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Analysis of Rainfall Characteristics and Ground Water Recharge in Hundri River Basin of Kurnool District, Andhra Pradesh

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Abstract
The aim of the study is to examine the Rainfall characteristics, rainfall recharge, and water balance of the Hundri River basin. The basin is situated in a semi-arid climate with low precipitation and high evaporation rates. The primary geological formations in the basin are Granite and Gneisses, which constitute a hard rock terrain with varying degrees of permeability contingent on fracturing and weathering. Over a span of 30 years, monthly precipitation data from 19 stations have been collected, converted, and tabulated to derive seasonal and annual rainfall figures. The mean annual rainfall is distributed as follows: winter (5 mm), summer (68 mm), South-west monsoon (414 mm), North-east monsoon (130 mm), and annual (617 mm). The analysis of seasonal rainfall reveals that the basin experiences the highest precipitation during the south-west monsoon season. The total surface water resources available in the basin are estimated to be 2,189,116,000 m^3. Groundwater recharge through rainfall was estimated using eight different empirical equations proposed by Radhakrishna, U. S. Geological Survey method, Chaturvedi, U.P. Irrigation Research Institute, Bhattacharjee, Amritsar Formula, Kumar and Seethapathi, and Krishna Rao formula. The recharge percentages calculated using these empirical equations were found to be 10, 15, 20, 29, 18, 20, 14, and 8, respectively. The mean annual recharge for the basin is calculated to be 103 mm. Furthermore, the total groundwater resources are estimated to be 365,444,000 m^3, which accounts for approximately 17% of the annual rainfall.

***Key words*:** Mean rainfall, Rainfall variability, Rainfall ratio, Rainfall recharge, Water balance

Rainfall is a critical ecological parameter that has significant impacts on the ecosphere, ecological community, and economic development of any region. In India, a country with a strong agricultural sector, rainfall plays a pivotal role in shaping various aspects of agriculture, including land cover patterns, intensity of land use, farming operations, farming systems, and farm productivity levels [1]. The agricultural sector, which includes horticulture, animal husbandry, dairy, and fisheries, heavily relies on the monsoon rains, which are essential for crop growth and production. However, the distribution of rainfall across the country is irregular and unequal, leading to dry spells during the rainy season, resulting in crop failures and low yields in some areas.

Understanding the rainfall patterns, including total rainfall, daily, monthly, seasonal, and annual distribution, is vital for effective crop and water management planning. It helps in designing irrigation, drainage, erosion control, and flood control structures. Furthermore, the analysis of monthly, seasonal, and annual rainfall patterns is essential for ensuring a continuous water supply for domestic and industrial uses [2]. Therefore, it is crucial to monitor and analyze rainfall patterns to ensure sustainable agricultural practices and water management in India. Policy decisions regarding cropping patterns, sowing dates, and the provision of drinking water in both urban and rural areas are facilitated through the examination of rainfall data [3]. Furthermore, such analyses contribute to the comprehension of micro-level rainfall variability, which is of utmost importance for the planning of agriculture, land, and water resource development [4]. The evaluation of surface and subsurface water resources plays a crucial role in addressing future hydro-meteorological disasters and guaranteeing sufficient water availability for agricultural, irrigation, industrial, and domestic purposes. A normal distribution of rainfall is indispensable for the maintenance of favourable vegetation cover, the promotion of ecosystem health, the facilitation of groundwater recharge, and the assurance of robust crop production and food security.

The analysis of rainfall and studies on groundwater recharge are of utmost importance in comprehending the hydrological dynamics of the Hundri River basin, particularly within a semi-arid climate characterized by restricted water resources [5]. Through an examination of historical rainfall patterns spanning a duration of 30 years, and the subsequent classification of these patterns into distinct seasons, researchers can acquire invaluable insights into the temporal dispersion of precipitation. This enables them to identify the prevailing monsoon season (South-west monsoon) as well as the comparatively drier periods (winter and summer). Such information holds significant significance for the effective management of water resources, the formulation of agricultural

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plans, and the mitigation of potential water scarcity concerns within the region.

The assessment of the overall water balance of a basin is a crucial aspect of groundwater recharge estimation through rainfall. To accurately calculate recharge percentages, researchers utilize various empirical equations proposed by experts, which consider geological characteristics, soil type, and vegetation cover. This analysis aids in determining the replenishment rate of groundwater aquifers, which are vital for sustaining domestic water supply, supporting agricultural activities, and preserving the ecological balance of the region.

MATERIALS AND METHODS

Study area

The Hundri River, a tributary of the Tungabhadra River, originates in the fields of Maddikera in Maddikera Mandal (Fig 1). It receives a stream from Erramalas at Laddagiri in Kodumur Mandal and eventually joins the Tungabhadra River at Kurnool town. The river covers parts of 13 Survey of India Topsheets on a scale of 1:50,000. It drains a significant portion of the Maddikera, Pattikonda, Deverakonda, Gonegandla, Kodumur, and Kallur Mandals. The river falls within the survey of India (SOI) top sheet numbers 57E/6 to 57E/16 and 57I/1 to 57I/3. The river basin is in the southwestern part of the Kurnool district, lying between Northern latitude 140 35' 35" N-160 09' 36" N and longitude 750 58' 42" E to 780 56' 06" E. It covers an area of 3548 square kilometers and spreads across parts of 20 mandals, encompassing 205 revenue villages.

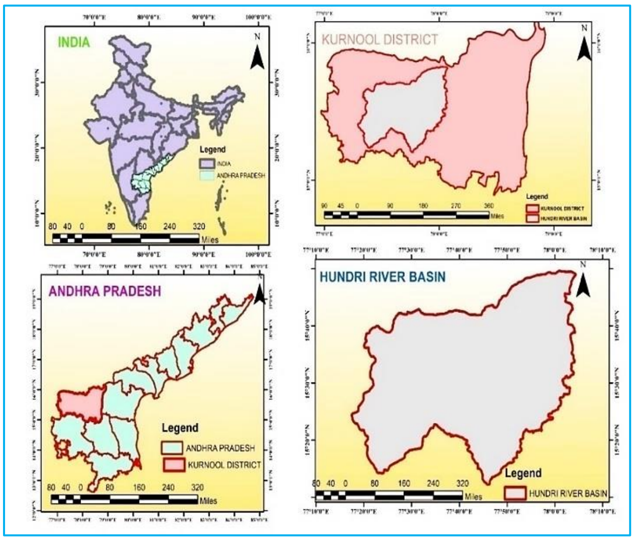

Fig 1 Location map of the study area

The investigation of the surface water resources within the Hundri River basin was conducted through an examination of the precipitation data obtained from 19 rain gauge stations. The monthly precipitation data spanning a duration of 30 years was procured from the Chief Planning Office of Kurnool district for these stations. To assess the precipitation data in terms of seasonal and annual patterns, the statistical methodologies outlined by Bhargava (1977) were employed. The average monthly precipitation, variability in precipitation, and precipitation ratio for each of the 19 stations were computed and organized in tabular form.

1). Mean rainfall = $\frac{\sum X}{N}$, Where X= variates and N = No. of. Varieties

2). Rainfall Variability = $\frac{SD}{AM} \times 100$, Where S.D =Standard deviation, AM =Arithmetic mean

3). Rain fall Ratio =$\frac{P_X P_n}{P_m} \times 100$,Where P_X = Maximum rainfall, P_N =Minimum rainfall

P_M and P_M =Average rainfall

In order to estimate groundwater recharge, a range of empirical methods proposed by Radhakrishna *et al*. [6], the U. S. Geological Survey method (1962), Chaturvedhi (1936), the Amritsar formula (1973), the U.P. Irrigation Research Institute Formula (1954), Krishna Rao (1970), Bhattacharjee (1954), and Kumar and Seethapathi (2002) were employed. The groundwater recharge was determined using each of these methods. Through the implementation of this comprehensive study, valuable insights into the surface water resources and groundwater recharge within the Handri River basin were acquired. These findings will contribute to enhanced water resource management, planning, and decision-making, thereby facilitating the sustainable utilization of water in the region.

Estimation of ground water recharge by using empirical formulas

4) Radhakrishna *et al*. (1974): 10% of the Annual Rainfall

5). U.S. Geological Survey method (1962): 15 % of the annual Rainfall

6). Chaturvedi formula (1936): R_g= 2(P-15) ^0.4

Where Rg is net Recharge and P is annual rainfall, both are measured in Inches

7). Amritsar Formula (1973): Rg= 2.5(P-16) ^0.5

Where R_g is net Recharge and P is annual rainfall, both are measured in Inches

8). U.P.I.R.I. Formula (1954): R_g= 1.35(P-14) ^0.5

Where R_g is net Recharge and P is annual rainfall, both are measured in Inches

9). Bhattacharjee Formula (1954): Rg =3.47(P-38) ^0.4

Where Rg is net Recharge and P is annual rainfall, both are measured in cm

10). Kumar and Seethapathi Formula (2002): Rg =0.63(P-15.28) ^0.76

Where R_g is net Recharge and P is annual rainfall, both are measured in inches

11). Krishna Rao Formula (1970): Rr = K (P-X)

Where R_r and P are measured in mm.

R_r =0.20(P-400) Where annual rainfall between 400- 600 mm

R_r =0.25(P-400) Where annual rainfall between 600- 1000 mm

R_r =0.35(P-600) Where annual rainfall greater than 2000 mm

RESULTS AND DISCUSSION

Seasonal analysis of rainfall of the handri river basin

Winter season

During the winter season, which comprises the months of January and February, the mean rainfall in the study area varies from a minimum of 3 mm at the Krishnagiri station to a maximum of 10 mm at the Asparistation (Table 1). The average rainfall for the entire basin is recorded as 5 mm (Table 1) indicating dry and arid conditions during this period. The Rainfall Variability analysis reveals fluctuations ranging from 155% at the Gudur station to 297% at the Kallur station with an average variability of 220 %. It suggesting significant Fluctuations in the amount of rainfall received during this period. Furthermore, the Rainfall Ratio, a measure of rainfall distribution, shows diverse patterns across the study area. It ranges from 521% at the Gudur station to 1561% at the Yemmiganur station, with average of rainfall ratio of 943%, it signifying substantial variations relative to the mean rainfall, which can have implications for water availability and agricultural planning [7-9].

Summer season

The summer season consists of March, April, and May Months. The values range from a minimum of 60 mm (Tuggali) to a maximum of 76 mm (Pattikonda) (Table 2). The overall average mean rainfall for all stations is approximately 68.5 mm (Table 2). which can be considered a relatively dry period Rainfall variability is a measure of how much the actual rainfall deviates from the mean rainfall. Higher variability indicates more significant fluctuations in rainfall amounts. The values range from a minimum of 47% (Alur) to a maximum of 87% (Bethamcherla). The overall average rainfall variability for all station is around 65.2%, indicating fluctuations in the amount of rainfall received this period. The Rainfall Ratio values ranges from minimum of 184% (Alur) to a maximum of 387% (Bethamcherla). The overall average rainfall ratio for all stations is approximately 264% reflecting considerable variations relative to the mean, which can have implications for water availability and agriculture [10-11].

Table 1 Mean rainfall, rainfall variability and rain fall ratio of the Handri River basin (Winter season)

Station	Mean rainfall in mm	Rainfall variability in %	Rainfall ratio in %
Adoni	5	223	1094
Alur	5	260	1390
Aspari	10	185	733
Bethamcherla	4	252	1086
Devanakonda	5	211	856
Dhone	3	197	771
Gonegandla	6	178	703
Gudur	5	155	521
Kallur	4	297	1542
Kodumur	6	230	933
Krishnagiri	3	196	815
Kurnool	5	178	718
Maddikera	6	190	700
Orvakal	5	275	1394
Pattikonda	4	220	916
Peapully	6	209	647
Tuggali	4	199	611
Veldurthi	3	232	931
Yemmiganur	6	294	1561

Table 2 Mean rainfall, rainfall variability and rain fall ratio of the Handri River

Station	Mean rainfall in mm	Rainfall variability in %	Rainfall ratio in %
Adoni	71	59	270
Alur	74	47	184
Aspari	65	53	211
Bethamcherla	67	87	387
Devanakonda	61	65	310
Dhone	67	71	311
Gonegandla	75	66	261
Gudur	68	66	283
Kallur	72	78	254
Kodumur	70	63	242
Krishnagiri	68	84	285
Kurnool	72	65	246
Maddikera	65	51	195
Orvakal	67	74	301
Pattikonda	76	61	251
Peapully	68	58	205
Tuggali	60	54	243
Veldurthi	67	77	316
Yemmiganur	69	62	252

South west monsoon

During the South West Monsoon season, which includes the months of June, July, August, and September, the mean rainfall in the basin varies between 318 mm at Maddikera station and 496 mm at Kurnool station (Table 3). The normal rainfall for the basin during this period is 414 mm (Table 3), Indicating the wettest season in the basin. The rainfall variability ranges from a minimum of 26% in Adoni to a maximum of 50% in Dhone station, with an average variability of 40% for the basin, indicating relatively stable and predictable rainfall patterns during this season. The rainfall ratio, of the basin varies from 110% at Adoni station to 257% at Dhone station, with an average rainfall ratio of 179% for the basin, indicating a relatively balanced distribution of rainfall compared to the mean, which can be favourable for agricultural activates [12].

Table 3 Mean rainfall, rainfall variability and rain fall ratio of the Hadri River basin (South west monsoon)

Station	Mean rainfall in mm	Rainfall variability in %	Rainfall ratio in %
Adoni	460	26	110
Alur	385	38	150
Aspari	388	35	136
Bethamcherla	411	45	202
Devanakonda	400	43	180
Dhone	405	50	257
Gonegandla	412	38	171
Gudur	469	39	195
Kallur	433	43	211
Kodumur	417	43	177
Krishnagiri	358	36	151
Kurnool	496	37	202
Maddikera	318	39	174
Orvakal	476	39	187
Pattikonda	400	43	173
Peapully	424	38	157
Tuggali	387	43	184
Veldurthi	392	35	162
Yemmiganur	439	45	228

Table 4 Mean rainfall, rainfall variability and rain fall ratio of the Handri River basin (North east monsoon)

Station	Mean rainfall in mm	Rainfall variability in %	Rainfall ratio in %
Adoni	131	79	401
Alur	142	76	350
Aspari	122	66	220
Bethamcherla	151	58	240
Devanakonda	120	69	244
Dhone	121	67	245
Gonegandla	133	80	410
Gudur	130	76	291
Kallur	126	79	268
Kodumur	113	69	295
Krishnagiri	124	69	284
Kurnool	129	76	261
Maddikera	127	56	249
Orvakal	134	70	270
Pattikonda	135	68	255
Peapully	143	56	216
Tuggali	118	62	231
Veldurthi	129	63	208
Yemmiganur	138	89	397

North east monsoon

During the North East Monsoon season, which covers the months of October, November, and December, the mean rainfall in the basin varies from a minimum of 113 mm at Kodumur station to a maximum of 151 mm at Bethamcherla (Table 4). The average rainfall for the entire basin during this period is 130 mm (Table 4), Making it moderately wet season. Rainfall Variability across the study area shows diversity, ranging from a minimum of 56% at Peapully station to a maximum of 89% at Yemmiganur station, with an average variability of 70%, suggesting fluctuations in rainfall amount during this period. The rainfall ratio in the basin has a wide range, with a minimum of 208% at Veldurthi station to a maximum of 410% at Gonegandla station. The normal rainfall ratio is recorded as 281%, Indicating significant variations relative to the mean, which may impact water resources and local ecosystem.

The basin experiences diverse rainfall patterns across the four seasons, with varying mean rainfall, rainfall variability, and rainfall ratio. Understanding these seasonal characteristics is crucial for water resource management, agricultural planning, and climate adaptation strategies in the region [13-15].

Annual rainfall

The annual rainfall in the basin shows significant variation, ranging from a minimum of 515 mm at Maddikera station to a maximum of 702 mm at Kurnool station (Table 5). The average annual rainfall for the entire basin is calculated to be 702 mm. Regarding rainfall variability, it varies across the stations, with Adoni station experiencing the lowest variability at 25%, and Dhone station witnessing the highest variability at 39%. On average, the rainfall variability for the basin is around 33 %. The rainfall ratio also displays diversity, ranging from 103% at Krishnagiri station to 186% at Yemmiganur station. The normal rainfall ratio is recorded as 140% [16].

Table 5 Mean rainfall, rainfall variability and rain fall ratio of the Handri River basin (Annual)

Station	Mean rainfall in mm	Rainfall variability in %	Rainfall ratio in %
Adoni	665	25	117
Alur	606	34	150
Aspari	585	29	112
Bethamcherla	632	38	172
Devanakonda	586	36	156
Dhone	597	39	178
Gonegandla	627	31	128
Gudur	673	30	125
Kallur	635	38	175
Kodumur	605	32	128
Krishnagiri	552	28	103
Kurnool	702	31	148
Maddikera	515	32	108
Orvakal	683	33	146
Pattikonda	615	35	115
Peapully	641	32	132
Tuggali	569	38	155
Veldurthi	590	29	118
Yemmiganur	652	37	186

The basin experiences varying amounts of annual rainfall, with some stations receiving higher rainfall (e.g., Kurnool) and others have relatively lower rainfall (e.g., Maddikera). The variability in rainfall amounts differs across the basin, with some stations showing more stable patterns (e.g., Adoni), while others exhibit higher fluctuations (e.g., Dhone). The Rainfall Ratio provides insight into how the mean rainfall relates to the rainfall variability at each station, indicating variations in the basin's overall rainfall patterns.

The Total Surface Water resources the Handri River basin:
Total Geographical area of the basin × Mean annual rain fall
$3548\ Km^2 \times 617\ mm = 218, 911, 6000\ m^3$.

Ground water recharge

Radha Krishna method (1974)

The Radhakrishna approach (1974) proposes that the basin's aquifer recharge is equivalent to 10% of the total annual precipitation. The recharge rates fluctuate, with the lowest value being 51 mm at Maddikera station and the highest being 70 mm at Kurnool station (Table 6). The mean yearly groundwater recharge for the entire basin is estimated to be 62 mm.

U.S. Geological method (1962)

According to this According to the methodology proposed by the U.S. Geological Survey in 1962, the groundwater replenishment in the studied area, basin, or watershed corresponds to 15% of the total annual precipitation. According to this method, the recharge figures vary, with a minimum of 77 mm observed at Maddikera and a maximum of 105 mm recorded at Kurnool station (Table 6). On average, the annual replenishment of groundwater for the entire study area is assessed to be 93 mm.

Chaturvedi formula (1936)

Chaturvedi's formula (1936) derives the groundwater replenishment using the expression Rg = 2(P-15) ^0.4, with Rg and P expressed in inches. According to this method, the recharge amounts fluctuate, ranging from a minimum of 99 mm at Maddikera to a maximum of 140 mm in Kurnool District (Table 6). The average yearly recharge for the basin is determined to be 123 mm, constituting 20% of the overall annual precipitation.

Amritsar formula (1973)

Amritsar's method (1936) proposes the calculation of groundwater recharge using the formula Rg = 2.5(P-16) ^0.5, with Rg and P measured in inches. According to this approach, the recharge values exhibit variability, ranging from a minimum of 131 mm at Maddikera to a maximum of 217 mm in Kurnool District (Table 6). On average, the basin experiences an annual recharge of 182 mm, which constitutes 29% of the total annual rainfall.

U.P.I.R.I. formula (1954)

U.P.I.R.I has developed a method for estimating groundwater recharge using the formula Rg = 1.35(P-14) ^0.5, where Rg and P are measured in inches. According to this approach, the recharge values exhibit variation, ranging from a minimum of 86 mm at Maddikera to a maximum of 127 mm in Kurnool District (Table 6). On average, the basin experiences an annual recharge of 110 mm, which corresponds to 18% of the total annual rainfall.

Bhattacharjee formula (1954)

Bhattacharjee's approach has derived a means to estimate groundwater replenishment utilizing the equation Rg = 3.47(P-38) ^0.4, where Rg and P are expressed in centimeters. According to this method, the recharge quantities exhibit variability, spanning from a minimum of 98 mm at Maddikera to a maximum of 139 mm in Kurnool District (Table 6). The mean yearly recharge for the basin is determined to be 123 mm, corresponding to 20% of the entire annual precipitation.

Kumar and Seethapathi (2002)

Kumar and Seethapathi have formulated a method to calculate groundwater recharge using the equation Rg = 0.63(P-15.28) ^0.76, where Rg and P are measured in inches. According to this approach, the recharge values show variation, ranging from a minimum of 54 mm at Maddikera to a maximum of 108 mm in Kurnool District (Table 6). On average, the basin experiences an annual recharge of 123 mm, which constitutes 20% of the total annual rainfall.

Krishna Rao formula (1970)

In1970, Krishna Rao introduced an empirical relationship for approximating ground water replenishment, given by Rr = K(P-X), where Rr and P are measured in millimeters. According to Krishna Rao method.

For Regions with annual rainfall ranging from 400 to 600 mm, the recharge can be approximated using Rr =0.20(P-400)

For Regions with annual rainfall ranging from 400 to 600 mm, the recharge can be approximated using Rr =0.25(P-400)

For Regions with annual rainfall Exceeding 2000 mm, the recharge can be approximated using from 400 to 600 mm, Rr =0.35(P-600)

Based on this approach, the recharge values range from a minimum of 23 mm at Maddikera station to a maximum of 75 mm at Kurnool station (Table 6). On average, the basin experiences an annual recharge of 51 mm, which represents 8 % of the total annual rainfall.

Table 6 Average annual recharge of the Handri River basin

Mandal	Rainfall (mm)	Radhakrishna method (mm)	U.S. Geological method (mm)	Chaturvedi's formula (1936) (mm)	Amritsar's formula (1973) (mm)	U.P.I.R.I. formula (1954) (mm)	Bhattacharjee formula (1954) (mm)	Kumar and Seethapathi formula (2002) (mm)	Radha Krishna method (1970) (mm)	Recharge (mm)	Recharge (%)
Adoni	665	60.55	99.82	133.52	202.80	119.77	132.60	98.45	66.37	114.98	17.28
Alur	606	60.56	90.85	121.48	177.84	107.58	120.70	81.85	51.41	101.53	16.76
Aspari	585	58.45	87.68	116.79	168.16	102.95	116.05	75.74	36.91	95.34	16.31
Bethamcherla	632	63.19	94.79	126.98	189.21	113.10	126.13	89.26	57.98	107.58	17.02
Devanakonda	586	58.61	87.92	117.15	168.91	103.30	116.41	76.21	37.23	95.72	16.33
Dhone	597	59.67	89.50	119.53	173.81	105.64	118.76	79.28	39.34	98.19	16.46
Gonegandla	627	62.69	94.04	125.97	187.11	112.07	125.13	87.87	56.73	106.45	16.98
Gudur	673	67.32	100.98	134.95	205.79	121.25	134.02	100.52	68.29	116.64	17.33
Kallur	635	63.47	95.20	127.54	190.36	113.66	126.68	90.02	58.67	108.20	17.05
Kodumur	605	60.47	90.70	121.28	177.42	107.38	120.49	81.57	51.17	101.31	16.75
Krishnagiri	552	55.19	82.78	108.89	151.95	95.31	108.24	65.96	30.37	87.34	15.83
Kurnool	702	70.18	105.27	140.10	216.55	126.60	139.11	108.10	75.45	122.67	17.48
Maddikera	515	51.49	77.24	98.79	131.27	85.89	98.26	54.32	22.99	77.53	15.06
Orvakal	683	68.30	102.45	136.75	209.55	123.11	135.80	103.15	70.75	118.73	17.38
Pattikonda	615	61.54	92.31	123.56	182.14	109.66	122.75	84.62	53.84	103.80	16.87
Peapully	641	64.09	96.13	128.78	192.93	114.92	127.91	91.74	60.22	109.59	17.10
Tuggali	569	56.93	85.39	113.20	160.79	99.45	112.50	71.22	33.85	91.67	16.10
Veldurthi	590	59.04	88.57	118.13	170.92	104.26	117.37	77.46	38.09	96.73	16.38
Yemmiganur	652	65.18	97.77	130.91	197.37	117.09	130.02	94.73	62.94	112.00	17.18

The average annual recharge of the basin has been calculated by taking the average of eight different methods, resulting in a range of values from 78 mm to 123 mm. The overall average recharge for the entire basin is 103 mm. This average recharge accounts for 17% of the annual rainfall in the region. The recharge values vary across different stations in the basin. Maddikera and Krishnagiri stations have the lowest recharge values, being less than 90 mm. Apari, Devanakonda, Dhone, Tuggali, and Veldurthi stations experience recharge between 90 mm and 100 mm. On the other hand, Adoni, Alur, Bethamcherla, Orvakal, Pattikonda, Peapully, and Yemmiganur stations have the highest recharge values exceeding 100 mm.The total Ground water Potential of the basin is worked out by ground water recharge method.

Total water resources recharge to ground water = Geographical area of the basin × Average annual recharge $3548\ Km^2 \times 103$ mm = $365{,}444{,}000\ m^3$

The total Ground water resources accounts to 16.7% of the total surface water resources.

Water balance of the Handri River basin

1). The total surface water resources = Geographical area of the basin × Average annual rain fall $3548\ Km^2 \times 617$ m = $2189116000\ m^3$.

2). Total water resources Recharge to Ground water=Geographical area of the

Basin × Average AnnualRecharge $3548\ Km^2 \times 103$ m =$365444000\ m^3$. (16.7%)

3). Total Water resources stored in Reservoirs, Ponds, lakes etc = $2189711600\ m^3$ (10%).

4). Total water resources lost in the form of run-off = $437823200\ m^3$. (20 %)

5). Water lost in the form of Evaporation and Evapotranspiration 2189116000 – 1022178800 = 1166937200 (53.3%)

From the above analysis it is found that out of $218911600\ m^3$ of water available 10% is stored in the ponds and tanks and reservoirs if the basin, 16.7% recharge to ground water, 20 %is lost in the form of run-off and 53.3% is lost in the form of evaporation and evapo-transpiration. The surface water loss in the form of run-off could be saved and stored efficiently by constructing check dams and percolation ponds in the basin [17-18].

CONCLUSION

In summary, the research reveals distinct seasonal rainfall patterns with significant fluctuations in the study area. Winter and summer experience dry conditions, impacting water resources and agriculture. The South West Monsoon brings the wettest period with stable rainfall patterns, while the North East Monsoon is moderately wet with variable rainfall. The annual rainfall shows notable variation, affecting water availability and agricultural planning. The study analyzed multiple methods to estimate groundwater recharge, showing diverse values across different stations. The overall average annual recharge for the basin was 103 mm, accounting for 17% of the total annual rainfall. Understanding these variations is essential for effective water resource management and sustainable agricultural planning.

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