Augmentation of Groundwater Resources in the Hard Rock Region of Noyyal River Basin, Tamil Nadu, India

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Abstract

Worldwide rapid growth of population, industries and agricultural activities has brought about a steep increase in water demands which have to be met from available surface and groundwater resources. Many parts of the world have diverse hydro-geological and hydro-meteorological conditions and so is the diversification in its hydrological problems which are mostly governed by the regional conditions. Vagaries of monsoon and withdrawal of groundwater in excess to replenishment of aquifer system in many parts of India and elsewhere results into continuous declining of water table causing economic problems and deterioration of water quality. In case of Tamil Nadu, the problem is manifold in hard rock regions where the water table has gone below the weathered zone and it could be extracted only from deeper fractured zones. The aquifer systems in many hard rock areas have been over exploited. At many places many farmers have drilled borewell without knowing the potential of aquifer system and thereby end up with debt trap due to failure of the borewells.

Groundwater is a renewable resource and its spatio-temporal availability on annual basis is almost fixed. Groundwater recharge and its conservation through judicious use can increase its availability to some extent. Hence, management of groundwater resources in a planned manner along with surface water resources is necessary for its sustainability. To improve the management of groundwater resources, comprehensive database of different aspects such as hydro-meteorological, hydrological and hydro–geological data; and greater understanding of groundwater system to know about their availabilities in space and time, associated quality parameters and demands by different sectors are required. If the comprehensive data are used in state of art models, they can be very useful to devise management plans.

A research was undertaken in the hard rock region of Noyil river basin and is subdivided into Upper Noyyal, Avanashi and Lower Noyyal sub-basins (Source: WTC, TNAU, CBE). It comprises the entire drainage basin area of the Noyyal river (3,510 km^2), a tributary of the Cauvery river, which flows eastward and joins the Bay of Bengal. In this basin, 13 rain gauge stations are monitored for annual rainfall and 48 observation wells are monitored for monthly water level fluctuations from 1998-2005. The average annual rainfall recorded from the stations is found to be 641.51mm. Recharge has been estimated to be 8 to 15% throughout the Noyil river basin.

Keywords: Noyil basin, groundwater resource, assessment, recharge and management.

1. INTRODUCTION

Water is a unique substance and it is essential for human, animal as well as plant survival. The quantity and quality of water available for human use is linked to the ecosystem, sustainable management of natural resources and giving priority of water uses between different sectors. Factors like deforestation, disruption of hydrological cycle, surface run off, over extraction of groundwater, pollution of water sources, silting of lakes and tanks etc., contribute mainly to the scarcity of water. Although natural resources such as land, water and forest resources, ecology movements have increasingly focused on these links and there is a need to have a holistic and integrated approach.

Ninety seven per cent of our planet's water is contained in the oceans and seas, 2.5 per cent is bound in snow and ice and only 0.5 per cent is at all accessible. According to United Nations study, the availability of fresh water in Asia is only 3000 cubic metres per person per year, the lowest figure for any continent. In India, the availability is put at 2500 cubic metres and a dire prognosis is that India may reach a state of water stress (that is, when average annual per capita availability falls to 1000 cubic metres and below) before 2050. The need for rainwater harvesting has become more prominent due to many problems like groundwater exploitation, groundwater pollution, etc. Extraction of groundwater has skyrocketed in the past 40 years in our country.

Tamil Nadu is one of the water starved states in India. Groundwater has emerged as the major source to meet the ever-increasing demands of irrigation, industrial and domestic sectors in Tamil Nadu. Groundwater abstraction has been increased and resulted in the declining of water table rapidly in many parts of the state. These problems are very acute in those areas underlain by hard rocks, since the hard rock aquifers have limited storage capacity and store only limited quantity. Effective groundwater management requires, firstly, a good understanding of the aquifer system; secondly, practical measures to control abstraction that can be identified and thirdly augment groundwater resource through artificial recharge. A study was carried out to assess the contribution of rainfall from different seasons in order to augment the groundwater resources at feasible locations through artificial recharge and discussed in this paper.

1.1 Tamil Nadu Scenario

In Tamil Nadu about 65 per cent of the area is under dry land agriculture. The conservation of the rainwater source in dry land areas obviously provides the key for success. In recent years, watershed is recognized as the most suitable physical unit for integrated development. It is worthwhile to opine that the next breakthrough towards increased production would accrue from dry lands through watershed management encompassing rainwater conservation and utilization.

The total geographical area of Tamil Nadu State is 1,30,069 sq.km. More than 98 per cent of the surface potential has been already utilized. The supply demand gap in water was estimated to be about 40 per cent in year 2030 AD. Out of total groundwater resources of 26,395 MCM/year, total quantity of groundwater resources earmarked for drinking and industrial uses worked out to be 3962 MCM/year and the drinking water need alone worked out to be about 952 MCM/year.

The ultimate irrigation potential available from groundwater in Tamil Nadu works out to be 3.144 M.ha. The irrigation potential created from groundwater is estimated as 1.954 M.ha and the balance irrigation potential available is 1.190 M.ha. Average development is about 60% and it was ranging from as low as 7 per cent to as high as 100 per cent. Water table also fluctuates between open and dug wells and it was seen that the fluctuations were higher in districts like North Arcot, Salem, Coimbatore and Erode indicating possible heavy drawl as well as less recharges. Among the wells, dug wells were prone for more fluctuations ranging from 0.5 to 1.0 m/year. In Tamil Nadu the number of dug wells has increased from 0.79 million to about more than 1.8 million and the shallow tube wells from few hundreds to 0.14 million in the last four decades.

Out of 386 blocks, a total of 136 blocks, where the level of groundwater development is more than 100 percent, with pre or post monsoon water level showing declining trend have been categorized as 'OVEREXPLOITED'; 67 blocks, where the level of groundwater development is between 90 and 100 percent and pre or post monsoon water level showing declining trend have been categorized as 'CRITICAL'. The level of groundwater development in 33 blocks is between 70 and 90 percent and with pre or post water level showing declining trend have been categorized as 'SEMI-CRITICAL'. The level of ground water development in 139 blocks is below 70 percent with both pre and post monsoon water level not showing declining trends are categorized as 'SAFE'. The groundwater available in the phreatic zone is totally saline in 11blocks in the State.

During the last ten years, the average farm size has declined in all the categories of blocks from 2.20 ha to 1.72 ha. The average area irrigated per well has also declined over years both under the open and borewells and the current area irrigated per well is comparatively higher under borewells (0.99 ha) than under open wells (0.65 ha) indicating that increase in the number of wells will not result in proportionate increase in area irrigated per well over years due to groundwater over-draft. For example, in many villages, the average number of wells owned by a farmer has ranged from 3 to 6 borewells and one open well. The increasing number of wells without assured aquifer supply has resulted in stagnation of the net area irrigated by wells wherein several cases well yield was ranging from 3 to 5 liters per second which means 64.8 to 108 m^3 per day (with 6 hours pumping).

The percentage of wells failed was higher in the overexploited and critical blocks indicating the seriousness of groundwater over-draft. Further, the percentage of open wells dried up was higher (48.68 per cent) compared to borewells (9.99 per cent) and this might be due to comparatively shallow depth of the wells. The average depth of open well was about 26 m and it was about 228 m for borewells. The well failure and investment in new bore wells reflected the direct and indirect costs incurred by the farmers. The direct costs are those costs which included the capital costs of open wells, which have dried up before the expected average life period, and the costs of new borewells and pumps. Indirect costs are those costs that are associated with the reduction in crop area and crop income. These costs are expected to increase as the water table goes down and irrigated area reduces.

2. STUDY AREA DETAILS

The river Noyyal originates at the Vellingiri hills in Western Ghats and passes through Coimbatore district (Coimbatore South and Sulur taluks), Tiruppur district (Palladam, Tiruppur, Kangeyam taluks), Erode district (Perundurai, Erode and Kodumudy taluks) and Karur district (Aravankurichi taluk) in Tamil Nadu State and joins river Cauvery at Kodumudy. The Noyyal river basin comprises the entire drainage basin area of the Noyyal river (3510 km^2), a tributary of the Cauvery River, flow eastward joining the Bay of Bengal. The Noyyal river basin located between North latitude $10^o56'$ and $11^o19'$ / East longitude $76^o41'$ and $77^o56'$ and falls in the Survey of India topographic degree sheets 58A, 58B, 58E and 58F on scale 1:50000 is shown in Fig. 1. It has a length of about 140 km from west to east with an average width of 25 km. It is widest in the central part having a width of about 35 km. The area is more or less plain country bounded by the mountain chains of the Western Ghats and their peaks range in altitude from 1600 to 2600m above mean sea level. The plain that covers the major part of the area has an altitude from 200 to 450 m. The monotony of the plains in the central and eastern parts of the basin is broken by a few scattered hills such as Sivanmalai, Alagumalai, and Chennimalai.

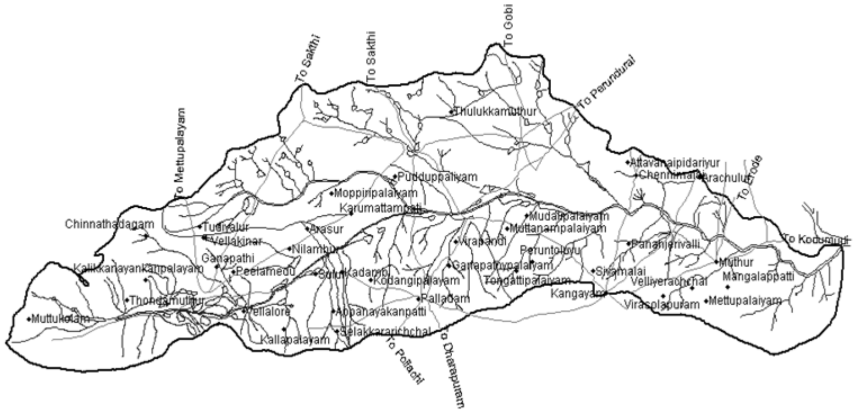

Fig.1 Noyyal river basin

3. RESULTS AND DISCUSSION

3.1 Basin Characteristics

The basin characteristics include Shape Index (S_w), Form Factor (R_f), Circulatory Ratio (R_c) and Elongation Ratio (R_l). The Noyyal river basin area is 3510 km^2. The length of major streams running along the basin is 140 km. The perimeter of the basin is 360 km. With these major parameters, various basin characteristics were found and listed below.

The shape index was found to be 5.58. The form factor, which is the inverse of shape index, was found to be 0.18. The shape parameters like shape index and form factor can be used to quantify the degree of similarity of basin shapes.

The circulatory ratio was arrived as 0.34. The elongation ratio was found out to be 0.48. The values of elongation ratio and circulatory ratio imply the shape of the basin. If these values approach unity, it means that shape of the basin approaches that of a circle. In this study, the values of elongation ratio and circulatory ratio are not approaching unity and hence the basin is nearly a fern leaf shaped one. The fern leaf shaped basin produces lesser flood intensity and time of concentration is more. Because of more time of concentration, the runoff production is relatively low resulting in more recharge.

3.2 Rainfall Analysis

The annual and seasonal rainfall of the 13 stations located in the study area for the years 1990-2004 are given in Table 1. From the analysis of the rainfall data of the stations, it is seen that there is very wide variation in the mean annual rainfalls over the years from 387.59 mm (Annur) to 898.05 mm (P.N.Palayam). This is due to the Orographic effect of the Western Ghats, which form the western border of the basin.

The post monsoon and pre monsoon season periods produced about 80 mm to 222 mm of rain and most of it is received during the month of April and May. The first three months (January to March) form generally the dry period. The post monsoon and pre monsoon rains occur in the form of showers or thunderstorms and provide the much required soil moisture for the survival of vegetation till the onset of monsoon. In terms of percentage, the post monsoon and pre monsoon rains

Table 1 Annual and Seasonal Rainfall (mm) of Selected Rain Gauge Stations in Noyyal Basin (1990-2004)

Rain gauge stations	Latitude	Longitude	Jan	Feb	Winter	Mar	Apr	May	Summer	Jun	Jul	Aug	Sep	S.W.	Oct	Nov	Dec	N.E.	Annual RF
1Agrl. College	11°00' 26"	76°56 '43"	8.89	4.85	13.73	16.98	68.73	47.57	133.29	32.73	46.67	36.12	63.15	178.67	174.57	140.76	28.63	343.97	669.65
2.A.N.Palayam	11°25' 00"	77°41 '00"	4.30	3.36	7.66	6.13	29.36	68.62	104.11	32.50	33.90	66.17	95.51	228.07	169.97	118.09	18.83	306.89	646.73
3.Annur	11°14' 00"	77°07 '00"	2.98	3.71	6.69	9.69	32.32	30.65	72.66	18.35	23.94	36.62	56.76	135.67	86.11	68.91	17.56	172.57	387.59
4.Avinashi	11°12' 00"	77°17 '00"	2.73	12.51	15.24	17.43	56.49	72.87	146.78	36.19	48.00	60.88	93.94	239.01	173.57	139.15	26.45	329.89	730.92
5.Chennimalai	11°10' 00"	77°36 '30"	3.60	4.89	8.49	6.85	32.14	82.23	121.23	41.93	37.69	61.58	99.06	240.27	183.31	136.13	19.83	339.26	709.25
6.Kangeyam	11°00' 17"	77°33 '50"	4.15	2.45	6.60	6.43	40.72	51.84	98.99	30.83	18.56	47.61	84.55	181.55	154.59	129.67	30.79	315.05	602.19
7.Kodumudi	11°04' 35"	77°53 '05"	4.07	14.17	18.24	33.17	62.79	42.95	133.45	17.96	15.89	33.56	43.69	111.11	179.39	97.96	25.91	303.26	566.05
8.P.N.Palayam	11°09' 00"	76°57 '00"	13.05	22.10	35.15	28.12	84.21	74.62	186.95	37.48	31.33	50.29	76.44	195.54	236.11	196.97	47.32	480.40	898.05
9.Palladam	10°59' 35"	77°17 '28"	1.93	1.85	3.79	17.25	33.05	55.33	105.63	19.48	15.09	22.89	38.29	95.75	161.11	130.68	28.09	319.87	525.04
10.Podanur	10°58' 07"	76°59 '45"	1.83	18.79	20.62	21.93	60.97	39.68	122.58	39.38	34.33	19.15	36.81	129.67	128.67	138.82	24.75	292.23	565.11
11.Pongalur	10°58' 31"	77°22 '12"	3.53	5.73	9.27	23.27	43.89	79.67	146.83	19.98	12.11	40.89	85.00	157.98	174.84	180.48	37.64	392.96	707.03
12.Sulur	11°02' 00"	77°08 '00"	3.25	11.69	14.93	19.60	55.15	32.81	107.56	16.65	15.03	18.30	49.33	99.31	146.90	139.31	22.33	308.54	530.34
13.Thondamuthur	10°59' 22"	76°50 '59"	14.47	2.84	17.31	19.63	37.21	48.44	105.28	54.73	79.46	33.56	50.01	217.76	142.65	103.79	13.37	259.81	600.15

contribute between 15 % and 25 % of the annual rainfall. It is significant that it forms 25 % of the annual rains in the eastern part of the basin. It may be mentioned here that almost the entire basin falls in the dry plain area of the rainfall regime, while the upper reaches of the Noyyal river bordering the western side and forming part of the Chitrachavadi sub basin comes under 'wet mountain type' and the hilly region forming part of Chinnatadagam sub basin forms the 'dry mountain' type, as much the seasonal rainfall pattern is different.

The southwest monsoon period produces about 100 to 240 mm of rain received almost uniformly during the months of June, July, August and September. In terms of percentage, the southwest monsoon rains contribute between 20 % and 35 % of the annual rainfall. During the northeast monsoon (October to December) almost the whole of the basin gets 50 % of its rain ranges from 170 to 480 mm of the annual rainfall.

Apart from high variation in the distribution of rainfall over the basin there are high variation within the annual course of rainfall received within the basin. This very large range is to be attributed to the seasonally changing pattern of monsoon over the area. The plot is presented in Fig. 2.

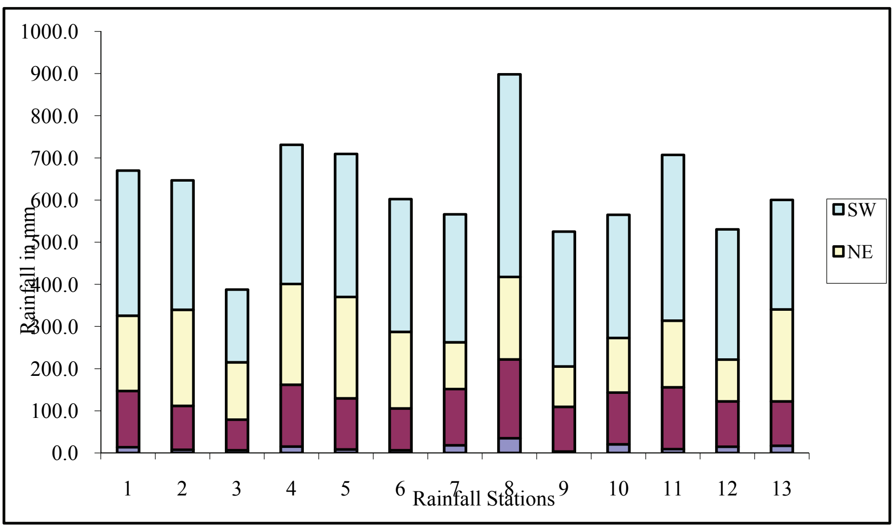

Fig. 2 Histogram of Mean Annual Rainfall (1990-2004)

3.3 Groundwater Recharge

In Noyyal river basin, the region's *viz* (Head, Middle and Tail) average water level fluctuations were found for different years 1998 to 2005. The basin's average water level fluctuations in head, middle and tail regions were 1.78 to 3.94, 1.94 to 4.44 and 1.74 to 3.72 m respectively. The area influence of the each observation wells are shown in Fig. 3 and tabulated for area of each wells below.

The basin's seasonal rainfall and groundwater level fluctuations for different years were arrived graphically as shown in Fig. 4. The water level fluctuation during 2005 is very high due to high seasonal rainfall contribution as compared to previous years. In all the wells, the shallowest water table had occurred during the month of December and the water level declined gradually depending upon the rainfall and groundwater abstraction.

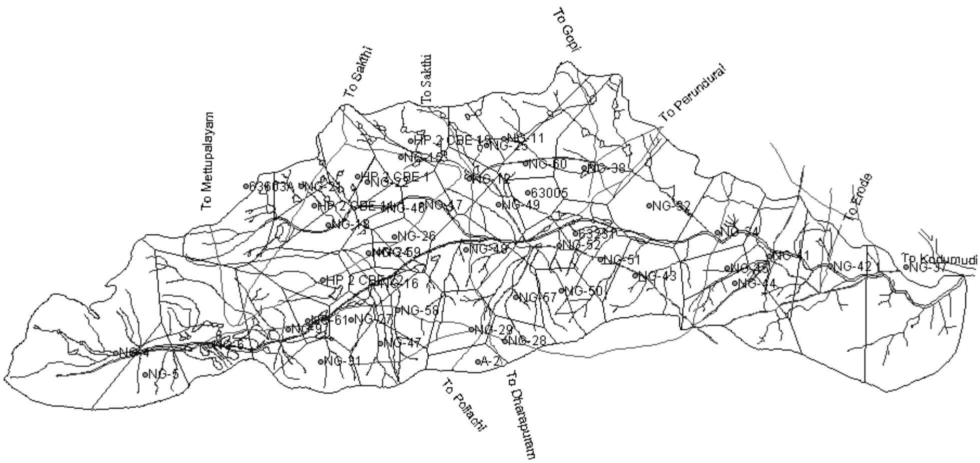

Fig. 3 Distribution of observation wells in Noyyal river basin

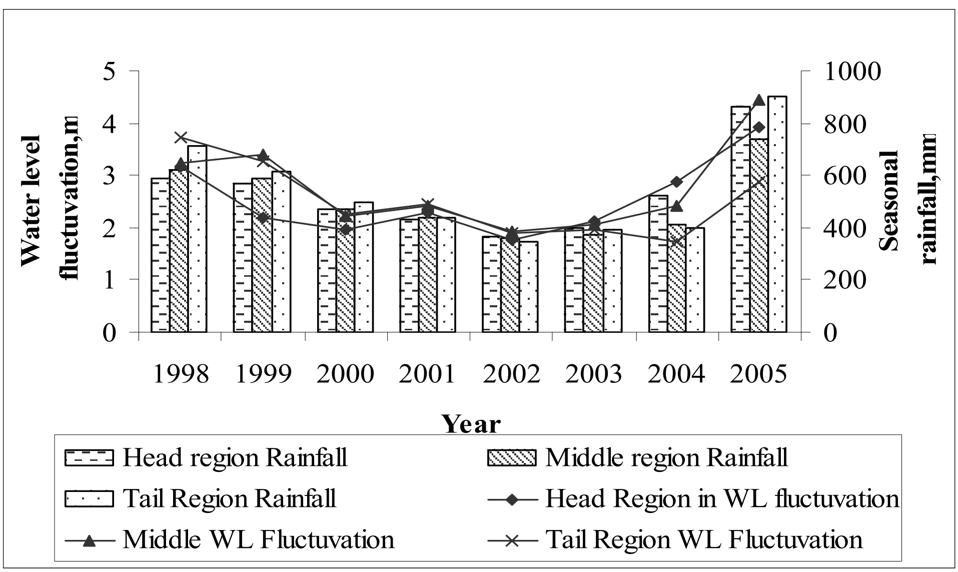

Fig. 4 Seasonal rainfall and water level fluctuations for Noyyal river basin

Table 2 Thession polygonal area of observation wells

S. No.	Well No	Thession polygon Area (in km^2)
1	A-2	31.90
2	NG-4	281.95
3	NG-5	82.77
4	NG-6	181.86
5	NG-9	88.53
6	NG-11	86.78
7	NG-12	46.77
8	NG-15	49.86
9	NG-16	32.33
10	NG-17	47.66
11	NG-18	43.35
12	NG-21	42.08
13	NG-22	19.64
14	NG-24	24.53
15	NG-25	43.42
16	NG-26	35.11
17	NG-27	35.91
18	NG-28	38.48
19	NG-29	63.23
20	NG-31	63.55
21	NG-32	129.62
22	NG-34	94.34
23	NG-37	208.57
24	NG-38	166.38
25	NG-41	98.35
26	NG-42	188.65
27	NG-43	99.33
28	NG-44	111.62
29	NG-45	41.11
30	NG-46	28.47
31	NG-47	70.62
32	NG-48	86.69
33	NG-49	46.38
34	NG-50	76.33
35	NG-51	45.03
36	NG-52	44.29
37	NG-57	61.97
38	NG-58	60.59
39	NG-59	14.19
40	NG-60	70.09
41	NG-61	29.36
42	HP 2 CBE 1	62.27
43	HP 2 CBE 11	38.92
44	HP 2 CBE 19	66.32
45	HP 2 CBE 22	74.75
46	63005	39.10
47	63231	41.64
48	63603A	103.19
49	Total	3537.86

Source: WTC, IWMI report 2006)

The average seasonal rainfall of the basin ranged from 343.32 mm to 902.6 mm. The natural recharges were arrived region wise for the period from 1998 to 2005 viz., Head 9.6 to 13.7%, Middle 11.8 to 14.9% and Tail 7.9 to 13.8% (Tables 2 & 3). In this recharge percentage is not sufficient to meet sustainable groundwater resources in the basin because of over exploitation of groundwater due to urbanization, free subsidies, power schemes and industrial development.

Table 3 Recharge estimation (Head, Middle and Tail region) using water level fluctuation method

Head Region Wells	**Water level Difference between Southwest monsoon and Northeast monsoon (in m)**							
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
NG-21	-	-	-	-	1.80	1.29	-	12.32
HP 2 CBE 11	4.92	-	-	1.56	1.35	6.64	3.25	2.10
NG-18	0.09	6.74	-	-	0.99	-	-	-
HP 2 CBE 22	3.37	1.72	1.96	2.77	3.13	1.69	-	1.75
NG-61	4.05	-	-	3.89		1.38	1.65	3.00
NG-31	0.08	0.93	-	0.92	2.55	2.87	-	3.00
NG-4	-	1.85	-	-	-		-	-
NG-5	5.45	0.80	-	-	-	0.80	5.40	-
NG-6	3.55	1.0	-	-	0.90		-	-
63603A	1.65	-	2.65	-	2.00	0.27	2.10	4.07
NG-9	5.50	2.27	1.30	-	1.50		2.00	1.13
Average Water Level fluctuation	3.18	2.19	1.97	2.29	1.78	2.13	2.88	3.91
Area (ha)	1030.31	1030.31	1030.31	1030.31	1030.31	1030.31	1030.31	1030.31
Rainfall (mm)	588.26	567.44	468.16	430.1	368.28	395.48	525.316	865.46
Recharge Volume=(Area*Avg. WLF*Sp.Yield)	8202.42	5633.59	5074.28	5885.65	4578.44	5497.45	7418.24	10071.29
Recharge (%)	13.5	9.6	10.5	13.2	12.0	13.4	13.7	11.2

Middle Region Wells	**Water level Difference between Southwest monsoon and Northeast monsoon(in m)**							
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
NG-38	2.43	7.15	5.59	6.02	4.24	4.29	4.08	4.90
63231	-	0.46	-	1.28	6.00	-	-	-
NG-52	-	2.83	-	0.52	0.75	1.94	4.19	-
NG-57	4.50	1.03	-	2.83	0.57	1.03	0.48	0.11
NG-28	-	-	-	-	-		-	1.55
A-2	4.03	4.52	-	-	0.69	2.06	0.70	2.26
NG-29	-	2.32	1.50	-	2.00	2.09	0.45	6.46
NG-48	-	4.64	-	4.30	2.00	2.20	4.42	7.49
NG-49	0.86	3.34	-	-	0.77	2.97	0.21	11.64
63005	-	0.05	0.65	1.92	-	1.52	5.25	1.25
NG-60	2.52	5.01	-	1.70	1.04	1.51	1.24	-
NG-11	0.32	7.02	-	-	0.83	2.94	0.74	3.10
NG-25	-	-	-	-	-	-	-	1.05
NG-12	-	-	-	-	4.20	3.22	0.17	3.33

Contd…

NG-17	5.08	6.30	-	-	-	-	-	4.20
NG-26	-	1.10	-	-	-	-	-	-
NG-59	-	3.89	-	-	-	-	-	-
NG-16	4.71	3.89	-	-	-	-	-	10.15
NG-58	4.34	6.85	-	-	-	2.29	-	-
NG-47	2.62	0.86	-	0.88	1.75	1.80	2.54	1.97
NG-27	2.42	2.61	-	-	1.30	1.18	8.76	3.55
NG-24	3.10	2.12	-	-	-	-	4.80	1.9
NG-46	4.20	4.27	-	-	-	0.66	-	8.71
NG-22	3.20	4.02	-	-	-	-	1.16	3.83
NG-15	4.42	4.43	-	-	-	-	-	7.55
HP 2 CBE 19	2.60	1.82	-	-	1.20	-	0.85	5.53
HP 2 CBE 1	4.31	2.15	1.14	-	1.09	1.20	5.02	6.99
NG-50	2.50	2.51	-	-	2.66	1.91	1.00	0.12
Average Water Level fluctuation	3.23	3.41	2.22	2.43	1.94	2.05	2.42	4.44
Area (ha)	1490.93	1490.93	1490.93	1490.93	1490.93	1490.93	1490.93	1490.93
Rainfall (mm)	619.52	586.62	470.13	435.86	360.78	371.42	411.06	740.24
Recharge Volume=(Area*Avg WL F*Sp.Yield)	12043.47	12701.30	8274.71	9062.11	7242.70	7632.29	9035.87	16542.63
Recharge (%)	13.0	14.5	11.8	13.9	13.4	13.7	14.7	14.9

Tail Region Wells	Water level Difference between Southwest monsoon and Northeast monsoon (in m)							
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
NG-32	0.29	1.64	-	1.51	0.97	2.11	0.11	5.30
NG-51	0.49	1.02	-	2.27	2.63	1.19	2.81	1.18
NG-43	6.50	-	-	-	-	-	-	1.66
NG-34	7.30	4.65	0.70	0.96	0.33	1.03	0.94	2.17
NG-45	1.80	5.05	4.19	5.98	-	-	3.24	5.00
NG-44	-	4.40	3.14	2.45	2.50	-	0.08	1.64
NG-41	1.20	3.05	0.45	1.20	-	4.01	2.70	4.36
NG-42	1.45	5.30	3.59	3.31	3.35	-	2.37	4.20
NG-37	0.93	1.06	1.42	1.87	1.66	1.50	1.69	0.40
Average Water Level fluctuation	3.72	3.27	2.25	2.44	1.91	1.97	1.74	2.88
Area(ha)	1016.61	1016.61	1016.61	1016.61	1016.61	1016.61	1016.61	1016.61
Rainfall (mm)	714.54	614.12	495.12	440.34	343.32	390.7	400.16	902.6
Recharge Volume=(Area*Avg. WL F*Sp.Yield)	9458.26	8313.98	5714.21	6210.87	4845.85	5001.73	4428.62	7316.78
Recharge (%)	13.0	13.3	11.3	13.8	13.8	12.5	10.8	7.9

*NG-open wells, *HP CBE – Bore wells

4. SUGGESTED PLAN OF ACTION FOR LOCALIZED RAINWATER HARVESTING BY FARMERS

4.1 Using abandoned/defunct wells on farmer holdings for rainwater harvesting

Tamil Nadu state has large number of abandoned open wells (about 1.6 lakhs) and their numbers is on the rise. The farmers may be encouraged to plan and execute structures on their farms to collect the rainwater, direct to the abandoned wells and thereby recharge the groundwater. This will help to harvest the rainwater in relevant areas besides utilizing the capital investments that have already been made by the farmers.

4.2 Spacing norms among wells (NABARD)

In Tamil Nadu, development of groundwater is taking place from time memorial for various uses without observing proper groundwater discipline. The groundwater development is mostly by private individuals, mainly for the agricultural purposes. As on date there is no legislation to regulate exploitation of groundwater for the sustainable development and equitable distribution. Based on the scientific studies conducted, NABARD has formulated the following spacing stipulation between two minor structures is shown in Table 4.

Table 4 Spacing norms between two wells by NABARD

Sl.No	Spacing between	Distances in metres
1.	Two dug wells	150
2.	Two shallow tube wells, two filter points, two dug cum bore wells	175
3.	Two medium tube wells	600
4.	Two deep tube wells, medium tube wells, and deep tube wells	600
5.	Shallow tube wells and medium tube wells	400
6.	Dug wells and shallow tube wells	175
7.	Dug wells and medium tube wells	375
8.	Dug wells and deep tube wells	375

4.3 Rehabilitation of village ponds through community effects

The village ponds are silted up by 3 ft every year and thereby storage capacities are reduced. Encroachment is also one of the main reasons for reduction of storage capacity of ponds. Desilting of ponds once in 3 years may be carried out through village community organizations and it is the best way to increase the storage capacity of village ponds. It is very useful for recharging the groundwater of community wells.

4.4 Improving the storage capacity of tanks through productive desiltation

One of the major factors responsible for the declining performance of the tanks is the siltation that reduces the storage capacity of the tanks, which is relevant atleast in normal and above normal rainfall years, though with lesser frequencies. Some of the tanks have been completely silted and could no more serve their intended purpose. Since the tanks get the full storage 2 in 10 years, partial desilting can be attempted periodically. Restoring the original dead storage level (10 per cent of full storage) will be therefore sufficient. In this context, a plan may be drawn to devise a scheme whereby the farmers in tank intensive areas will be involved in using the silt paying for the delivery on to their farms.

4.5 Water saving in agriculture

Drip irrigation method is adopted for wider spacing crops like sugarcane, banana, cotton, tapioca, mulberry and vegetables. In this method, 40-70 per cent of water is saved than surface irrigation methods. Therefore, irrigated area can be doubled. This is a best method under water scarcity conditions.

Sprinkler irrigation method is adopted for crops like cotton, groundnut, green gram, lab-lab and soybean. In this method, 15-50 per cent of water is saved than conventional irrigation methods depending on the type of crops.

5. CONCLUSION

The entire Noyyal basin is in the rain shadow region of southwest monsoons and forms part of the semi-arid tract of the country. So the main resource will be rainfall and recharge to groundwater mainly depends upon the northeast monsoon period between October-December. Nearly 50% of the annual rainfall is received during the northeast monsoon rains. It is recommended to recharge the groundwater artificially by digging percolation ponds wherever feasible in the basin.

An attempt has been made to estimate groundwater recharge in the Noyyal river basin. The basin was divided into Upper Noyyal, Avanashi and Lower Noyyal sub-basins and recharge component was estimated by using water level fluctuation method. The groundwater recharge has been estimated to be 8 to 15 % throughout the Noyyal river basin. This recharge contribution is not sufficient for sustainability of groundwater resources in the basin. Developing effective strategies for responding to groundwater overdraft is challenging, due to the variety of problems, the scale of problems and responses and the pace of social and economic change. Standardized approaches are therefore inappropriate. To be effective, responses need to be closely tailored to local conditions and capable of adapting to changing conditions. The interactive process should be guided by broad-based and participatory working groups.

The efforts of state and central agencies to provide an adequate water supply to rural people, irrigation and industries have failed miserably due to non-availability of reliable sources of water. Rainwater harvesting has become the order of the day in as much as every drop of water counts for not only the survival of human being but also for the stabilization of agricultural production. In situ water harvesting structures like a farm pond or an earthen embankment across a gully help to stabilize agricultural production during non-rainy season by the way of supplemental irrigation. Water harvesting structure such as a percolation pond not only serves the purpose of supplemental irrigation but also helps to recharge the groundwater status benefiting a group of farmers in the vicinity. However the effectiveness of rainwater harvesting lies primarily on the method to induce runoff and the method to store the harvested runoff over a sufficiently longer period with minimum losses. Rainwater harvesting should be an integral part of any watershed development programme and farm development programme in order to conserve both soil and water.

6. REFERENCES

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