

Development of Groundwater Irrigation in Telangana State: Challenges, Management and Way Forward

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ABSTRACT

Groundwater based irrigation, which was started in India as early as “*Indus Civilizations*” got impetus during 3rd five-year plan. In India, at present 78 m ha of irrigation potential is created and 80 percent is utilized. One of the World’s highest user of groundwater is India with 63 percent of its dynamic groundwater resources. Similarly, Telangana State is also utilizing the dynamic groundwater resources up to 65 percent. Groundwater a reliable source of irrigation with high yields and brings equity among its users as ~99 % of structures are owned by individuals. In the state, well irrigation increased from ~0.46 lakh ha from 1875 to 23.35 lakh ha during 2017-18 and well density increased to ~13 wells/km² leading to decrease in irrigation potential under each well to < 1 ha. As a result of it many challenges like water logging & salinity in canal command areas, over-exploitation leading to de-saturation of shallow aquifers, underutilization in north eastern part, groundwater pollution (both geogenic and anthropogenic) and sustainability, etc have cropped up. The management steps taken up in water sector like water transfer through KLIP, providing protected water supply through Mission Bhagiratha, de-siltation through Mission Kakatiya, forest rejuvenation through Haritha Haram, construction of various ARS, modernization of canals, conjunctive use of surface and groundwater, user centred aquifer level groundwater management, tank management, IEC activities etc brought positive changes in water availability in the state more particularly surface water. In order to sustain these efforts, formation of WUA at watershed/village level for agricultural planning, change in cropping pattern from highly intensive paddy to ID crops more particularly from non-command areas, conjunctive use of water, warabandhi (on/off) method of releasing irrigation water, developing intercepting drains, soil treatment, declaring crop holidays, separate electric grids for agriculture and domestic supply, legally separating water and land rights and strict implementation of regulatory measures. The other measures suggested are policy interventions that involve regulatory mechanisms and linking village-based institutions to government departments that manage groundwater etc.

INTRODUCTION

“*Green Revolution*” in early sixties led to foundation for groundwater development in India and presently it is the backbone of India’s economy as ~ 62 % of irrigation, 85 % drinking water needs from rural area and 50 % from urban area is met through groundwater (Siebert, S. et al., 2010; Gandhi & Bhamoriya, 2011; Ramachandra, G., 2017; Saha, D. et al., 2018 and CGWB, 2019). In India, during 1950s groundwater was developed through shallow dug wells (< 30 feet depth), in 1970s, through dug cum bore wells (100 feet depth) and after early 80s, through deep bore/tube wells (300-400 feet) leading to more exploitation (Singh, D., 2003 and Jeet, I., 2005). During 5th Minor Irrigation (MI) Census, irrigation potential created was 78.9

million hectares (m ha) through groundwater & 10.6 m ha through surface water schemes with 80 % & 74 % utilization respectively (Govt of India, 2017). Presently at 253 km³/year, our country is one of the highest users of groundwater in the World, utilizing ~28 % of all groundwater extracted globally, ahead of the US and China (Shah, et al., 2007; Giordano, M., 2009 & Saha and Ray, 2018). The annual per capita water availability has come down to 1381 m³/year (as per 2018 population) from 5177 m³/year (during 1951) and further likely reduced to 1140 m³/year in the year 2051. Country with per capita availability of < 1700 m³/year is said to be under water stress and thus, India is under water stress category (Sharad, J., 2019; CGWB, 2019). Among 18 major basins of India, the rivers Ganga, Godavari and Krishna holds ~172, 40.65 & 26.41 billion cubic meter (bcm) of replenishable groundwater resources respectively (i.e., 39.6 %, 9.4 % and 6.1 % of India’s total resources) (Gandhi and Bhamoriya, 2011).

Though groundwater-based irrigation started during “*Indus civilization*” in western parts of India, but actual development started after the Famine Commission of 1880, which recommended “*taccavi loans*” for construction of wells. In 1883, the Govt. of India enacted the Land Improvement Loans Act, enabling it to advance money for specific land-improvement purpose (Govt. of India, 1972) and this was followed by Agriculture Loan Act, 1884 and these measures produced moderate impact on irrigation development. However, by 1900, groundwater contributed 35 % to its total irrigation (Govt. of India, 1972). Establishment of 1st Irrigation Commission (1901) has given importance to development of private irrigation works, however, the Royal Commission (appointed in 1928 on agriculture) did not find significant expansion in well irrigation as irrigated areas increased very marginally from 4.68 m ha during 1902-03 to 4.73 m ha in 1925-26 with lots of fluctuation. Decrease in flows in Ganga canal during 1931-34 gave fillip to tube well irrigation in eastern parts of Uttar Pradesh (UP), encouraged by this, Punjab started developing groundwater in Western Yamuna Canal areas and thus in 1940s, the area increased to 5.57 m ha. The “*Grow More Food Campaign*” launched during 1943 gave new stimulus in states like UP, Punjab, Bihar and Gujrat. During 1910-1950, growth in irrigation through wells was just ~0.54 %. At the time of Independence, the share of wells in irrigation was ~23 % and got impetus during the 3rd Plan, where ~600 thousand wells were added. During 1988-89, Govt. of India introduced “*Million Wells Schemes*” (MWS) with main aim to provide free of cost open well irrigation to poor, small and marginal farmers belonging to SC/ST and freed bonded labours where ~ 13.1 lakh wells were added with an expenditure of ~4977 crores (Mahipal, 1996; Shodhganga.inflibnet.ac.in) and this was followed by “*Ganga Kalyan Yojana*” (GKY) launched during 1996-97 with focus on small and marginal farmers, which couldn’t give much success due to operational problems and added ~7700 beneficiaries only (Shodhganga.inflibnet.ac.in). According to Moench (2003) number of shallow & medium wells (< 70 m depth) doubled every 3.7 years

between 1951 to 1991 and at the same time it was noticed that there was a decline in dug wells by 4.5 % and increase in deep bore wells/tube wells (> 70 m depth) by 80 % between 4th (2006-07) and 5th (2013-14) MI census (Govt. of India, 2017). Studies have revealed that yields from groundwater-based irrigation are 30-50 % higher than surface water irrigation (Dhawan, 1995) and groundwater irrigation brings equity as ~98.7 % of structures are owned by individual farmers and rest by public (Govt. of India, 2017).

The ever-increasing demand for groundwater triggered by unplanned and uneven groundwater development leading to over exploitation in certain pockets, de-saturation of shallow aquifers, groundwater pollution and underutilization in command areas of the major projects. As per latest dynamic groundwater resource estimates (2016-2017), annual groundwater recharge is 432 billion cubic meter (bcm), annual extractable groundwater resource is 393 bcm, annual groundwater extraction for all uses is 249 bcm of which 89 % (221 bcm) is used for irrigation and 27 bcm for Domestic & Industrial (11 %) with average stage of groundwater extraction of 63 % (CGWB, 2019). The stage of groundwater extraction is very high in the states of Delhi, Haryana, Punjab and Rajasthan, where it is > 100 %, in Himachal Pradesh, Tamil Nadu, Uttar Pradesh and UT's of Chandigarh and Puducherry, it is between 70-100 %, in rest of the states/UT's, it is < 70 % including Telangana where it is ~65 %. Out of total 6881 assessment units (Blocks/Mandals/Talukas/Firkas) in the country, 1186 units (17 %) have been categorized as 'Over-Exploited' (extraction is > 100 % of annual recharge), 313 units (5 %) are 'Critical', (extraction between 90-100 %), 972 as 'semi critical' units (14 %), (extraction between 70-90 %) and remaining 4310 units (63 %) as 'Safe' (< 70 % extraction). Apart from these, 100 assessment units, have been categorized, as 'Saline' where groundwater in phreatic aquifers is brackish or saline in nature (CGWB, 2019).

Topography and rainfall pattern in Telangana state, made tank irrigation as an ideal type of irrigation along with knowledge and technology and till the decline and end of Kakatiya dynasty, construction of tanks was a common feature and many of the age old tanks like Ramappa, Pakhala, Laknavaram, Bayyaram etc. are still functioning. The projects like Kadam, Nizamsagar, Mir Alam, Hussain Sagar, Osmansagar, Himayatsagar, Palem, Pocharam and Ghanapuram etc are some of the important contributions by Nizam rulers (Pingale, G., 2011). The real momentum in canal irrigation came after independence when big dams like Nagarjuna Sagar, Sriram Sagar, Priyadarshini Jurala project were undertaken during various 5-year plans. The present Government has brought revolution in water sector by re-engineering of many projects like KLIP, PRLIS, Sita Rama, DLI etc.

ABOUT TELANGANA STATE

Telangana state having ~1.12 lakh km² area lays between 15°50' and 19°55' north latitude and 77°14' and 81°19' east longitude and physiographically, broadly divided into the 'Gondwana Graben' and the 'Deccan Plateau' (GSI, 2018) (Fig.1). Geographically, the state is in a semi-arid zone having predominant hot and dry climate and drained mainly by two major rivers, the Godavari and the Krishna and their tributaries (SGWD & CGWB, 2019). The major crops grown in the state are paddy (48 %), cotton (37 %), maize (10 %) and pulses (9 %) (DES, 2017).

Rainfall (Precipitation)

The state receives an annual rainfall from ~730 mm (Mahabubnagar in south) to ~1120 mm (Adilabad in north) with average rainfall of 942 mm in 50 days. ~80 % of rainfall occurs during south-west monsoon months (June-September) and is the main source of recharge to groundwater, e.g., during the year 2004-05, the state received deficit rainfall (-30 %) and deep-water levels were observed

(14 m bgl) and subsequent year it received excess rainfall (+ 19 %) where a rise of 2.1 m was observed. The rainfall data along with rainy days from 6 rain gauge station located at different rainfall zones analysed for the period 1988-89 to 2018-19. Results shows, 3 stations (Adilabad-north, Midjil-south) and Siddipet-central are showing decrease in rainy days @ 0.05, 0.16 and 0.29 days/year respectively, Sangareddy (west) and Secunderabad (Hyderabad) have shown rise in rainy days @ 0.05 & 0.045 days/year and Bhadrachalam (east) have shown neither rise nor fall in rainy days (Figs.2a-f). Thus, the analysis indicates that there is a negligible variation in number of rainy days even in different rainfall zones of the state.

Hydrogeological Setup

~85 % of the state area is covered by hard rock aquifers namely banded gneissic complex (BGC), basalt, granite, laterite, quartzite and remaining ~15 % by sedimentary rocks (sandstone, limestone and shale etc) and alluvial formations (SGWD, 2019a) (Fig.1). The hard rock aquifers (BGC and granite) are essentially massive and lacks primary porosity and secondary porosity is developed due to weathering and fracturing and thus forms the productive aquifers in the state. In these rocks, weathering varies from 10-20 m depth and occasionally up to 40 m. Studies have revealed that ~95 % fractures occur within 100 m depths having 75-150 litre/minutes (lpm) yields (CGWB, 2010; Sudarshan, et al., 2008 and Madhure, et al., 2016). The hydraulic properties like transmissivity (T), specific yields (Sy) and storativity (S) varies from 1-630 m²/day (with general 5-80 m²/day), from 0.1-4 % and from 0.00001-0.001 respectively. The boreholes drilled down to 40 to 120 m in basalt yielded 60-180 lpm discharge, having transmissivity in the range of <10-200 m²/day and 1-2 % specific yield. Gondwana rocks (soft rocks) which are deep seated (north-eastern part) forms productive aquifers between 25 and 297 m depth having high yields between 250 and 2000 lpm and T between 20 and 700 m²/day respectively. Filter point wells (5-15 m depth) are more common in river alluviums, having 150-1000 lpm of discharge.

The average annual groundwater levels (wl) during last 34 years is 9.32 m below ground level (m bgl). These water levels display three distinct patterns, 1st up to 2004-05 where shallow water levels

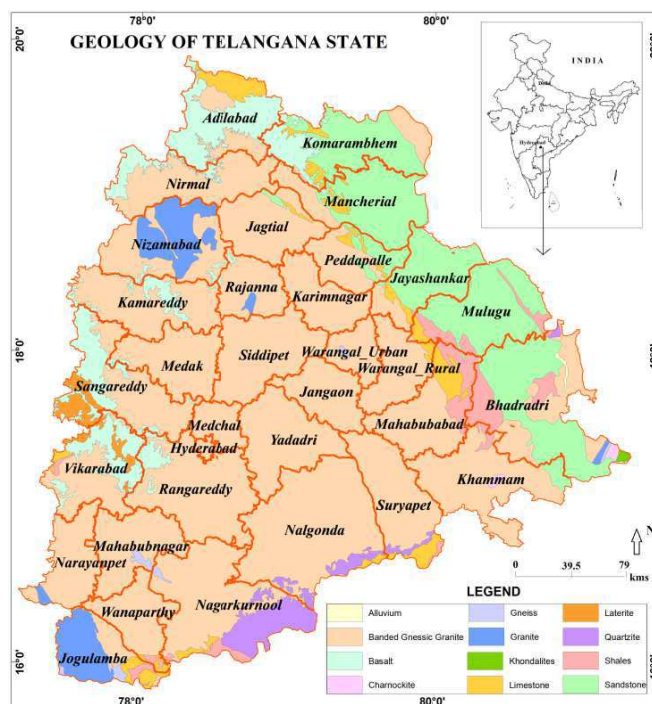


Fig.1. Geology of Telangana State.

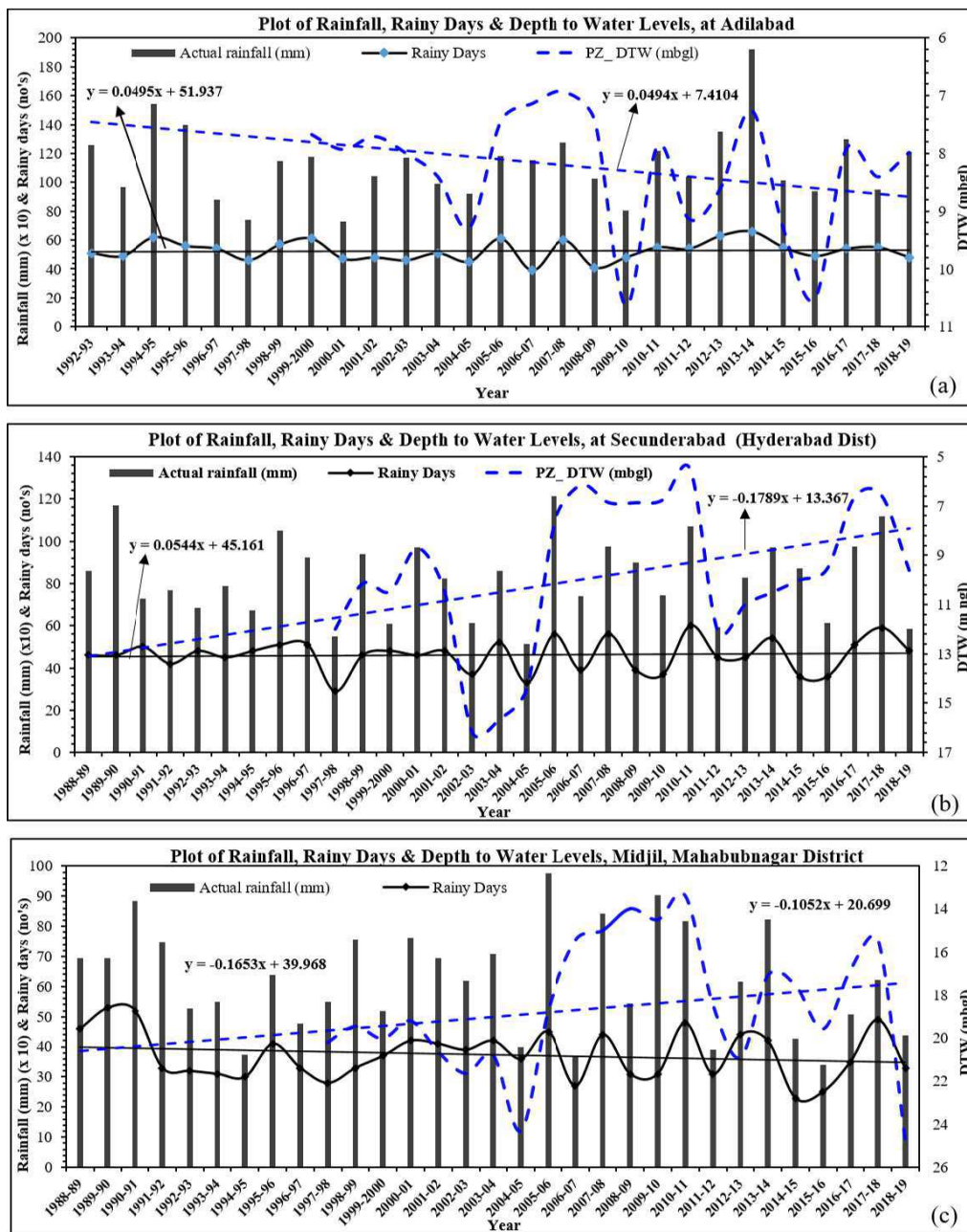


Fig.2. Plot of Rainfall, Rainy Days & Depth to Groundwater levels located at different rainfall zones.

(average wl :8.6 m bgl) showing falling trends @0.4 meter/year (m/yr) were observed, 2nd between 2005-06 and 2013-14 having moderate wls (average wl:10.1m bgl) and showing rising trends @ 0.08 m/yr and 3rd between 2014-15 & 2018-19 (after formation of state), with deep water levels (average: 11.50 m bgl) and rising trends @ 0.11 m/yr (Figs.3a-c).

But, these water levels are not evenly distributed as observed during pre and post-monsoon season of 2019, where, shallow water levels (< 10 m bgl) occur in northern and eastern part, deeper (> 20 m bgl) in central and western parts and moderate (10-20 m bgl) in rest of the areas (Figure 4a-b). In order to see variations in water levels, 6 hydrograph stations having different hydrogeological setting and rainfall pattern have been studied (located at north, west, south, east and central region). Two stations viz., Adilabad in the north and Sangareddy in west are showing decline in water level trends @ 0.05 and 0.14 m/year respectively, 3 stations, Midjil in south and Secunderabad (Hyderabad) & Siddipet from central part are showing rising trends @ 0.10, 0.18 & 0.35 m/year respectively and

Bhadrachalam station in east is showing neither rise nor fall in water levels. The fall in water level trends is mainly due to applied irrigation through groundwater and rise is due to increase in rainfall along with rainy days and various artificial recharge measures taken up by the state.

DYNAMIC GROUNDWATER RESOURCES (as on March 2017)

The National Water Policy of India (2012) enunciates periodic assessment of groundwater resources for quantification, sustainable development and management (Govt of India, 2012). In the state, groundwater resource estimations are carried out jointly by State Ground Water Department and Central Ground Water Board (Govt of India) and the earlier estimates carried out for the year 2002-03, 2004-05, 2006-07, 2008-09, 2010-11 and 2012-13 (SGWD and CGWB, 2019). The groundwater utilisation has been increasing continuously from 51 % in 2006-07 to 65 % in 2016-17, whereas not much changes are observed in annual replenishable groundwater recharges (SGWD and CGWB, 2019). This is mainly due to bringing additional area

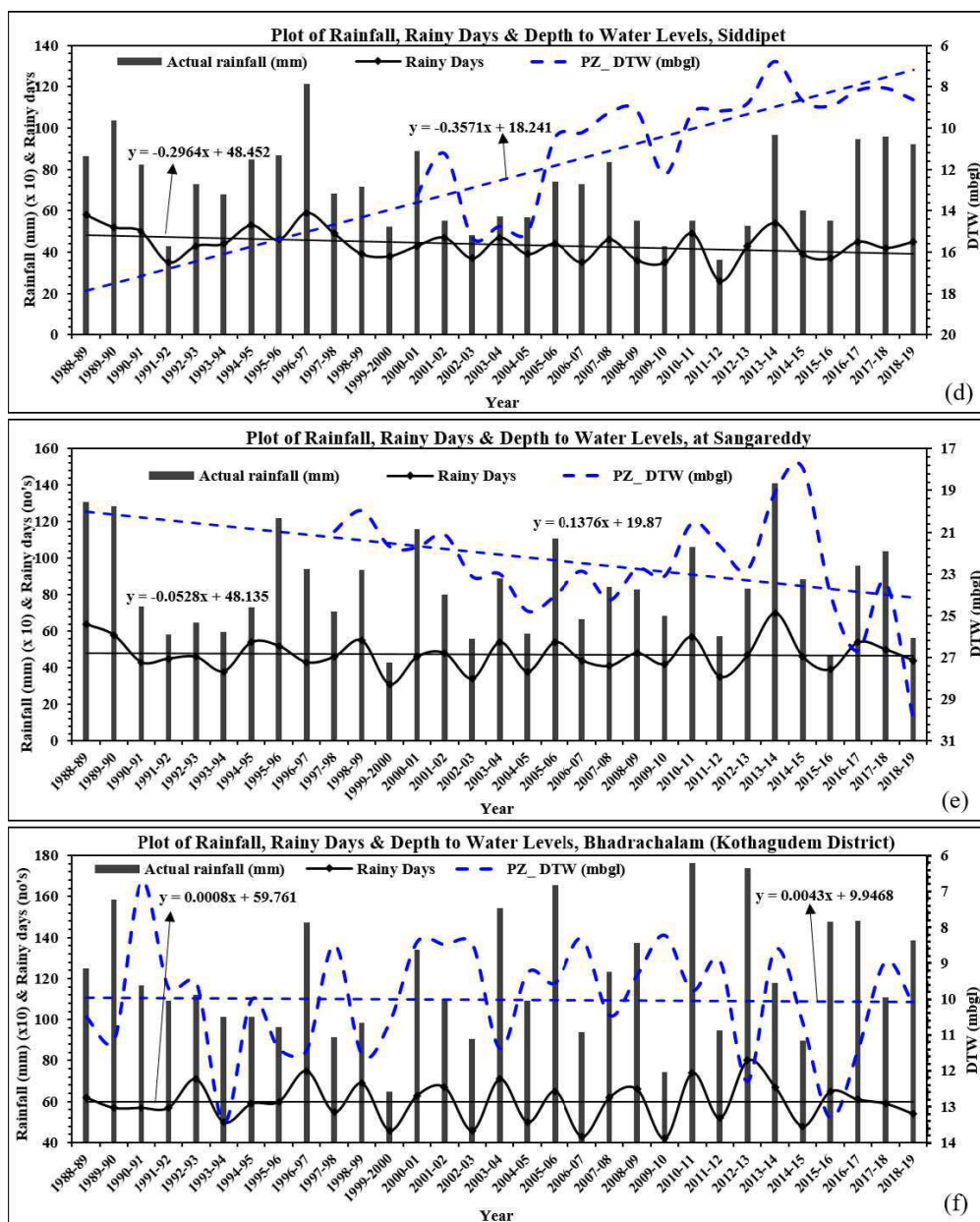


Fig.2. Contd.... Plot of Rainfall, Rainy Days & Depth to Groundwater levels located at different rainfall zones.

under groundwater irrigation (Gross area under groundwater irrigation almost doubled from 2002-03 to 2016-17 i.e., from 12.55 lakh ha during 2002-03 to 22.43 lakh ha during 2016-17) (Table 1). The other reasons are reduction in well yields from $> 150 \text{ m}^3/\text{day}$ to $< 10 \text{ m}^3/\text{day}$ during 1st MI census to $> 13 \text{ wells}/\text{km}^2$ during 5th MI census.

As per the latest resource estimation (2016-17), net annual groundwater availability is 12367 million cubic meter (mcm), the current annual groundwater extraction for all uses is 8094 mcm (7094 mcm for irrigation and 1001 mcm for domestic and industrial use) and the annual extractable groundwater resource for future irrigation needs is 4325 mcm (Table 2) (SGWD and CGWB, 2019). District wise stage of groundwater extraction varies from 23 % to 94 % (State average: 65 %) (Excluding Hyderabad where it is 340 %). It is noticed that out of 31 districts, 16 are categorized as high usage ($> 70 \%$ usage), 7 as moderate usage (60-70 % usage) and 8 as low usage districts ($< 60 \%$ usage).

STATUS OF GROUNDWATER DEVELOPMENT

Groundwater based irrigation in the State is in existence for a long time and it was an assured source of irrigation during monsoon failure

years of late 19th century. Development of drilling technologies in hard rock areas in early 1980's, brought more area under groundwater irrigation, overtaking tank and canal irrigations (Pingale, G., 2011). Most of well irrigation in state is in the hands of individual farmers who have invested their capital in digging of dug wells, dug-cum-bore wells or construction of bore/tube wells (bw/tw) fitting of pump sets and laying pipelines to their fields and the only concession given to them is free power since 2004 by earlier Govt. in 2 spells in a day (Pingale, G., 2011). From 01/01/2018, the present Govt. is giving free quality power to agriculture pump sets for 24 hours (PD, Govt. of Telangana, 2018). Presently there are ~24.2 lakh power connections to pump sets in the state (The Hindu, 20th March 2020. COVID-19: bane for many boons for some), extracting ~8084 million cubic meter (mcm) of groundwater for irrigation; drinking and industrial use (SGWD and CGWB, 2019).

At the time of 1st minor irrigation (MI) census (1986-87), only 0.21 lakh bore wells/tube wells (bw/tw) were existed in the state followed by 1.23 lakh during 2nd census (1993-94) and their numbers increased to 4.28 lakh during 3rd census (2000-01). During 5th MI census, there are 9.51 lakh bw/tw (7 % of country) and 5.05 lakh dug

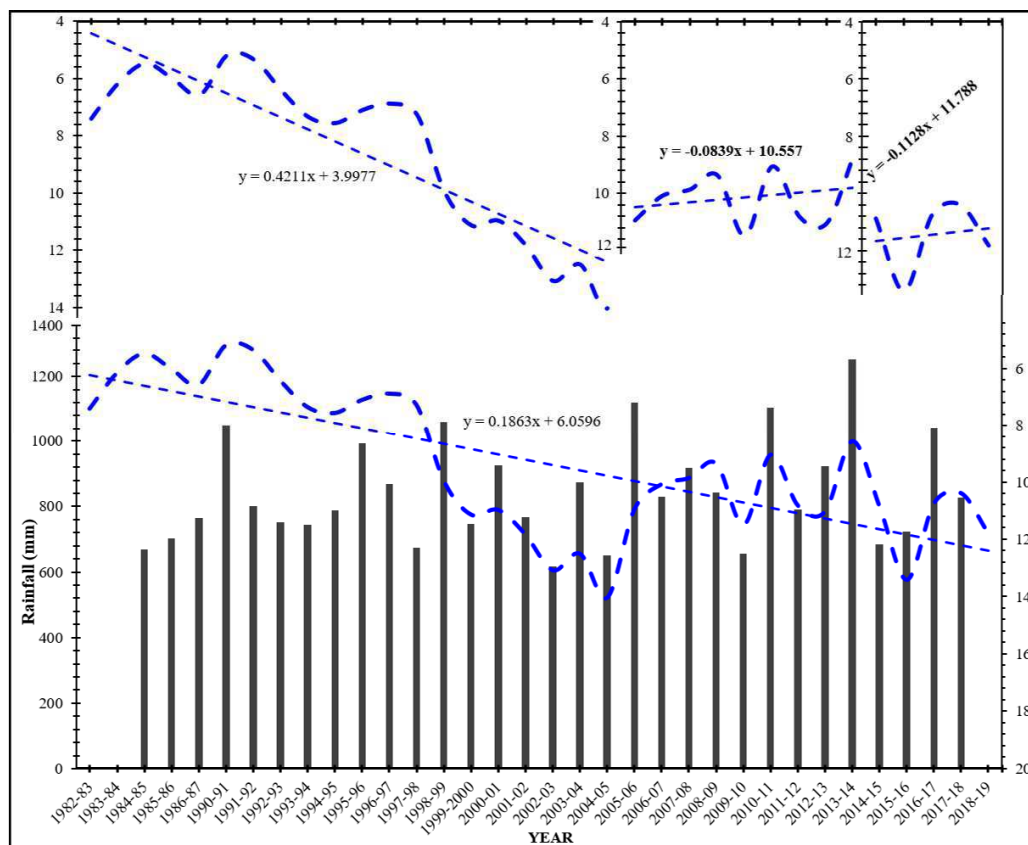


Fig.3. Average groundwater level trends and average annual rainfall (mm) in the State.

wells (dw) in the state with a combine investment of ~ 9120 crores (in structures) (Govt of India, 2017). The district wise number of dug wells/bore wells/tube wells (DW/BW/TW) existing in the state during 1 to 5th census is given in Figs.5a-b and as per 5th MI census data, ~ 57 % of area based on groundwater is grown under kharif crops, 41 % under rabi crops and 2 % under perennial crops (Govt of India, 2017). In Telangana, well irrigation increased substantially from 0.46 lakh ha in 1875 (50 % to total irrigation) and reached to its maximum of 23.35 lakh ha in 2017-18 (Fig.6) (Pingale, G, 2011;

DES, 2017; NABARD, 2020). More growth was achieved after beginning of rural electrification programme under Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) during 2006-07 under which ~26.59 lakh connections were given in the combine state of Andhra Pradesh (as on 31/10/2011) (<https://pib.gov.in/newsite/PrintRelease.aspx?relid=77617>). Among 3 regions of erstwhile Andhra Pradesh, in Telangana region more growth was observed (56 % of total well irrigation in combine state is contributed by Telangana farmers) (Pingale, G, 2011 and Pradeepta Kumar, S. 2015). Canal irrigation

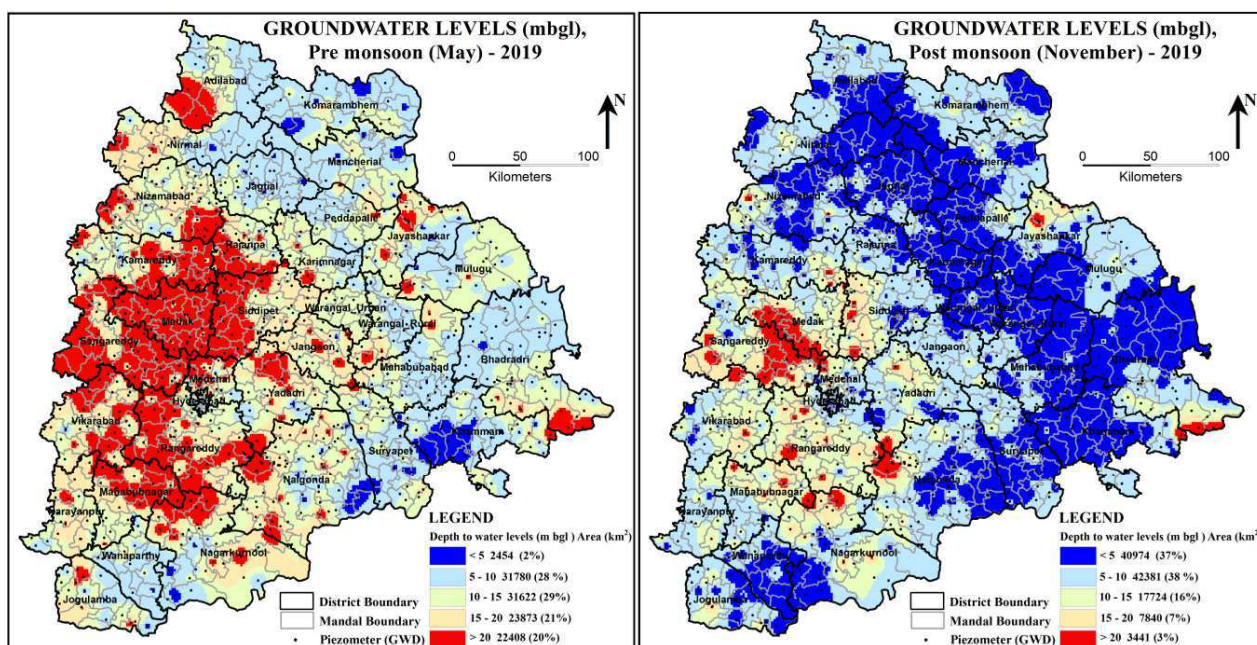


Fig.4. Areal distribution of depth to water levels (m bgl) during pre and post-monsoon season-2019.

Table 1. Categorisation of Watersheds/Mandals during various Groundwater Estimations Years

Category	Unit	2002-03	2004-05	2006-07	2008-09	2010-11	2012-13	2016-17
Gross irrigated area through Groundwater	(lakh Ha)	12.55	13.29	13.33	19.81	21.1	22.07	22.43
Over-exploited (nos.)	Watersheds	50	86	64	40	37	28	29
	Mandals	98	102	74	38	42	46	70
Critical (nos.)	Watersheds	29	37	27	16	8	29	59
	Mandals	46	41	32	14	8	12	67
Semi-Critical (nos.)	Watersheds	108	104	101	51	65	92	165
	Mandals	93	92	81	45	55	74	169
Safe (nos.)	Watersheds	278	267	304	387	384	335	249
	Mandals	209	211	260	349	343	311	278

reached its peak during 1990-92 and then declined and later recovered. Tank irrigation, on the other hand, declined drastically ever since 1956-57 when it reached its peak of 5.30 lakh ha. According to the figures of Dept. of Economic and Statistics, Govt. of Telangana (2017), the irrigation intensity is highest in Nizamabad district (1.57) and lowest in Mahabubnagar district (1.14) with average of 1.25 (Dept. of Agriculture, Govt. of Telangana, Agriculture Action Plan, 2019-24) and according to estimates the likely food grain production is 13.1 million tonnes (MT) during the year 2019-20 (PD, 2020; <https://timesofindia.indiatimes.com/city/hyderabad/ts-crop-production-in-2019-20-highest-since-state-formation/articleshow/74050910.cms>).

In Telangana, gradual increase in well density along with decreasing well yields (more particularly hard rocks) are observed from 5 wells/km² with > 150 m³/day during 1st MI census to >13 wells/km² & < 10 m³/day during 5th MI census respectively. It also observed that irrigation potential through each well decreased from 1-2 ha to < 1.2 ha and ~11 % of wells are not functioning, due to non-availability of water at shallower depths, against ~20 % at all India level (Govt of India, 2017). Presently, ~57 % of states population is dependent on some form or other on farm activity for their livelihood and agriculture contributes ~9.8 % to its Gross Domestic Products (GDP) (SGWD and CGWB, 2019). Studies at national level have shown, 30-50 %

Table 2. Dynamic Groundwater Resources of Telangana, 2017 (in mcm).

S. No.	District	Net available extractable groundwater resources	Net groundwater extraction	Allocated for industrial & domestic use	Net annual groundwater availability for future irrigation use	Stage of groundwater extraction(%)	Category
1	Adilabad	26271	16635	37.6	91.5	63	Safe
2	Bhadradi_Kothagudem	74058	19934	43.3	534.1	27	Safe
3	Hyderabad	4148	14164	0.0	0.0	341	OE
4	Jagityal	42374	31224	55.3	134.3	74	SC
5	Jangaon	30095	27793	20.5	25.9	92	Critical
6	Jayashankar Bupalapally	27835	17698	15.9	101.4	64	safe
7	Jogulamba_Gadwal	18787	8669	12.0	94.4	46	Safe
8	Kamareddy	46636	35993	39.1	90.3	77	SC
9	Karimnagar	33161	24965	36.7	71.7	75	SC
10	Khammam	58886	38115	50.2	222.9	65	Safe
11	Komurambheem_Asifabad	32352	7337	21.5	248.8	23	Safe
12	Mahabubabad	40081	28886	33.9	111.5	72	SC
13	Mahabubnagar	27464	20349	24.6	71.2	74	SC
14	Mancherial	53581	21982	25.6	306.7	41	Safe
15	Medak	38571	24608	27.9	120.9	64	Safe
16	Medchal_Malkajgiri	7753	7286	49.7	8.8	94	Critical
17	Mulugu	31197	13323	10.9	178.7	43	Safe
18	Nagarkurnool	48291	31825	47.4	161.4	66	Safe
19	Nalgonda	75324	55920	76.4	203.4	74	SC
20	Narayanpet	19843	11968	16.6	78.8	60	Safe
21	Nirmal	50469	18718	22.7	315.2	37	Safe
22	Nizamabad	74891	56496	55.5	189.8	75	SC
23	Peddapalli	39949	20864	28.6	180.4	52	Safe
24	Rajanna_Sircilla	24324	19998	18.8	45.8	82	SC
25	Rangareddy	37988	30881	61.8	68.9	81	SC
26	Sangareddy	38071	26876	59.5	101.0	71	SC
27	Siddipet	46510	43608	44.2	34.4	94	Critical
28	Suryapet	49896	30569	43.4	177.9	61	Safe
29	Vikarabad	33069	18624	36.5	137.9	56	Safe
30	Wanaparthy	17200	11536	19.8	52.6	67	Safe
31	Warangal_Rural	32018	27584	27.6	51.9	86	SC
32	Warangal_Urban	20167	18340	22.8	31.9	91	Critical
33	Yadadri_Bhuvanagiri	35450	26579	37.1	80.0	75	SC
		12367	8093	1123	4325	65	

(Note: SC-Semi-critical).

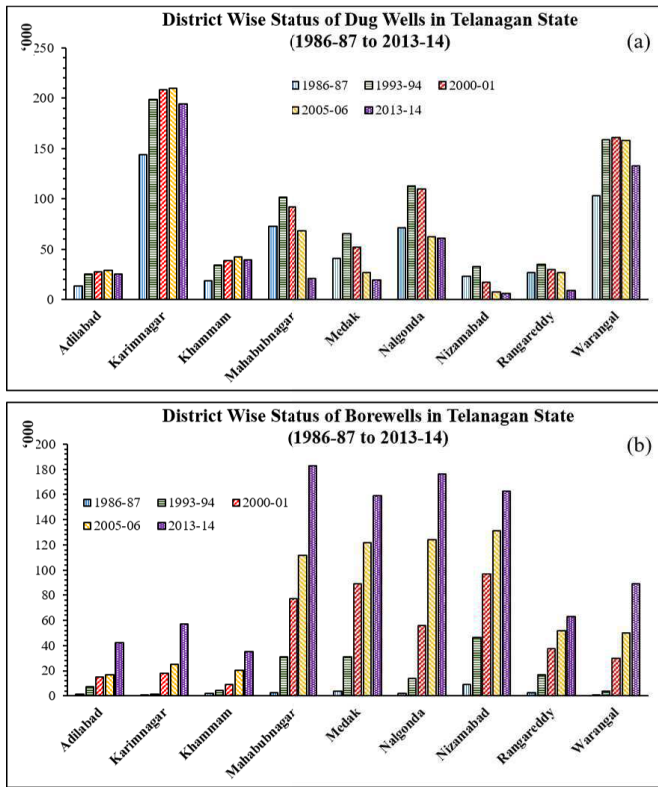


Fig.5. District wise status of dug wells/bore wells, in Telangana State (1986-87 to 2013-14).

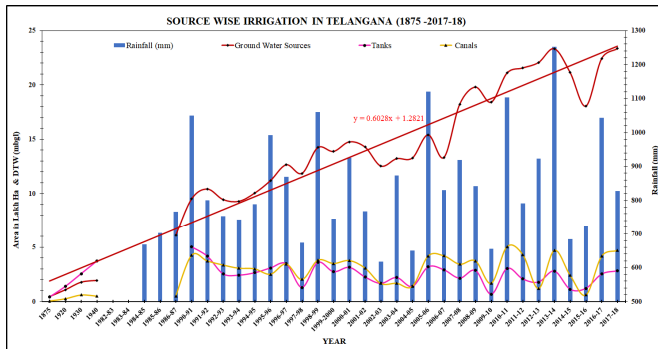


Fig.6. Source wise irrigation in Telangana State.

higher crop yields through groundwater (from well owned by farmer) compared to canal irrigation because it delivered precisely when required and its judicious use by farmers (Shah, et al., 2000; Dhawan, 1995; FAO, 2011, Foster, et al., 2015).

After the formation of Telangana State, the present Government has brought revolution in water sector like re-engineering of Pranahita Chevella Sujala Shrivanthi Projects (PCSSP) into Dr. B.R. Ambedkar Pranahita Project and Kaleshwaram Lift Irrigation Project (KLIP). Sitarama Project, Palamuru-Rangareddy Lift Irrigation Scheme (PRLIS), Bhakta Ramdasu Project (BRP), Dindi lift irrigation (DLI) etc. The completed, under completion and contemplated irrigation projects (major and medium) in the state are depicted in Fig.7. Besides, rejuvenation of minor irrigation tanks under Mission Kakatiya, Mission Bhagiratha Project is implemented to ensure safe and sustainable piped drinking water supply, Haritha Haram Project to rejuvenate the degraded forest cover, soil conservation & moisture retention, construction of 1200 check dams on 4th order and above streams, construction of > 200 recharge shafts in existing water bodies in over-exploited watersheds etc are also taken up by the Government of Telangana.

CHALLENGES AND ITS MANAGEMENT

In the state, groundwater resources are not extracted evenly, and it is mainly concentrated in central part. There are areas in the north-eastern part of the state where additional development of groundwater resources is possible (SGWD & CGWB, 2019). This unplanned and uneven development of groundwater is leading to many challenges like water logging (over abundance) and salinity in few pockets, over-exploitation leading to de-saturation of shallow aquifers in central and western part of state, groundwater pollution due to fluoride (geogenic) and anthropogenic due to nitrate and sustainability etc.

Water Logging (over abundance): Water logging is caused due to saturation of soil pores by water in crop root zones and this is mainly due to rise in sub-soil water table (Govt. of India, 1972 and CGWB, 2019). Other causes are periodic flooding, overflow by runoff, over irrigation, artesian conditions and impeded sub-surface drainage. These conditions affect growth and yield of crops and in course of time such lands become saline and alkaline and ultimately become unfit for cultivation. In the State water logging conditions are mainly observed mainly in canal command areas of Nagarjuna Sagar Left Bank Canal (NSLC), Sri Ram Sagar Project (SRSP) canal command and Rajoli Banda canal command area of Ieeza and Alampur mandal of Jogulamba Gadwal District. During post-monsoon season of 2019, out of 5242 km² area from NSLC and 9343 km² from SRSP, water logging (< 2 m bgl) and prone to water logging conditions (2-3 m bgl) are observed in ~1163 km² (22 %) and 2682 km² (28 %) area respectively, whereas, during May-2019 (pre-monsoon season) 19 % and < 1 % area was occupied. Based on 10 years average water level data (2010-19), it is observed that permanent logging and prone to water logging conditions affecting crop growth and yields are observed in 2 % and 52 % of command area of NSLC during post monsoon season. Whereas, in SRSP and Rajoli Bandha command area only prone to water logging conditions are observed in 7 % and 8 % of command area respectively. Whereas, during pre-monsoon season prone to water logging conditions are observed in 2 % of NSLC command area only.

Salinity: The inland or secondary salinity (EC > 3000 μ Siem/cm at 25 °C) is observed in 1 % of State area during both pre- as well as post-monsoon seasons of 2019 mostly in parts of Rajoli Banda (Jogulamba Gadwal District) and NSLC area from Nalgonda, Suryapet & Khammam and eastern parts from Yadadri districts. Prone for salinity (where EC between 2250-3000 μ Siem/cm at 25 °C) occupies 3 % and 5 % of area during pre- & post monsoon seasons of the same period (SGWB, 2019b).

Over utilization: In the state ~16 % villages (1745 nos.), 29 watersheds (out of 502 watersheds) and 70 mandals (out of 589) and entire Hyderabad district falls under “over-exploited” category (extraction is > 100 % to its annual recharge in the dynamic zone) mainly covering central and western part of state (SGWD & CGWB, 2019) (Figs.8a-b). The over-exploitation of groundwater resources is leading to decline in groundwater levels in the state from 1982-83 to 2018-19 (@ 0.18 m/year) (Figs.3a-c). In the last decade (2010-19), ~10 % of wells both during pre and post-monsoon season are showing fall in water levels during 2019 as compared to average of last 10 years, more particularly in central and western part of state and this is leading to de-saturation of shallow aquifer (wls more than 20 m bgl) in ~6 % and ~1 % of state area during pre and post-monsoon season respectively (more particularly in central part of Medak, southern part of Siddipet and Rangareddy and northern part of Nagarkurnool districts).

Under Utilization: Out of 31 districts (now 33 districts), low

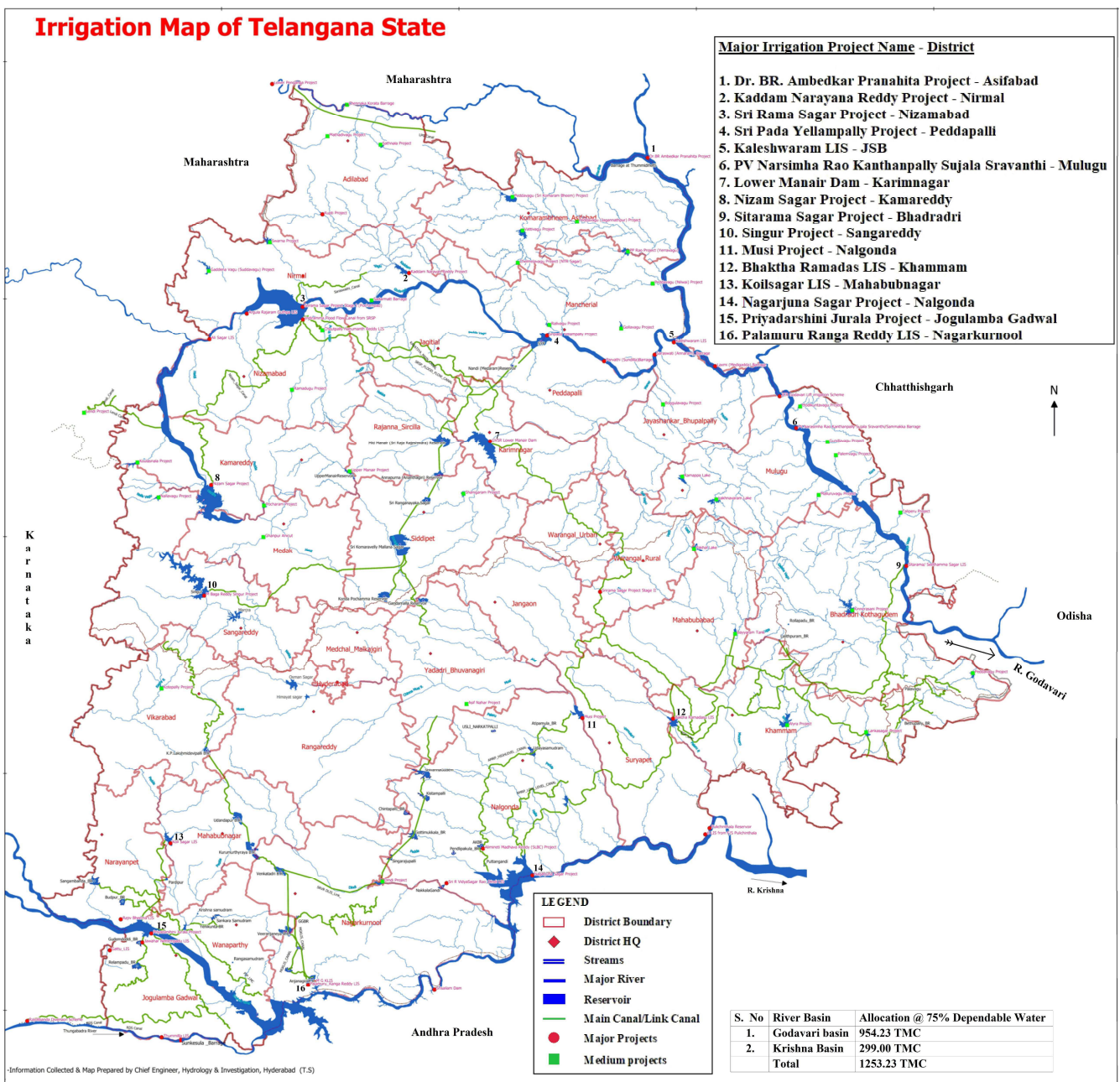


Fig.7. Irrigation map of Telangana State.

utilization of groundwater resources (23-60 % usage) is observed in 8 districts covering north-eastern part of state. These districts are underlain by highly potential Gondwana sandstone aquifer where resources can be further developed to alleviate the poverty and to bring prosperity & socio-economic equity among the rural population.

Groundwater quality deterioration: Groundwater quality in some areas is deteriorated due to geogenic contamination by fluoride (F). Fluoride concentration beyond maximum drinking permissible limits of 1.5 mg/l (BIS, 2012) is observed in ~15 % & 11 % of state area during pre- & post monsoon seasons of 2019 respectively (Figs.9a-b). High concentration of F (>1.5 mg/l) in localized patches are detected in Nalgonda, Kamareddy, Warangal (U), Sangareddy, Rangareddy, Jagityal, Yadadri-Bhongir and Asifabad districts in both seasons. Uranium (U) is other geogenic contamination which occurs in southern parts of Nalgonda and north-eastern parts of Nagarkurnool district where, its concentration is > 60 ppb (exceeding maximum drinking water standards (60 ppb) prescribed by Atomic Energy Regulatory Board, 2004). The other causes of deterioration in groundwater quality

is occurrence of NO₃, an anthropogenic contaminant due to excess utilization of fertilizers and nitrogen fixation by leguminous plant in canal command area of Rajoli Banda, NSLC & SRSP and major urban centres. During pre- & post-monsoon seasons of 2019, ~46 % samples (out of 8700 samples) falls above maximum permissible limits of 45 mg/l (BIS, 2012). The other anthropogenic contaminations are due to occurrence of heavy metals such as Fe, Cd, Mn & Ni in Katedan; Fe, Zn, Cd, Pb and Cr in Jeedimetla-Balanagar; Ni, Cd, Fe and Mn in Nacharam and Pb, Ni, Mn, Cd and Cr in Jinnaram industrial areas of the state (Sudarshan, et al., 2008 and SGWD, 2019b).

Sustainability: Gradual increase in well density from 5 wells/km² during 1st MI census to >13 wells/km² during 5th MI census has resulted in decreasing well yields from > 150 m³/day to < 10 m³/day and due to this irrigation potential under each well reduced from 1-2 ha to <1.2 ha (Sudarshan et al., 2008 and Govt of India, 2017). This phenomenon is more common in central & southern part of State (underlain by compact hard rocks) where comparatively more bore wells are there than dug wells.

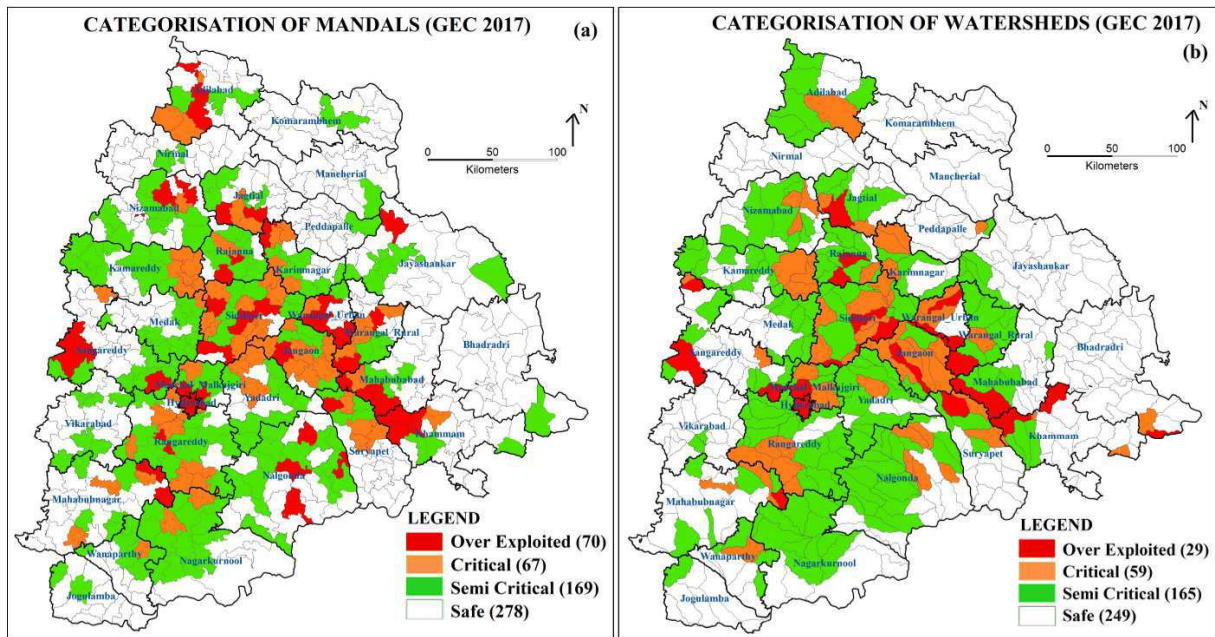


Fig.8. Categorisation of Mandals and Watersheds (GEC-2017).

Management Strategies

To overcome above issues, the Government of Telangana has taken up a giant step in managing water resources (both surface and groundwater) by adopting technological and institutional solutions.

The major technological solution adopted by State is re-engineering of Pranahita Chevella Sujala Shraavanthi projects (PCSSP) into Dr. B.R. Ambedkar Pranahita project & Kaleshwaram Lift Irrigation project (KLIP). Dr. B.R. Ambedkar Pranahita project is constructed across river Pranahita at Tummidi Hetti (Asifabad district) for diversion of 20 thousand million cubic feet (TMC) of water to irrigate ~2 lakh acres in Asifabad and Mancherial districts. The KLIP, one of the biggest lift irrigation project in the World is constructed on the river Godavari at Medigadda at 90 meter above mean sea level (m amsl) and to lift ~180 TMC water in stages to > 600 m amsl height into the mainland canals to irrigate additional 18.25 lakh acres area in 13 districts. It

will also cater to the drinking water needs of Greater Hyderabad Municipal Corporation (GHMC) area up to outer ring road and enroute villages. The releasing of water into mainland canals during 2019 “Yasangi” (rabi) season has shown positive impact on water levels as shallow water level area (< 10 m bgl) which, occupied 27 % of total command area during post-monsoon season (November) of last decade (2009-18) increased to 51 % during the same season of 2019 (Source: SGWD data base). The other major schemes taken up to irrigate are the Sitarama project, to irrigate ~3.29 lakh acres in Khammam district; the Palamuru-Rangareddy Lift irrigation Scheme to irrigate ~12.5 lakh acres in Rangareddy and Mahabubnagar districts; the Bhakta Ramdasu project to irrigate ~0.6 lakh acres in Khammam district; the Dindi lift irrigation project in Nagarkurnool and Nalgonda district to irrigate ~3.4 lakh acres and to mitigate drinking water needs of fluorosis endemic villages.

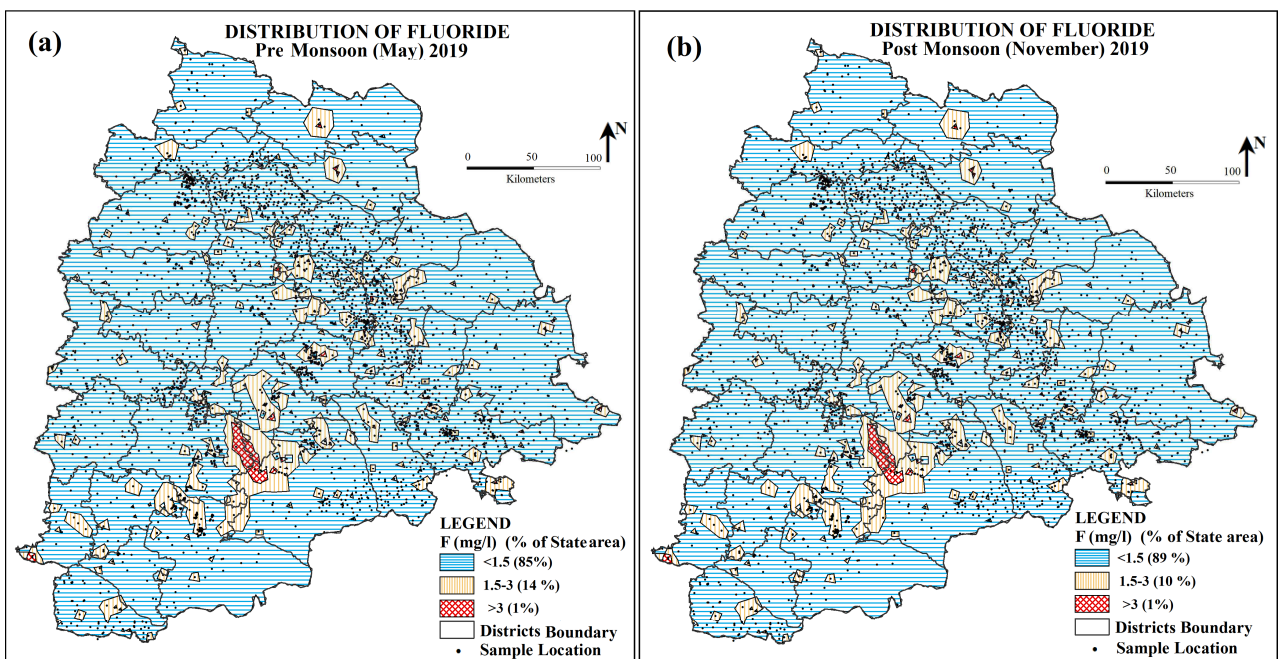


Fig.9. Distribution of fluoride during pre and post-monsoon season-2019.

The other measures include Mission Kakatiya, to fill up the gap ayacut of ~10 lakh acres, by restoration of existing ~46530 MI tanks in phased manner and by end of March 2018 (till 4th phase) ~27700 tanks are taken up which, has created a perceptible impact on agriculture and their livelihood, benefitting small and marginal farmers (NABCONS). To ensure safe and sustainable piped drinking water supply from surface water sources Mission Bhagiratha project is taken up at a cost of ~42853 crores to provide @ 100/135 and 150 litres/capita/day (lpcd) of water in rural, urban and municipal areas and for industrial supply by bringing ~86 TMC of surface water and this imported water (surface) from outside the basins (watersheds) will definitely save the groundwater resources in the basins/watersheds. To rejuvenate the degraded forest cover from 24 % to 33 % and for soil and moisture conservation on watershed approach, Haritha Haram project was started in July 2015 and so far, (up to 2019), ~81.6 crores seedlings are planted. To bring on fast track of Accelerated Irrigation Benefit Program (AIBP) under Long Term Irrigation Funds (LTIF), Govt under PMKSY sanctioned an amount of Rs.3413 crores and released Rs.297 crores to complete existing projects at early date (<https://www.nabard.org/content1.aspx?id=655&catid=8&mid=488>).

As recharge measures, the Govt has constructed >19000 various artificial recharge structures (ARS) in the state and recently sanctioned construction of an additional of 1200 new check dams (CD) on the 4th and above order streams with NABARD funding and work is already grounded for 600 CD's this year. To recharge the de-saturated aquifers in over-exploited villages, the SGWD has taken up construction of recharge shafts in existing water bodies (202 no's) and already completed 138 structures including the Chief Minister adopted 2 villages in Medchal-Malkajgiri district. According to NABARD, there is a need as well as good scope for bank financing of new irrigation, recharge structures, pumping systems etc and for considering it, the credit potential of Rs 935.18 Cr is assessed for water sector in the state for the year 2020-21 (NABARD, 2020).

The demand side measures like Andhra Pradesh Farmer Managed Groundwater System (APFAMGS) with FAO funding and Andhra Pradesh and Telangana State Community Based Tank Management Programme (AP & TS CBTMP with World Bank funding was adopted in erstwhile Andhra Pradesh state (including erstwhile Nalgonda and Medak districts from present Telangana state) (World Bank, 2019). Review of results from APFAMGS implemented areas shows improved awareness and behavioural changes, this helped the communities to adapt to droughts because of a shift from monocrop culture to mixed/multiple crops (Reddy, V.R. and Reddy, M.S., 2020). World Bank funded restructuring and modernization of canals of NSLC area, User centred aquifer level groundwater management pilot study in Nalgonda district and conjunctive use of surface and groundwater in NSLC from Khammam district under water sector improvement project (WSIP) were taken up. The aquifer level groundwater management plan from Nalgonda district was taken up to develop institutional model and community based water management plan for which the SGWD, Govt of Telangana received Rs. 1 lakh cash prize (3rd position) from 1st National Water Mission, MOWR, Govt of India during 2019. The other measures include water conservation measures under MGNREG, on and off method of releasing of canal water in NSLC command area and by adopting water saving technological solutions. The state has brought ~7.42 lakh ha area under micro irrigation from ~95000 ha benefitting ~7.46 lakh farmers during 2016 under Micro Irrigation Project (MIP) (Suresh and Manoj, 2020) (<http://horticulture.tg.nic.in/TSMIP/TSMIP.html>). The other water saving measures includes changing cropping pattern to low water consuming crops like oil seeds, palm oil cultivation, ground nut, pulses etc., enhancing support price for dry crops, implementation of Jalam-Jeevam a rainwater harvesting programme in GHMC area etc. To bring awareness among the farmers/

students and users for conserving water, awareness is created under Jal Shakti Abhiyan and under National Hydrology Project (NHP) in 139 over-exploited and critical mandals. The department is creating information, education and communication (IEC) activities in over-exploited villages as part of regular activities in all districts from the year 2018-19 and so far, 35 such programmes are conducted benefitting ~3500 participants by the end of March 2020. As regulatory measures, the state is implementing TSWALTA-Act where powers are given to notify the over-exploited villages for control and regulation of groundwater development, registration of rigs etc.

CONCLUSIONS AND WAY FORWARD

Conclusions

- ~85% of the state area is underlain by hard rock aquifers having poorer yields and rest by soft rock aquifers having good yields in north-eastern part of State.
- The State receives annual normal rainfall of 942 mm and is the main source of groundwater recharge.
- In the State, groundwater irrigation reached to its maximum of 23.35 lakh ha during 2017-18 from 0.46 lakh ha during 1875 and having well density of 13 wells/km² presently. About 57 percent of State population depends on agriculture and groundwater contributes 9.8 percent of State GDP.
- The average groundwater level in the State during last 35 years is showing decline in water level trends @ 0.18 m/yr more particularly from areas that are lying in western parts of the State.
- Main issues identified in the State are water logging & salinity in canal command areas of NSLC, SRSP & Rajoli Bandha, over-exploitation & de-saturation of shallow aquifers in central and western part, groundwater pollution due to geogenic contamination by fluoride, anthropogenic contamination by nitrate and under-utilization of groundwater from highly potential sandstone aquifer in north-eastern parts.
- The management strategies adopted by Govt of Telangana like KLIS, Mission Kakatiya and Mission Bhagiratha are giving positive results in food production (this year total food grain production is expected at 13 MT) and in ameliorating groundwater conditions & quality in affected areas.

Way Forward

No doubt the measures taken up by the Government of Telangana State are manifesting positive results. To sustain and to continue the impacts further, the following suggestions are made.

- Change in cropping pattern from highly water intensive crops like paddy in non-command areas to less water consuming irrigated dry (ID) crops and creating awareness through various IEC activities.
- The water logging and salinization is caused due to mis-management in irrigation system in general and can be solved through proper management of irrigation system by adopting conjunctive use of surface and groundwater and development of artificial drainage system as done earlier under water sector improvement project in NSLC command area from Khammam district.
- Implementing "warabandhi" (on/off) method of water releasing in water logged and prone to water logging areas in both kharif as well as rabbi seasons along with developing intercepting drains, soil treatment and declaring crop holidays.
- Improving water use efficiency in surface water supply through piped system at the delivery channel, micro-irrigation (drip & sprinkler) and adopting other water conservation measures.
- Groundwater user associations at watershed/village level should be formed for making annual planning in cropping pattern based on rainfall and groundwater availability.

- Monitoring mechanism existing in Groundwater Department of state and central should be strengthened and integrated by increasing scientific manpower, monitoring stations installed with automatic water level recorders. This will help in estimation of groundwater resources more precisely and accurately in future.
- As the electric pumps are extensively used for extraction of groundwater, controlling their use will go a long way in reducing extraction and this can be achieved by making separate grids for irrigation and other users on Gujarat model.
- For addressing drought and climate vulnerability, the participatory groundwater management must include policy interventions that involve regulatory mechanisms and village-based institutions must be linked to government departments that manage groundwater (Reddy, V.R. and Reddy, M. S., 2020).
- Presently, the rights to groundwater belongs to the land owner and gets transferred and there is no control over its use, therefore land and water rights should be legally separated for better management as suggested by Gandhi and Bhamoriya (2011).
- Strict implementation of regulatory measures in controlling groundwater over-extraction in notified areas.
- In areas where underutilization of groundwater resources is there, more impetus to development of groundwater resources should be given under PMKSY (Har Khet ko Pani) scheme.

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