Analysis of Rainfall Variation and Groundwater Level in Mysuru Taluk using GIS

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Abstract - *Precipitation is the water released from clouds in various forms. It is the primary connection in the water cycle that provides for the delivery of atmospheric water to the Earth. Rise in temperature results in increase in the evaporation of surface water bodies & transpiration in wetlands. The aim is to analyze the rainfall variation and groundwater table fluctuation in the study area through GIS. Groundwater level data provides direct value of groundwater occurrences below ground level (bgl). We evaluated 5 rain gauge stations data of 10 years (2011-20) in determining the rainfall fluctuation; while 9 observations well points are considered to determine the groundwater table fluctuation in Mysore Taluk, Karnataka, India. We have used QGIS and ArcGIS for the analysis of seasonal variation of rainfall and groundwater for ten years (2011-2020) data.*

Key Words: Rain gauge stations, Groundwater monitoring stations, GIS, Inverse Distance weighted (IDW) and Thiessen polygon method.

1. INTRODUCTION

Water is an inorganic, transparent, tasteless, odourless, and nearly colourless chemical substance, which is the main constituent of Earth's hydrosphere and the component of all known living organisms in which it acts as a solvent. Groundwater is the readily available fresh water resource used for drinking, agricultural and industrial purposes. Its availability depends on rainfall and recharge. As India is a monsoon reliant country for its major portion of rainfall, it is necessary to analyse the occurrence and distribution of rainfall. In this regard, a detailed study of annual and seasonal variation of rainfall is done using GIS. 10 years (2011 to 2020) rainfall data from 5 representative Rain gauge stations have been collected and analysed for its variation. QGIS software has been used for rainfall trend analysis with the aid of various interpolations and ArcGIS for spatial distribution of groundwater trends and Inverse Distance Weighted (IDW) method.

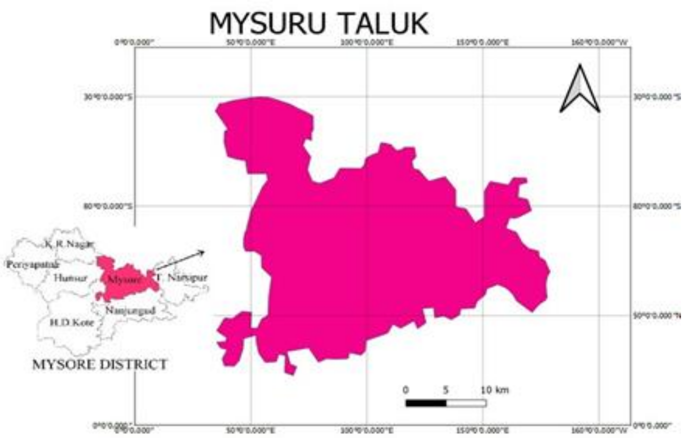

Figure 1: Location map of the study area

2. LITERATURE REVIEW

Basavarajappa H.T et al., (2016) Suggested to analyze the rainfall variation impacts on groundwater table fluctuation in the study area through GIS potentiality. A sincere attempt has been made to evaluate 6 rain gauge stations data of 11 years in determining the rainfall fluctuation; while 9 observation well points are considered to determine the groundwater table fluctuation of the same 11 years. Arithmetic mean, theissen polygon and iso-hyetal methods are well utilized in the present study in digitization of spatio-temporal maps using field data collection through GIS's software. The final results highlight the capability of GIS tool in mapping, management and periodic monitoring of rainfall variation and groundwater table fluctuation in Mysore taluk, Karnataka, India.

C. Ganapathy et al., (2014) Conducted a study on spatial distribution of rainfall in the study area, it depicts that southwestern part gets more rainfall than the north-eastern part during pre-monsoon and northeast monsoon periods. Frequency distribution analysis over a scale of 10 indicates that the annual variation has the maximum frequency of 9.0 in the range of >1000 mm at Yercaud rain gauge station and the other two rain gauge stations (Salem and Omalur) in the study area shows frequency values 3.0 to 4.0 for the same rainfall range. Groundwater level fluctuation analysis shows that some of the places have deeper water levels during southwest monsoon season. The water levels remain stable only up to November but during January to May, the water level declines gradually due to water extraction for irrigation.

Rethinam Arumugam et al., (2019) carried out a GIS overlay analysis wherein 8 layers viz. geology, geomorphology, slope, soil, land use, post monsoon water level, weathering depth and waterbodies/drainage were integrated. Groundwater level from the monitoring stations and weathering thickness data from the 248 deep wells constructed were used for the integration. About 45% of the study area was categorised as high to very highly feasible zone. The existing artificial recharge structures in the region were also plotted and proposed artificial recharge structures were calculated. About 166 masonry check dam, 155 nala bunds, 575 recharge shafts (within tanks), 716 percolation ponds (repair, renovation and restoration) have been calculated and implementation of the proposed structures would create an additional water resource of 198 million m3 annually.

In the study conducted by **Moung-Jin Lee et al., (2020)** ensemble models of decision tree-based machine learning algorithms were used with geographic information system (GIS) to map and test groundwater yield potential in Yangpyeong-gun, South Korea. A total of 53 well locations with both specific capacity (SPC) data and transmissivity (T) data were selected and randomly divided into two classes for model training (70%) and testing (30%). First, the predicted dataset of SPC showed values of 80.48% and 87.75% for the BCT and FR-BCT models, respectively. The accuracy rates from T were 72.27% and 81.49% for the BCT and FR-BCT models, respectively. The results of this study may be used for sustainable development of groundwater resources by identifying areas of high groundwater potential.

Jeffrey C et al., (2021) explains that the implications of variations in rainfall and land-use on groundwater level fluctuations in the Kathmandu Valley, Nepal. The seasonal fluctuations in groundwater level showed the direct influence of monsoonal rainfall. In areas with agricultural land use, 80% of the analysed wells showed a strong and statistically significant correlation between rainfall and groundwater levels. Our study highlights the ability of citizens to generate meaningful hydrogeologic datasets, and the importance of rainfall and land use planning to groundwater recharge. Understanding these complex relationships must form the basis for the sustainable management of the rapidly declining groundwater resources of the Kathmandu Valley.

Basavarajappa H et al., (2020) studies and aims to augment groundwater resources in stressed areas of Mysore taluk for groundwater sustainability. Efforts have been made to evaluate the thematic layers of geology, geomorphology, drainage density, lineament density, soil, slope, land use/ land cover, rainfall and overlay weightage analysis using GIS environment. The derived thematic layers were then assigned suitable ranks and weightages using Analytical Hierarchy Process (AHP). Artificial Recharge Structures (ARS) are studied and stated that it is the effective and efficient techniques to overcome critical and over-groundwater exploited areas to augment the groundwater system. The Weighted Overlay Method was built in ArcGIS software wherein all the thematic layers were given as input parameters. The obtained result exhibited the best sites for ARS in the regions where infiltration rate is high i.e. regions near the water bodies, croplands, and in the floodplains and least suitable sites of the regions having low infiltration rates.

L. Elango et al., (2013) presents a review of research works carried out on the impact of check dams in improving the groundwater quantity, quality and livelihood of people. Further, investigation has been done on the effectiveness of a check dam across Arani River, located north-west of Chennai, Tamil Nadu. In general, the MAR through check dams is found to be one of the efficient methods to improve the groundwater head and quality. It was concluded that MAR through check dams is found to be one of the efficient methods to improve the groundwater head, and quality which in turn improve the livelihood of the community as indicated by most of the studies. Thus for efficient and sustainable management of water resources, MAR by check dam can be considered as a best option.

Sid E et al., (2013) compares the accuracy of several commonly used interpolation methods in estimating arsenic concentrations in 48000 wells in Texas by the leave-one-out-cross-validation technique. Correlation coefficient between measured and estimated arsenic levels was compared and was found that it is greater with inverse distance weighted (IDW) than kriging Gaussian, kriging spherical or cokriging interpolations when analysing data from wells in the entire Texas. In regression analysis, the best models are when well depth and/or elevation were entered into the model as covariates regardless of area/aquifer or interpolation methods, and models with IDW are better than kriging in any area/aquifer. In conclusion, the accuracy in estimating groundwater arsenic level depends on both interpolation methods and wells' geographic distributions and characteristics in Texas.

IliyasuGarba et al., (2017) evaluates the effect of rainfall on groundwater level fluctuation using the rainfall, Evapotranspiration, and groundwater level fluctuation data from 2001 to 2013 in Terengganu Malaysia. The daily groundwater level data from seven hydrological stations collected from the Department of Minerals and Geosciences. Terengganu Malaysia for the period of 2001 to 2013. Also, the Evapotranspiration and rainfall data for the same years were collected from the Department of Irrigation and Drainage (DID). The result illustrates that groundwater level decreased day by day due to mismanagement and unnecessary withdrawal from irrigation sectors and domestic uses. The result of this study entails that the groundwater level fluctuations in Terengganu depend solidly on rainfall patterns.

Jose D. Salas et al., (1986) intends to compare the applicability of various proposed interpolation techniques for estimating annual precipitation at selected sites. The interpolation techniques analysed include the commonly used Thiessen polygon, the classical polynomial interpolation by least squares or Lagrange approach, the inverse distance technique, the multiquadric interpolation, the optimal interpolation and the Kriging technique. Thirty years of annual precipitation data at 29 stations located in the Region of the North Central continental United States have been used for this study. The comparison is based on the error of estimates obtained at five selected sites. Results indicate that the Kriging and optimal interpolation techniques are superior to the other techniques. The inverse distance interpolation and the Thiessen polygon gave fairly satisfactory results while the polynomial interpolation did not produce good results.

Jeevan L et al., (2015) generates the primary data to map the groundwater table fluctuation in hard rock terrain of Chitradurga District through Geomatics technique. Efforts have been made to evaluate a total of 20 representative rain gauge station samples and analyze the seasonal rainfall variation over a period of 31 years (1981- 2011). 47 representative well samples are collected to study the season-wise groundwater fluctuation of about 11 years (2000-2011). Rain gauge stations are plotted on a base map with their respective amount of rainfall. Then the contours of equal rainfall (isohyets) are drawn using GIS software. The average rainfall between the successive isohyets taken as the average of two isohyetal values is weighed with the area between the isohyets. The final results highlight the impacts of climatic change over groundwater table fluctuation in typical Precambrian rocks of Chitradurga District, Karnataka, which is a suitable model in similar geological conditions

I. Matinet al., (2013) conducted a study in five Upazilas under Chapai Nawabgonj district from 2007 to 2011 to evaluate the effect of rainfall on groundwater level fluctuation. Rainfall and groundwater fluctuation data were collected from BMDA, Rajshahi and evapotranspiration data were collected from IWM, Dhaka. The data were analysed to show the rainfall variations, runoff, infiltration and groundwater fluctuation levels in different years. The maximum water table was found during July - September due to rainwater infiltration. The results also observe that the minimum water table was shown throughout March – May, during the irrigation period of the area. The study illustrates that there were no significant changes in rainfall and infiltration patterns during the study period, but the overall ground water table was declining day by day due to over withdrawal of groundwater for irrigation purposes.

3. MATERIALS AND METHODS

Rainfall and groundwater levels data of Mysuru Taluk was collected by respective rain gauge stations and groundwater monitoring stations for a period of one decade (2011-2020). Rainfall data and Groundwater data was obtained from Karnataka State Natural Disaster Monitoring Centre (KSNDMC) and district groundwater office, Kuvempunagar, Mysuru respectively. We have used QGIS and ArcGIS for the analysis of seasonal variation of rainfall and groundwater for ten years (2011-2020) data. Interpolation techniques such as in IDW and Thiessen polygon method have been adopted for the analysis. Analysis of the variation in annual rainfall recorded in 5 rain gauge stations was done using Thiessen polygon method and analysis of seasonal variation was done using Inverse Distance Weighted and also seasonal variation of depth in 9 groundwater monitoring stations using inverse IDW.

2.1 Study area

The study area is Mysuru Taluk is one of the seven Taluks in Mysuru district of Karnataka state. It lies between 12°07' to 12°27'N latitude and 76°28' to 76°50'E Longitude with an aerial extent of 803.051Km^2. Mysuru Taluk exhibits flat to gently undulating topography with an elevation varying from 700-725 m above MSL with a gentle slope towards the south. The perennial Cauvery River flows from west to east in the northern parts of the district [11]. Mysuru has moderate rainfall and has an average annual rainfall of 63.06mm preferably during monsoon.

Sl. no	Station name	Latitude	Longitude
1	Mysore DC Office	12°18'35"	76°38'35"
2	Naganahalli	12°22'21"	76°39'44"
3	Jayapura	12°12'06"	76°33'24"
4	Elwala	12°21'24"	76°32'43"
5	Varuna	12°15'50"	76°44'40"
6	CSRTC	12°17'24"	76°38'48"

Table 1: Rain gauge stations with latitudes and longitudes.

(Source: Manjunath M.C, 2016)

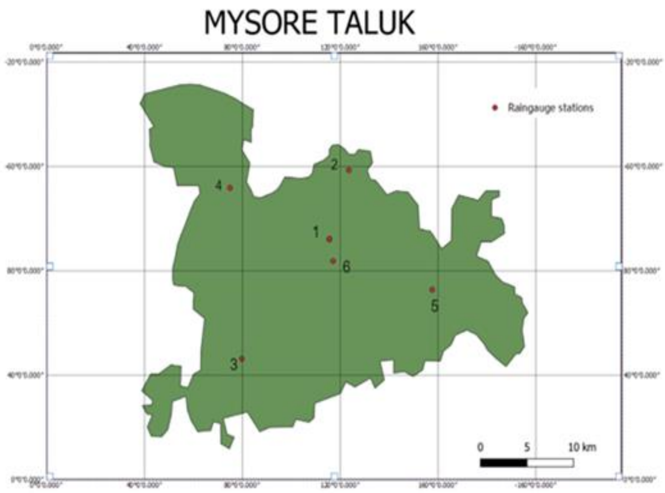

Figure 2: Mysuru taluk map which represents rain gauge stations

Sl.no	Station name	Latitude	Longitude
1	Jayapura	12°12’14”	76°33’23”
2	Siddalingapura	12°21’47”	76°39’43”
3	Elwala	12°21’29”	76°32’33”
4	Devalapura	12°13’23”	76°42’05”
5	Aalanahalli	12°17’52”	76°42’11”
6	Bhogadi	12°18’13”	76°35’56”
7	Elwala 1	12°21’16”	76°32’43”
8	Kadakola B	12°11’31”	76°40’02”
9	Keelanapura B	12°15’09”	76°49’05”

Table 2: Groundwater monitoring stations with latitudes and longitudes.

(Source: Manjunath M.C, 2016)

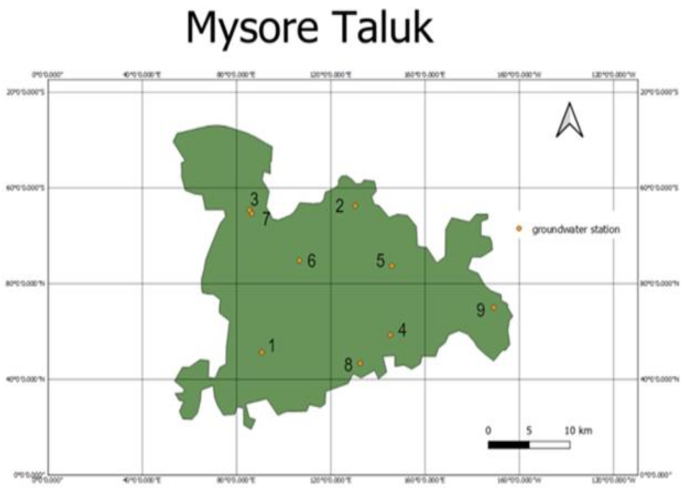

Figure 3: Mysuru Taluk map which represents Groundwater monitoring stations

2.2 Thiessen Polygon Method

The Thiessen polygon method is a common method of weighing the rain gauge observation according to the area. This method provides the individual areas of influence around each set of points. Area of Mysuru Taluk calculated using Thiessen polygon method is 803.051sqkm.

In the Thiessen method station weights are determined in proportion to their representative areas defined by a polygon. The mean precipitation was calculated by the following formula.

$$\text{Mean precipitation} = \frac{P1A1 + P2A2 + P3A3 + ...+PnAn}{A}$$

Where, P1, P2 ...Pn are the precipitation recorded in n rain gauge stations in mm.

A1, A2 ...An are the area of respective polygons and A is total area in sqkm.

2.3 Inverse Distance Weighted (IDW)

The IDW technique computes an average value for unsampled locations using values from nearby weighted locations. The weights are proportional to the proximity of the sampled points to the unsampled location and can be specified by the IDW power coefficient. The IDW maps for both rainfall and groundwater data of a decade (2011-2020) of Mysuru Taluk has been prepared using ArcGIS software.

2.4 **GIS software:** ArcGIS v10.3 & QGIS 3.14 versions

3. RESULTS AND DISCUSSION

3.1 Annual variation of rainfall

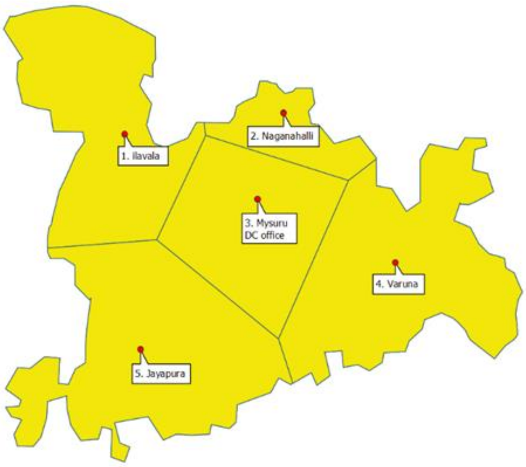

Figure 4: Mysuru Taluk map representing Thiessen polygon method

STATIONS	AREA_SQKM	PERCENTAGE
MYSORE DC OFFICE	138.913	17.298
NAGANAHALLI	49.72	6.191
ELWALA	178.574	22.237
JAYAPURA	221.551	27.589
VARUNA	214.29	26.685

Table 3: Area of five representative rain gauge stations and the percentage area covered by them.

The annual variation throughout the decade is calculated by Thiessen polygon method by using certain formulas and interpolations in QGIS. The mean precipitation is calculated by using a formula which includes areal influence to the rainfall value.

The figure.4 represents the aerial significance of rainfall by various rain gauge stations present. The five rain gauge stations such as Jayapura, Mysuru DC office, Elwala, Varuna, and Naganahalli are represented in Mysuru Taluk Map and the polygons for those respective stations are drawn using interpolation techniques in QGIS. From the figure.1 we can observe that Jayapura rain gauge station covers an area of 221.551 sqkm with highest area covering 27.589% of Mysuru Taluk's total area. Naganahalli rain gauge station covers an area of 49.720 sqkm with the lowest area covering 27.589% of Mysuru Taluk's total area.

Station weights are determined in proportion to their representative areas defined by a polygon.

Stations	Precipitation (pn)	Area(an)	Total area	Weights	Pn*an
Mysore dc office	67.01666667	138.913	803.051	0.172981542	9309.486
Naganahalli	44.68571429	49.72	803.051	0.061913876	2221.774
Ilwala	53.45833333	178.574	803.051	0.222369439	9546.268
Jayapura	69	221.551	803.051	0.275886588	15287.02
Varuna	62.74166667	214.293	803.051	0.266848556	13445.1
				∑(Pn*An)	49809.65
				Mean Precipitation	62.02551

Table 4: Table represents the mean precipitation calculated for the year 2011

We have calculated the mean precipitation for the decade 2011-2020 similarly as that of the above table.

The mean precipitation for all the years is tabulated and the variation is represented using a line graph wherein very less precipitation is observed in 2016 and also the highest rainfall of 91.553mm is observed just after the lowest rainfall i.e., in 2017.

Years	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Mean Precipitation	62.02	49.64	44.51	67.66	67.92	28.44	91.55	67.64	77.46	77.38

Table 5: The mean precipitation of a decade (2011-2020) calculated using Thiessen polygon method

By this method we calculate the average depth of precipitation over the specific area calculated on timescales on an annual basis. We can see the trend in which the mean precipitation is varying from the above figure.

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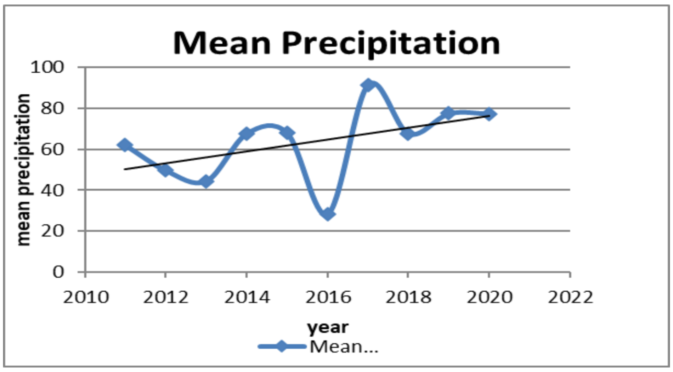

Figure 5: Line graph representing variation of mean precipitation over a decade.

3.2 Seasonal distribution of Rainfall

Monsoon season contributes the major portion of annual rainfall over the study area. Seasonal rainfall data is useful to determine the changes of agricultural activities, irrigation, groundwater recharge, its management and development. The rainfall of the study area in a year is divided into three seasons namely **Pre-monsoon, Monsoon and Post monsoon** and its variations and trends are studied.

Sl.No.	Station Name	Latittude	Longitude	Pre-Monsoon	Monsoon	Post-Monsoon
1	Varuna	12.26388	76.74444	39.43	89.675	68.24666667
2	Mysore DC office	12.30972	76.64305	48.45	92.0225	72.09333333
3	Jayapura	12.20166	76.55666	49.87	99	57.1
4	Naganahalli	12.3725	76.66222	36.97	76.85	64.77666667
5	Elwala	12.35666	76.54527	37.5	71.6625	61.5
	Average			42.444	85.842	64.74333333

Table 6: Seasonal station wise variation of rainfall of a decade.

3.2.1 Pre-Monsoon (Jan-May)

The study area received an average rainfall of 44.90 mm from 2011 to 2020 during the pre-monsoon seasons. The minimum rainfall recorded at Elwala rain gauge station is 37.5mm; while maximum is at Jayapura rain gauge station 49.87mm. Jayapura & a considerably large area surrounding it and Mysore DC Office with a little region around the station experienced highest range of rainfall as represented by darkest colour range in the IDW output shown below.

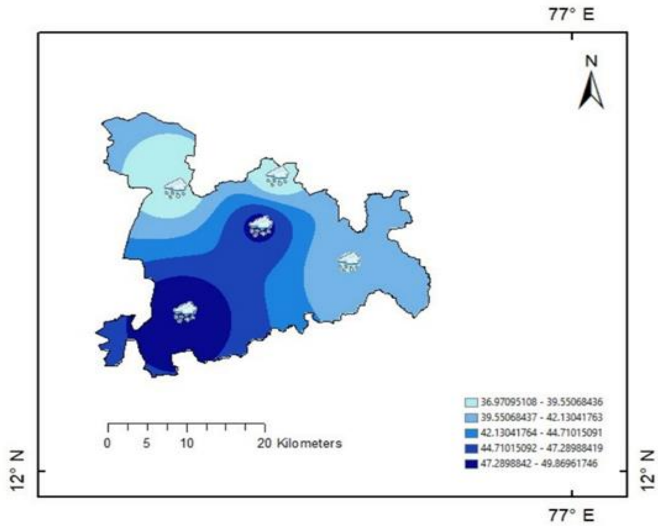

Figure 6: Pre-monsoon IDW Map

3.2.2 Monsoon (June–Sept)

The region that receives the majority of the rainfall during a particular season is known as south west monsoon season (June to Sept). The average rainfall recorded in the monsoon period is about 85.85mm (43.59%) providing a maximum contribution for normal annual rainfall. The minimum rainfall is received at Elwala 71.66mm and maximum is received at Mysore DC office 92.02mm. The most range of rainfall experienced was of 88-93.50mm covering the vast area around stations located at Mysore DC Office and Varuna.

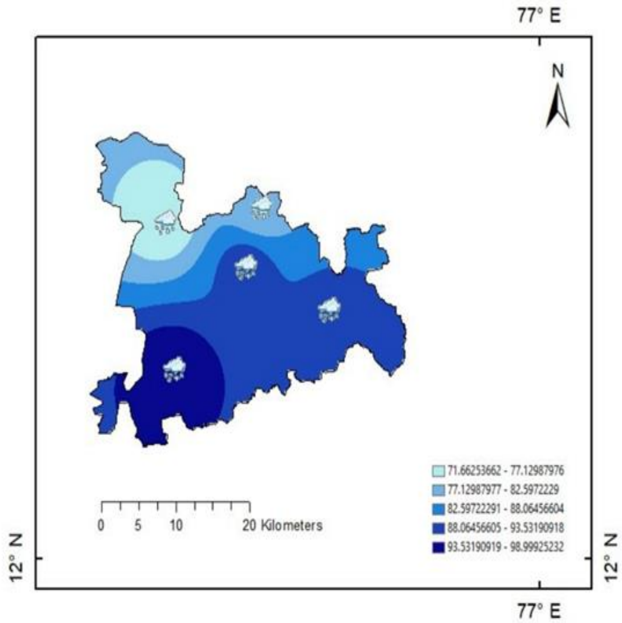

Figure 7: Monsoon IDW Map

3.2.3 Post Monsoon (Oct–Dec)

During post monsoon; most of the rainfall is closely associated with westward storms and depressions as a result of low-pressure systems moving into the Bay of Bengal. The average rainfall in this season is 64.74 mm from 2011 - 2020. The minimum rainfall recorded is at Jayapura 57.1 mm and maximum is at Mysore DC office 72.09 mm.

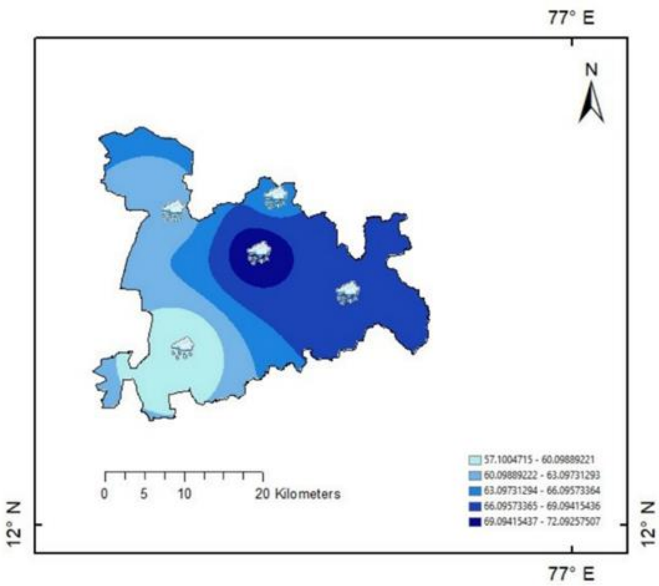

Figure 8: Post-Monsoon IDW Map

3.2.4 Annual Rainfall

The minimum rainfall recorded was 30.95 in 2016; while the highest observed rainfall was 91.125 mm in the year 2017.

Sl. No.	Year	Pre-Monsoon	Monsoon	Post-Monsoon	Annual
1	2011	59.425	57.97	66.1	59.38048
2	2012	34.78	59	69.6	50.84167
3	2013	25.88	60.275	56.63333333	45.03333
4	2014	34.48	109.5	64.06666667	66.755
5	2015	50.7	76.025	83.63333333	66.73333
6	2016	18.74	51.35	20.83333333	30.95833
7	2017	64.38	148.375	59.36666667	91.125
8	2018	54.18	86.775	50.36666667	66.125
9	2019	39.32	109.25	90.66666667	75.46667
10	2020	55.98	99.9	86.16666667	78.16667

Table 7: Year-wise rainfall variation in the study area (2011-2020)

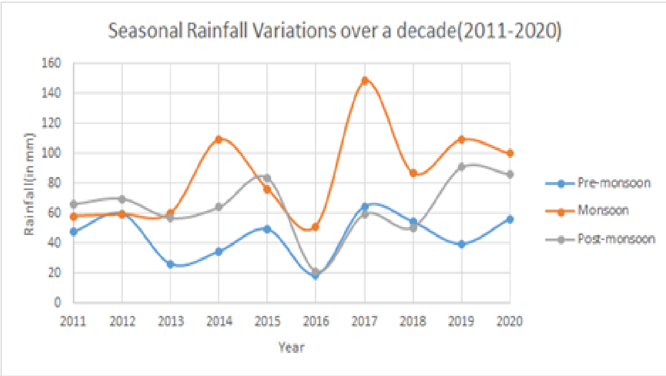

Figure 9: Line graph depicting 10 years seasonal fluctuation in rainfall data

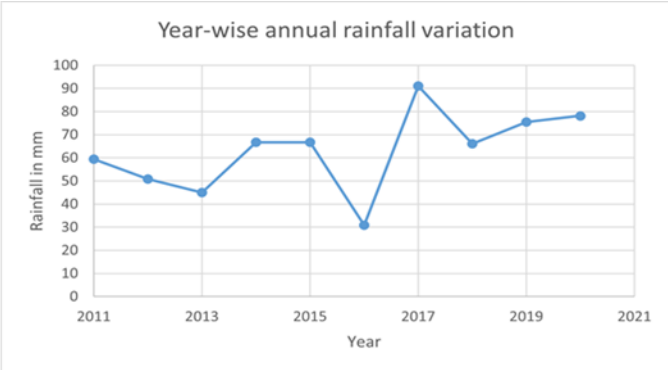

Figure 10: Line graph depicting 10 years annual fluctuation in rainfall data

3.3 GROUNDWATER TABLE FLUCTUATION

Groundwater is water that has infiltrated the ground to fill the spaces between sediments and cracks in rock. Groundwater is fed by precipitation and can resurface to replenish streams, rivers, and lakes.

Nine representative observations well points have considered in the present study to analyse the seasonal variation in groundwater table fluctuation from 2011 to 2020.

3.3.1 Pre-Monsoon Groundwater Table Fluctuation

During the pre-monsoon period (Jan-May); the water level ranges from 2.789 m (Siddalingapura) to 26.78 m (Jayapura) with an average of 12.65 m. Shallow groundwater levels are noticed in Bhogadi, whereas all other regions except Kadakola and Siddalingapura were found to have medium groundwater levels which range between 7.5-17.1m.

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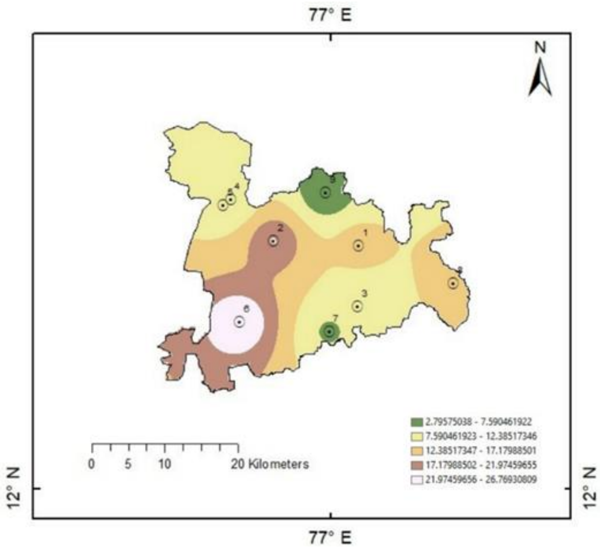

Figure 11: Pre-Monsoon Groundwater IDW Map

3.3.2 Monsoon Groundwater Table Fluctuation

During the south-west monsoon period; the water level ranges from 2.04 m (Siddalingapura) to 25.22 m (Jayapura) with an average of 12.46 m. N and SE parts depict better groundwater level conditions and gradually declining towards SW regions Most of the dig wells had a groundwater level between the range of 6.6-16.0m (in average estimations as shown in the output map below. The groundwater levels were noticed to be improved due to optimal rainfall which served as a natural replenishment.

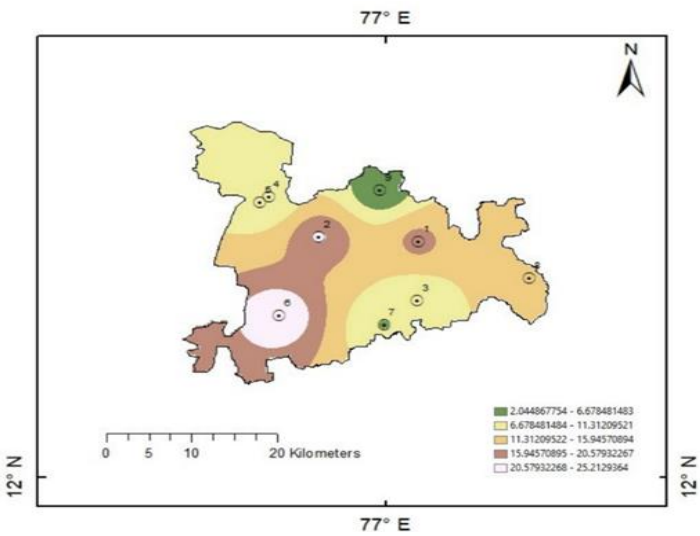

Figure 12: Monsoon Groundwater IDW Map

3.3.3 Post Monsoon Groundwater Table Fluctuation

During the south-west monsoon period; the water level ranges from 1.86 m (Siddalingapura) to 20.7 m (Jayapura) with an average of 10.64 m. Moderate groundwater levels are noticed towards N and SE regions and noticed to be decreasing towards SW parts. The ground water table rises at the end of the rainy season, gets lowered progressively and reaches the lowest level as the summer season advances. The effects of rainfall on groundwater levels seem to prevail in a prominent manner as most of the regions had a groundwater level ranging between 5.6-17m which is comparatively better than expected during a period of post-monsoon. Jayapura region was found to have significant improvement in groundwater levels which had the weightage of maximum range.

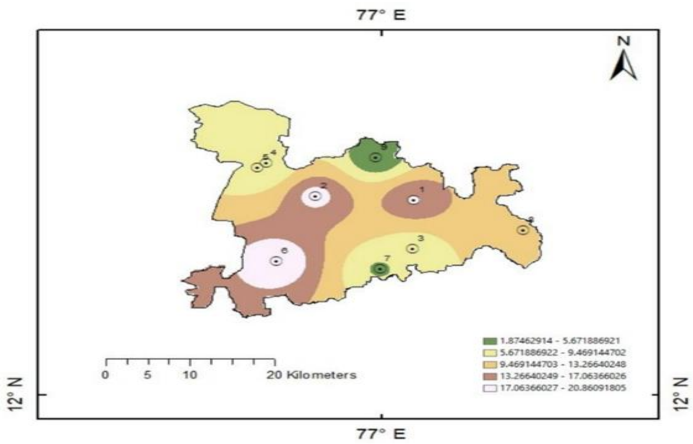

Figure 13: Post-Monsoon Groundwater IDW Map

3.3.4 Annual Groundwater Table Fluctuation

The annual average groundwater table ranges from 9.03 m to 17.89 m with an average of 11.85 m. High groundwater levels are noticed in N and SE parts due to its topography, gentle slopes and runoff. Constant groundwater levels are noticed at N and NE parts in all the seasons.

Sl. No.	Year	Pre-monsoon	Monsoon	Post-Monsoon	Annual
1	2011	11.17925	12.4796875	12.46666667	12.08979167
2	2012	14.53625	16.15625	15.78125	15.3875
3	2013	16.68259259	15.79638889	13.75208333	17.88932299
4	2014	12.7775	11.24479167	8.366666667	11.215
5	2015	10.24583333	10.89527778	6.831041667	10.95732155
6	2016	9.513416667	11.50142857	13.65833333	10.86339962
7	2017	10.3588	10.91166667	5.835555556	10.74972222
8	2018	10.6853125	9.0996875	8.17	9.502386364
9	2019	12.26391667	12.0675	7.167916667	10.94416667
10	2020	10.638	9.335625	5.9425	9.03

Table 8: Year-wise Groundwater Fluctuation in the study area (2011-2020)

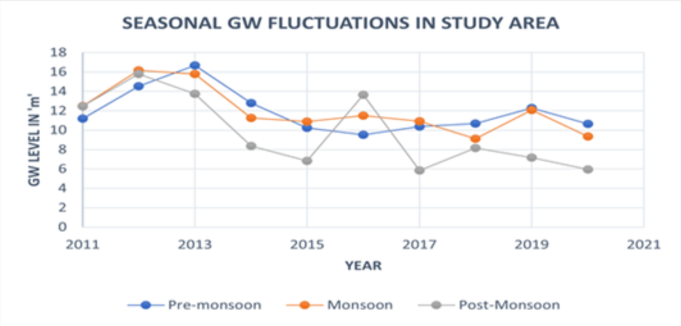

Figure 14: Line graph depicting 10 years seasonal fluctuation in groundwater level data

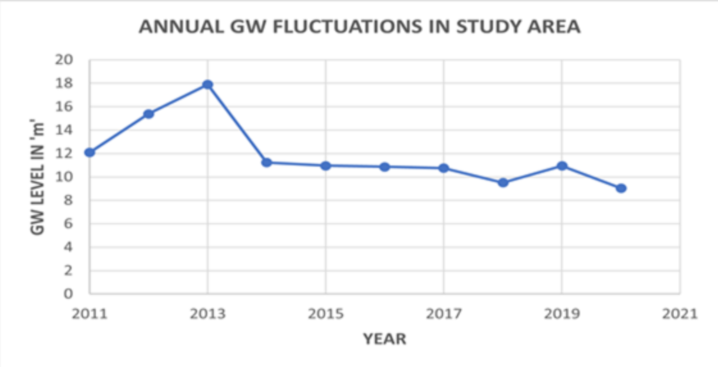

Figure 15: Line graph depicting 10 years seasonal fluctuation in ground water level data

CONCLUSION

10 years (2011 to 2020) rainfall data from 5 representative Rain gauge stations have been collected and analyzed for its variation.

Groundwater recharge is mainly through precipitation in the study area i.e. Mysuru Taluk. 10 years (2011 to 2020) groundwater data from 9 representative groundwater monitoring stations have been collected and analyzed for its variation. Thiessen polygon method and Inverse distance weighted methods have been applied for both rainfall and groundwater data to analyses trends and variations. By Thiessen polygon method, we observed that highest mean precipitation was found in the year 2017.The range of rainfall over a decade (2011-2020) was from 28.442mm to 91.55mm. IDW outputs of seasonal rainfall variation show that South-western parts of Mysuru taluk received maximum rainfall which accounted for the highest range of readings recorded at Varuna, Jayapura and Mysore DC office stations. This in-turn, can be accounted for medium groundwater levels in dug wells situated at South-eastern part as obtained in outputs of IDW interpolation for groundwater levels. Regions around Mysore DC office station had significant effect of low rainfall during the post-monsoon period which resulted in decrease in groundwater levels, can be identified through expansion of comparatively lower color range in IDW output. Line graphs of rainfall and groundwater table fluctuation revealed the maximum and minimum variations over a period of 10 years (2011-20). Groundwater based study is a much necessary task in major cities of Karnataka due to many uprising issues such as rapid increase of population, water supply & demand in various fields (major industries, factories, mining areas). This needs periodic monitoring and proper way of management for its future use and sustainability. [4]

4. ACKNOWLEDGEMENT

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