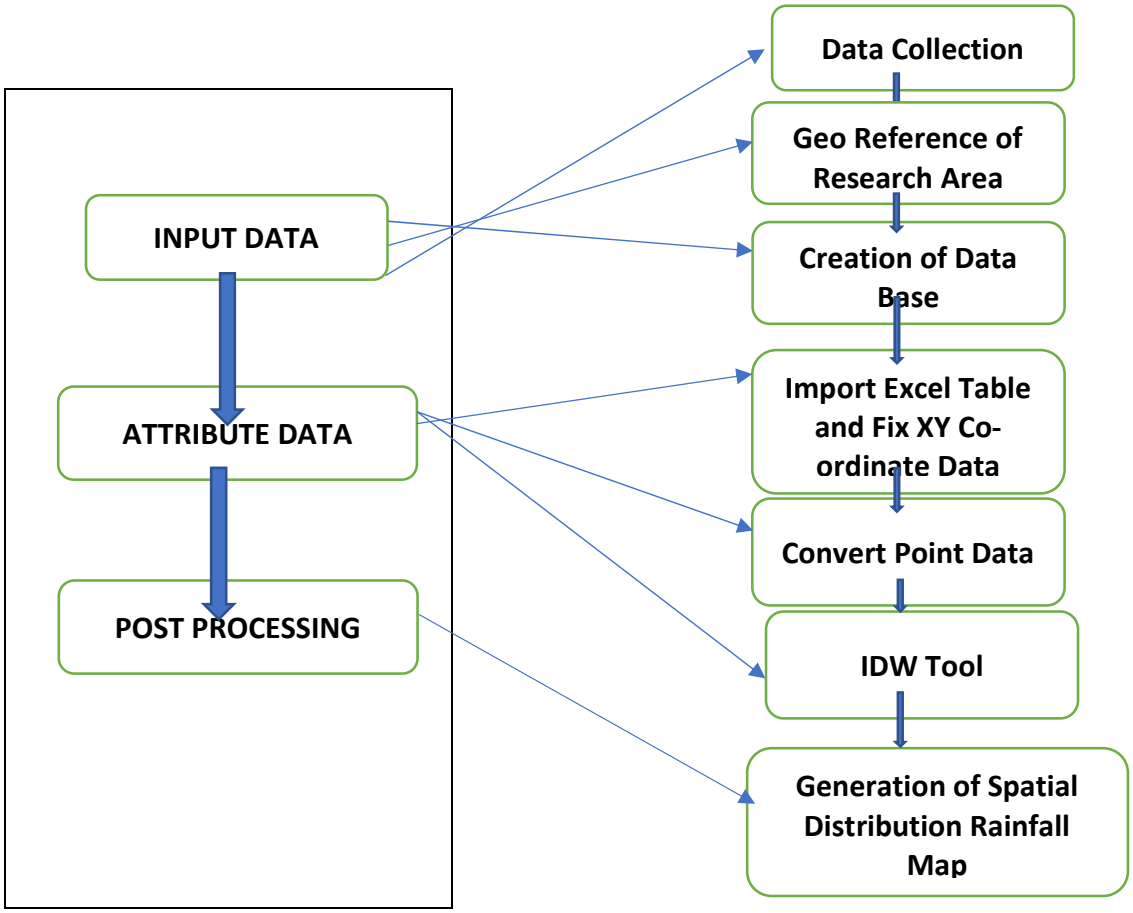

Figure 2. Flow Chart of Methodology

IDW Method

The IDW has become one of a great deal of often-used interpolation practices. It computes the value via a weighted mean of existing values in the targeted neighborhood. Everything is interconnected, but close things are more related than remote things. The IDW look entails giving values to unknown spots based on values from an associated array of known points. The value of the unidentified point is the weighted mean of the values of the N known points. As a consequence, IDW may be simply utilized to forecast unknown spatial rainfall data from known data from adjacent locations. The IDW Method Formula

$$R_P = \sum_{i=1}^{N} w_i R_i \qquad \text{equation---1}$$

$$W_i = \frac{d_i^{-\alpha}}{\sum_{i=1}^{N} d_i^{-\alpha}} \qquad \text{equation---2}$$

where Rp refers to the inaccessible precipitation data (mm); Ri refers to the accessible precipitation data (mm), N is the number of precipitation stations, W_i is the weighting of each rainfall station, di is the distance from each rainfall station to the unknown site, α refers to the power control parameter.

Results and discussion

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

Mean Annual Rainfall

The total precipitation is recorded and averaged throughout a specified month or year. Although the median (decile 5) is usually employed as the preferred meteorological metric of "average" or "typical" rainfall, both the mean and the median (decile 5) rainfall have been included in these figures. Because of the large daily variability in rainfall, a single uncommon rainfall event (such as a slowly moving, influential thunderstorm) will have less of an impact on the median than the arithmetic mean. Examining the seasonal variance of rainfall during the preceding 30 years at the four rain gauge stations in the research area. The four separate study seasons were pre-monsoon (March to May), post-monsoon (Jan. and Feb.), SW monsoon (June to Sep.), and NE monsoon (Oct. to Dec). The study's rainfall records were organized as follows: Southwest monsoon comes first, followed by North East monsoon, Pre-monsoon, and Post-monsoon. Thirty years of annual average rainfall at four places within the Narudaiyar watershed were researched (1991-2021).

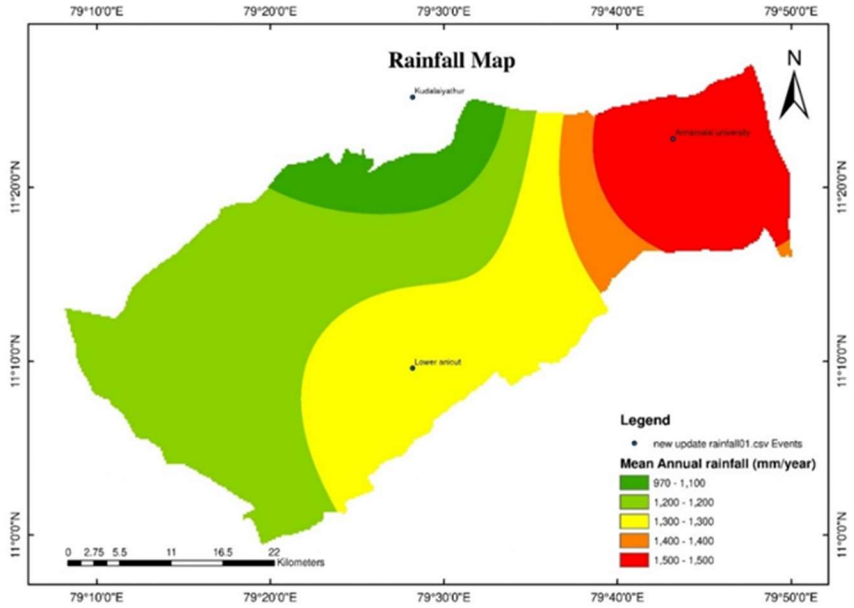

Figure 4. Mean Annual Rainfall Analysis Map of Narudaiyar Watershed

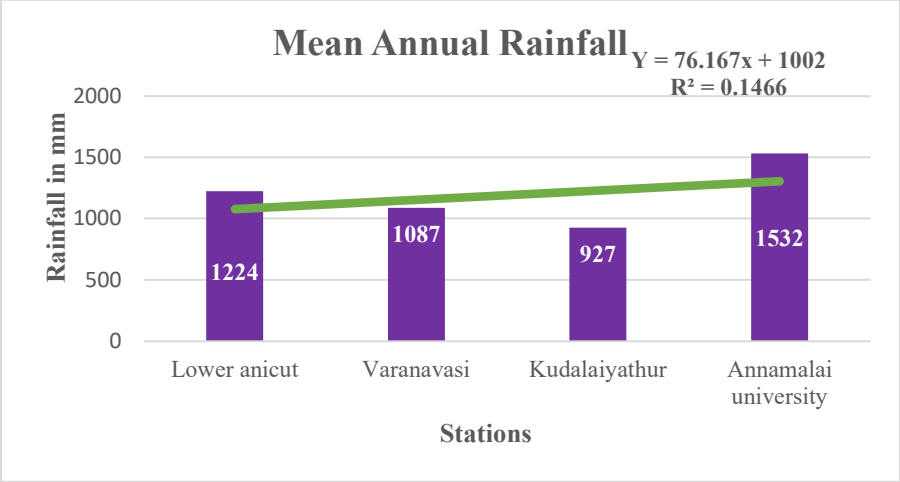

Figure 5. Mean Annual Rainfall Analysis of Narudaiyar Watershed

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

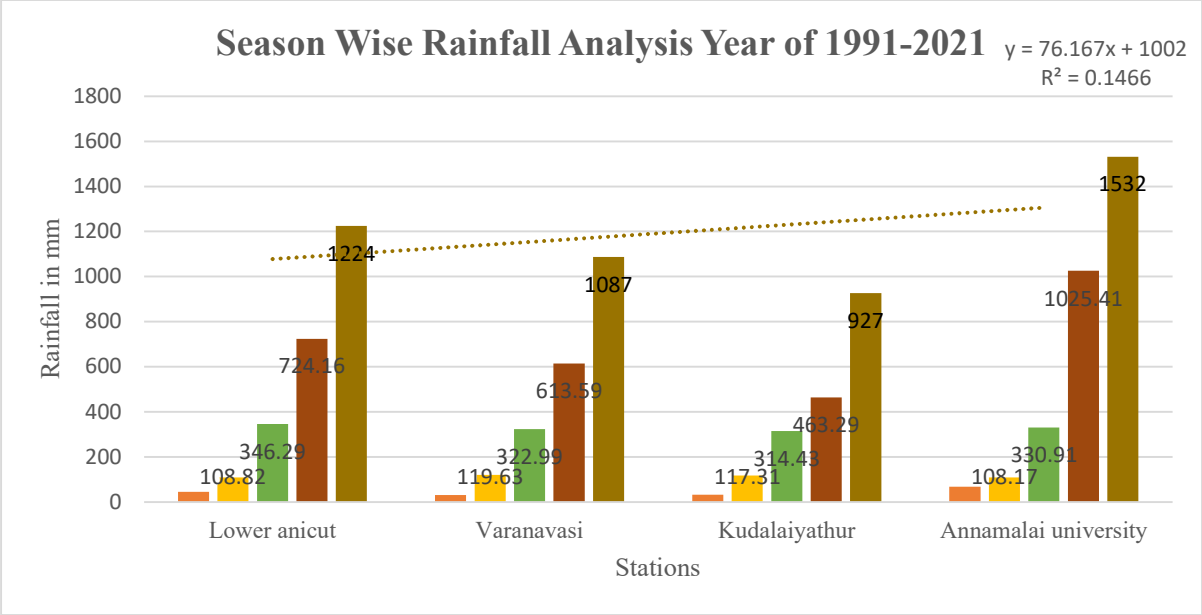

Figure 6. Season Wise Rainfall Analysis of Narudaiyar Watershed

Table 2 Datasets used in the study

`Station	Latitude	Longitude	Post Monsoon	Pre - Monsoon	SW Monsoon	NE Monsoon	Mean Annual Rainfall
Lower Anicut	11.16	79.47	45.06	108.82	346.29	724.16	1224
Varanavasi	11.093	79.08	30.80	119.63	322.99	613.59	1087
Kudalaiyathur	11.42	79.47	31.55	117.31	314.43	463.29	927
Annamalai University	11.38	79.72	67.21	108.17	330.91	1025.41	1532
Average			**43.65**	**113.48**	**328.66**	**706.61**	**1192**
Percentage			**3.66**	**9.52**	**27.57**	**59.28**	**100**

The study region experienced a rising annual average rainfall trend, with the lowest average rainfall recorded in 1999 at 601.34 mm and the greatest average rainfall recorded in 2004 at 1382.70 mm (Figures 4 and 5).

Post Monsoon

This season, which follows the southwest monsoon maxima, might continue from October through November depending on where you live. As precipitation decreases, the vegetation starts to dry out. This time period marks the transition from the wet to the dry season in the majority of India. The study region had a rising post-monsoon average precipitation trend, with the smallest mean

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

rainfall recorded in 1992 at 0.00 mm and the greatest average rainfall recorded in 1999 at 411.90 mm. Annamalai University station reported a maximum of 67.21 mm of mean annual rainfall during post-monsoon, while Varanavasi station recorded a minimum of 30.80 mm.

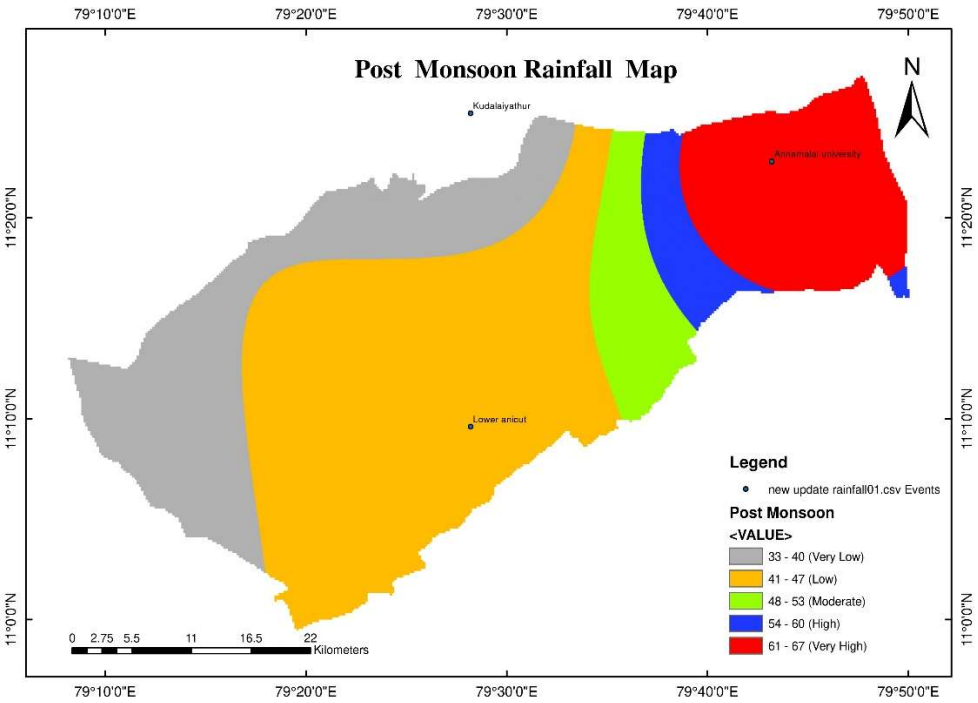

Figure 7. Post- Monsoon Rainfall Map of Narudaiyar Watershed

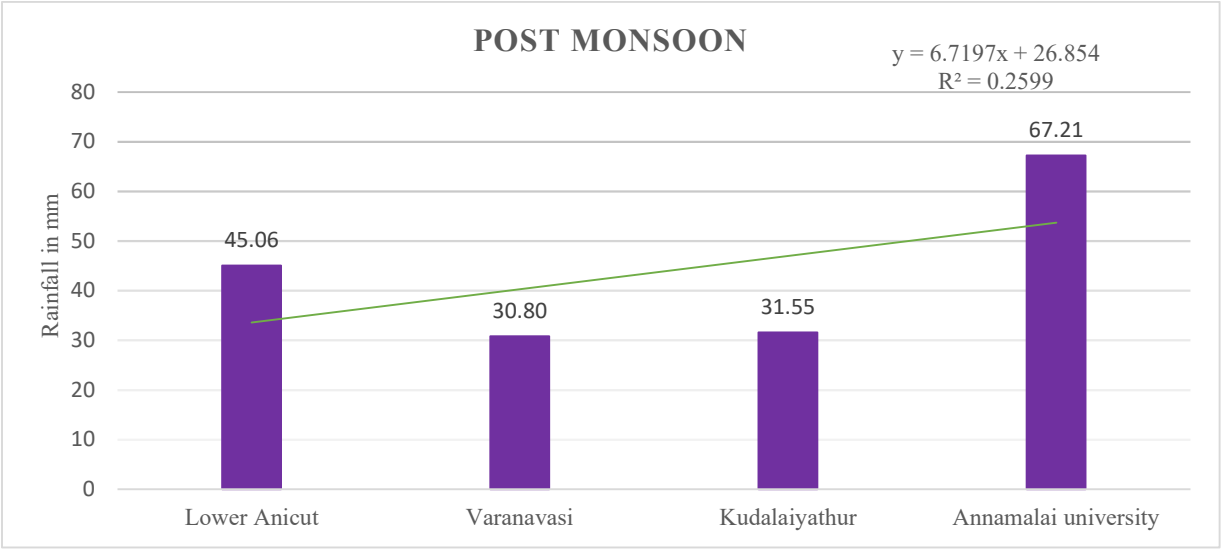

Figure 8. Post-Monsoon Rainfall Analysis of Narudaiyar Watershed

Pre-Monsoon

Pre-monsoon showers occur before the beginning of the rainy season, Between March and May, it takes place. They can range in intensity from short drizzles to intense thunderstorms. They hasten

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

the ripening of mangoes and are also known as summer rains or mango showers. The study region experienced an increasing Pre-monsoon average rainfall trend, with the smallest mean rainfall recorded in 1992 at 108.17 mm and the highest mean rainfall recorded in 2016 at 119.63 mm. Pre-monsoon rainfall was recorded at a maximum of 267.42mm at Varanavasi station and a minimum of 6.50 mm at Annamalai University station.

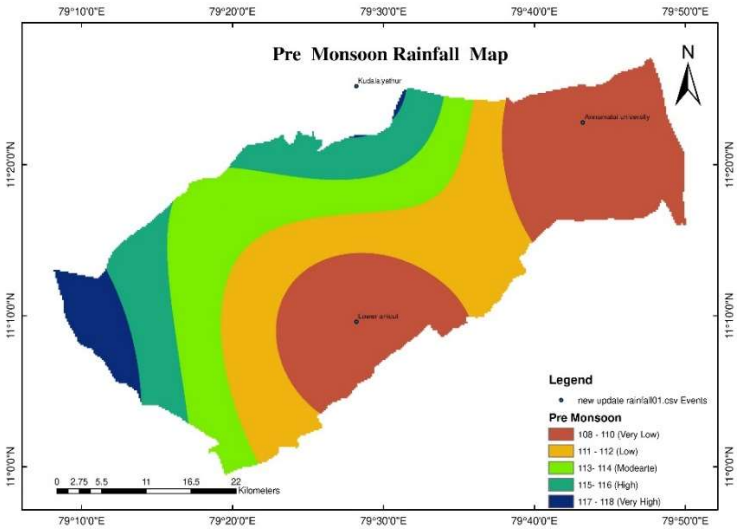

Figure 9. Post-Monsoon Rainfall Map of Narudaiyar Watershed

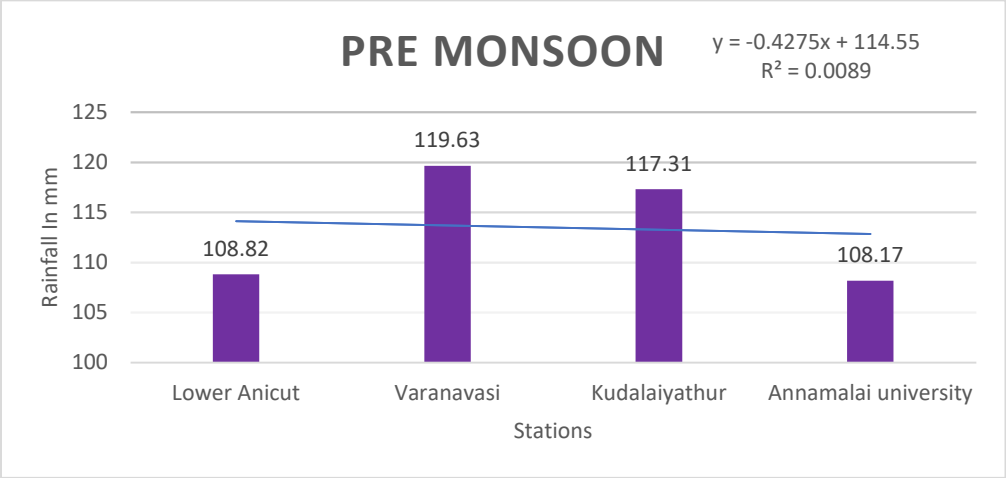

Figure 10. Post-Monsoon Rainfall Analysis of Narudaiyar Watershed

South West Monsoon

The southwest monsoons are the rainy seasonal winds that blow south-westerly from the Arabian Sea into the interior of India. The Southwest Monsoon showers occur in a range of June to September. The study region saw an elevated South-West monsoon average rainfall trend, with the smallest average rainfall recorded in 1994 at 322.99 mm and the greatest average rainfall

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

recorded in 2010 at 346.91 mm. The mean annual precipitation during the southwest monsoon was 155.16 mm at Varasavasi station and 601.99 mm at Lower Anicut station.

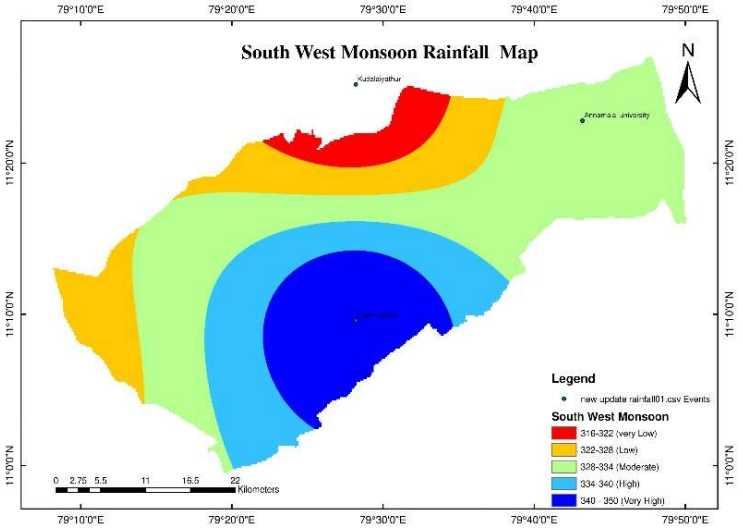

Figure 11. South-west Monsoon Rainfall Map of Narudaiyar Watershed

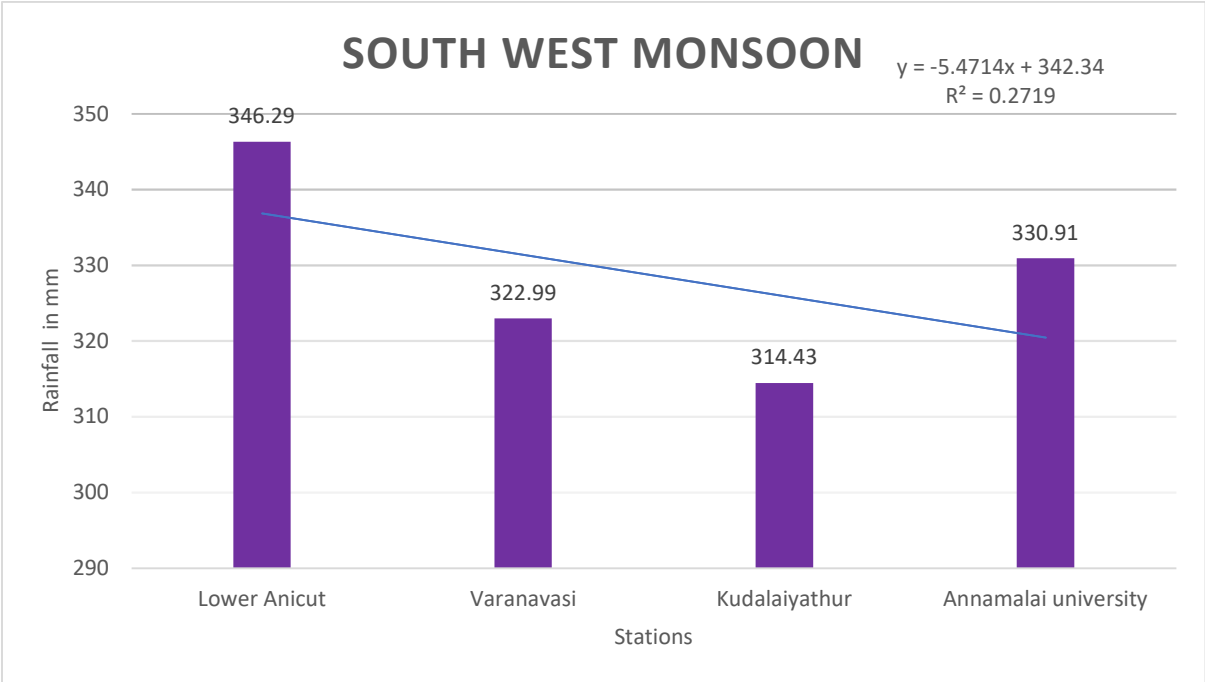

Figure 12. South-west Monsoon Rainfall Analysis of Narudaiyar Watershed

North-East Monsoon

The months of October through December, when there is a lot of rain in the southeast of peninsular India, are known as the Northeast Indian monsoon season. The North East monsoon average rainfall trend in the study region increased, with the smallest average rainfall recorded in 1999 at 423.69 mm and the greatest average rainfall recorded in 2010 at 1025.41 mm. ***Kudalaiyathur***

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

station recorded a minimum of 300.67 mm, while Annamalai University station recorded a maximum of 1526.60 mm of mean annual rainfall during the North East monsoon.

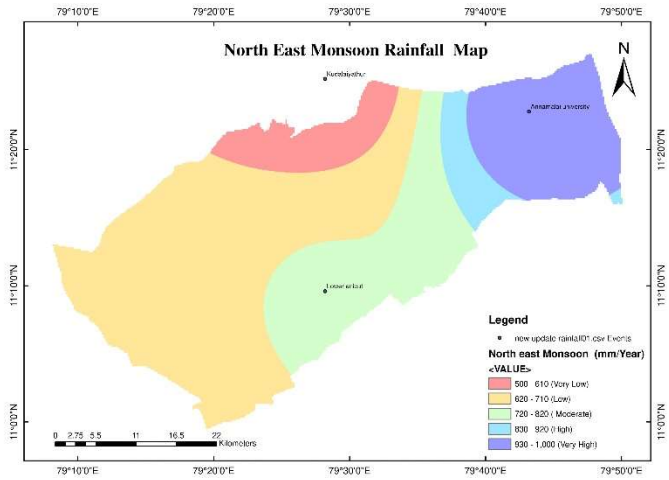

Figure 13. North-East Monsoon Rainfall Map of Narudaiyar Watershed

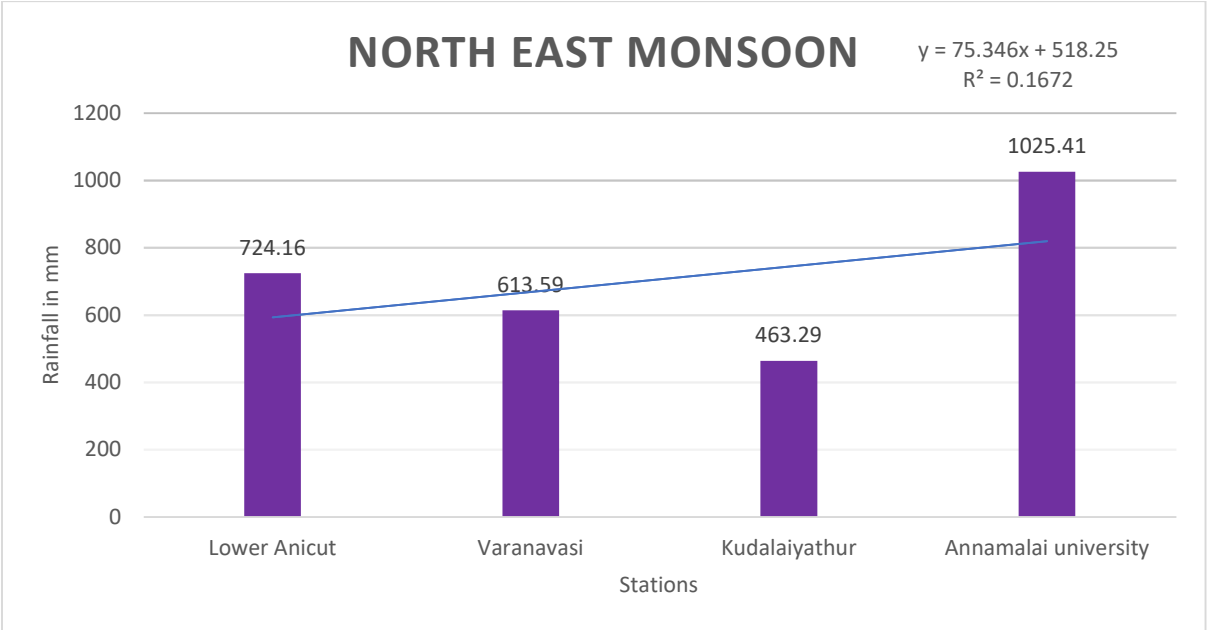

Figure 14. North-East Monsoon Rainfall Analysis of Narudaiyar Watershed

Conclusion

Mapping the spatial distribution of rainfall data is a useful application of Arc GIS. In order to identify places with high and low rainfall, it is helpful to prepare a rainfall map that shows the spatial variance of rainfall throughout various research areas. Through the use of GIS, it is possible to model these spatial variations into a frame that is simple to understand and can be applied to other related tasks. The current study's goal was to use Arc GIS to analyze seasonal and yearly rainfall for the Narudaiyar Watershed. For the entire study, trends have been detected through analysis of the four rain gauge stations. In the research area, Rainfall is particularly heavy in the

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

southeast, northeast, and central regions. In the northwest and southwest parts of the research area, it rains lightly to moderately. The studied region experienced the highest rainfall during the monsoon season, and by 2016, the majority of it had a high to extremely high rainfall distribution. The wettest years in the study region had average rainfall above 1000 mm in 1992, 1996, 1997, 1998, 1999, 2005, 2006, 2007, 2008, 2010, 2011, 2014, 2015, 2016, 2017,2019, 2020, and 2022. The proportion of post-monsoon rainfall, which is higher than winter rainfall but lower than pre-monsoon precipitation, is 3.66% of the annual average distribution of rainfall. The study's conclusions will provide information on the geographic rainfall distribution in the Narudaiyar watershed, which can be helpful for hydrological research, land use planning, and water management strategies.

References

[1] Sdoodee S, Rongsawat S (2012). Impact of Climate Change on Smallholders‟ Rubber Production in Songkhla Province, Southern Thailand. *Proceedings International and National Conference for the Sustainable Community Development of "Local Community: The Foundation of Development in the ASEAN Economic Community (AEC)*" February 16-19, pp 81-86, 2012.

[2] Holman IP (2006) Climate change impacts on groundwater recharge–uncertainty, shortcomings and the way forward? *Hydrogeol. J*. 14, 637-647, 2006.

[3] Arya VS, Chaudhary BS, Beniwal A, Babu TP, Hooda RS. Satellite Surveillance for Disaster Mitigation*, Proceedings of the Asian Conference on Remote Sensing,* Bangkok. 1996.

[4] Chiradeep Adhikari. A GIS - Remote Sensing Compatible Rainfall-surface Runoff Model for Regional Level Planning, *Map India, New* Delhi. 2003.

[5] Hassam SM. Recent rainfall trends in the FCT, Abuja. *Trans Inst. India Geographers,*31(1), 2009

[6] Tripathi SK. Rainfall analysis for crop planning a lesson from Utterkand. *Journal of applied hydrology*. 22(1),2009.

[7] Venkata Bapalu G, Rajiv Sinha. GIS in Flood Hazard Mapping: a case study of Kosi River Basin, India, *Conference Proceedings of Map Middle East,* UAE. 2005.

[8] Richard Y, Poccard, I. A statistical study of NDVI sensitivity to seasonal and interannual rainfall variations in Southern Africa. *Int J Climatol* 19(15) : 2907–2920,1998.

[9] Thiam E., Singh, V. Space–time–frequency analysis of rainfall, runoff and temperature in the Casamance River basin, southern Senegal, West Africa. *Water SA* 28(3) : 259–270, 2002.

[10] Nicholson, S. Comments on "The South Indian Convergence Zone and interannual rainfall variability over southern Africa" and the question of Enso's influence on southern Africa. *J Climate* 16(3) : 555-562,2003.

[11] Cook, K. The South Indian Convergence Zone and interannual rainfall variability over southern Africa. *J Climate* 13(21): 3789-3804, 2000.

[12] Smith B, Skinner M, Adaptation options in Agriculture to climate change: A typology, mitigation and Adaptation Strategies for Global Change. *Afr. J. Agric. Res. Econs* 3(5): 78-82, 2002.

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

[13] Sumedh R. Kashiwar et al., Evaluation of Long-Term Rainfall Variability of Bhandara (Maharashtra), India Using GIS. *Int.J.Curr.Microbiol.App.Sci* 7(7): 3846-3854,2018.

Villholth, K.G. 2006. Groundwater assessment and management: implications and opportunities of globalization. *Hydrogeology Jour.* 14 : 330-339, 2006

[14] Williams C., Kniveton D., Layberry., R. 2007. Climatic and oceanic associations with daily rainfall extremes over southern Africa*. Int J Climatol* 27(1) : 93-108, 2007.

[15] Hiscock, K.M., Rivett, M.O., Davison, R.M. 2002. Sustainable Groundwater Development. *Geological Society of London (Ed.),* Special Publication, 193 - 344p, 2002.

[16] Goovaerts P, Geostatistical approaches for incorporating elevation into the spatial interpolation of rainfall*, J Hydrol,* 228 (1) 113–129, 2000.

[17] Nandargi S. & Mulye S.S, (2012), Relationship between rainy days, mean daily intensity and seasonal rainfall over the Koyna Catchment during 1961-2005, *The Scientific World Journal,* Volume 2012, Article ID 894313, 10 pages, doi:10.1100/2012/894313, 2012.

[18] A. K. Gosain, Sandhya Rao and Debajit Basuray, Climate change impact assessment on hydrology of Indian river basins, *Current Science* Vol. 90, No. 3, 10 February 2006

[19] Jegankumar.R, Nagarathinam S.R, Kannadasan.K (2012) spatial distribution of rainfall in Salem and Namakkal districts. *International Journal of Geomatics and Geosciences.* Volume 2, No 4, 2012. pp. 976-994. 2012.

[20] Nandargi S. & Mulye S.S, (2012), Relationship between rainy days, mean daily intensity and seasonal rainfall over the Koyna Catchment during 1961-2005, *The Scientific World Journal,* Volume 2012, Article ID 894313, 10 pages, doi:10.1100/2012/894313, 2012.

[21] Ishappa Muniyappa Rathod, Aruchamy S., (2010), Spatial Analysis of Rainfall Variation in Coimbatore District Tamilnadu using GIS *International Journal of Geomatics and Geosciences*, 1(2), pp. 106-118, 2010.

[22] Abdul Bari J. and G Vennila (2020), Spatial analysis of rainfall in northern part of Erode district, Tamil Nadu, India using GIS, *Indian Journal of Geo Marine Sciences*, Vol. 49 (06), June 2020, pp. 1108-1113, 2020.

[23] Saravani.R, Thangamani.V and Alaguraja.P (2020), GIS in Analysing Rainfall Climatology: A Case of Vaigai River Basin in Theni District., *Journal of Information and Computational Science,* Volume 10 pp., 141-158, 2020.

[24] Rathod , Aruchamy (2010): Spatial Analysis of Rainfall Variation in Coimbatore District Tamilnadu using GIS, *International Journal Of Geomatics And Geosciences* Volume 1, No 2, pp: 106 – 118, 2010.

[25] Kumar D and Ahmed S 2003 "Seasonal Behavior of Spatial Variability of Groundwater Level in a Granitic Aquifer in Monsoon Climate"; *Current. Sci.* 84(2) 188–196, 2003

[26] Senthil Kumar, M and Elango, L (2002) Rainfall and groundwater level relationship in a part of the Lower Palar River Basin, Tamil Nadu, and India. In*: Proceedings of the International Groundwater Conference on Sustainable Development and Management of Groundwater Resources in Semi-arid Regions with Special Reference to Hard Rocks,* Oxford-IBH, New Delhi, pp 417-422, 2002,

Catalyst Research Volume 23, Issue 2, October 2023 Pp. 2213-2225

[27] Villholth KG (2006) Groundwater assessment and management: implications and opportunities of globalization. *Hydrogeol. J*. 14, 330–339, 2006.

[28] Smith B, Skinner M (2002). Adaptation options in Agriculture to climate change: A typology, mitigation and Adaptation Strategies for Global Change. *Afr. J. Agric. Res. Econs* 3(5): 78-82, 2002.

[29] Rudolf W, Hermann W (2009). Climate risk and farming Systems in Rural Cameroon. *Institute of Development and Agricultural Economics.* University of Hannover, Germany pp. 21-24, 2009.

[30] Molua EL, Lambi CM (2007). Economic Impact of Climate change on agriculture in Cameroon. *Policy Research paper No 4364 World Bank,* Washington, D. C. pp. 51-55, 2007.