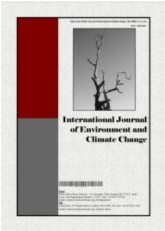

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Temporal Analysis of Trends in Groundwater Level in Northern Karnataka

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The present study was conducted in three districts of northern Karnataka *viz*., Belagavi, Vijayapur and Uttar Kannada based on the highest number of observation wells and secondary data collected for the year 1999 to 2018 from various sources like Central Groundwater Department and district Groundwater department. Compound Annual Growth Rate (CAGR) tool was used to analyze the trends in depth of groundwater level which revealed that, in Belagavi district, during 1999 with a ground water level of 4 MBGL has increased to 20.22 MBGL (Meter Below Ground Level) in 2018 at a rate of (2.72%) per year. Among 10 taluks of Belagavi district, Belagavi taluk recorded highest rate of increase in depth of groundwater level (4.82%) While, Ramdurg taluk recorded lowest growth in depth of groundwater level (0.43%). In Vijayapur district, during 1999 the depth of groundwater level was 7.37 MBGL and has increased to 19.09 MBGL in 2018 at a rate of 1.62 per cent per year. Among five taluks of Vijayapur district, Sindagi taluk recorded highest rate of increase in depth of groundwater level (2.79%). Whereas, Vijayapur taluk recorded lowest growth in depth of groundwater level (0.10%). While, Uttar Kannada district, with a the depth of groundwater level 6.94 MBGL during 1999 had increased to 17.41 MBGL in 2018 at a rate of 2.38 per cent per year. Among 11 taluks of Uttar Kannada district, Sirsi taluk recorded the highest rate of increase in depth of groundwater level (4.51%). However, Supa taluk recorded the lowest

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growth in depth of groundwater level (0.36%). The study indicated that over the years depth of groundwater level has increased significantly. The decline in groundwater availability might be due to over exploitation of groundwater over its recharge rate and inadequacy of rainfall over the period of time.

Keywords: Groundwater; northern Karnataka; meter below ground level; compound annual growth rate.

1. INTRODUCTION

Groundwater is the world most extracted raw material with withdrawal rates currently in the estimated range of 982 KM^3/ year [1]. About 70 per cent of groundwater withdrawn world wild is used for agriculture. Groundwater provides almost half of all drinking water worldwide [2]. Globally about 38 per cent of irrigated lands are equipped for irrigation with groundwater [3].

India is the largest groundwater user in the world, more than 1/4th of the global total (World Bank, 2010). About 85 per cent of India's rural domestic water requirements, 50 per cent of its urban water requirements [4] and around 64 per cent of the total irrigated area depends on groundwater and more than 70 per cent of irrigated agricultural production is attributed to groundwater irrigation (Deb Roy and Shah, 2003). The planet earth gives us this invisible asset that sustains a range of human activities. Blinded by Western development model of perennial GDP growth humanity is busy plundering even this resource. And foolishly take its availability for granted without bothering to know how the groundwater reservoirs replenish themselves. It may be surprising for many people to know that India is the world's largest user of groundwater, oblivious to the fact that since the 1980s the groundwater tables have been continuously dropping.

1.1 Groundwater Use Pattern

As mentioned earlier, the availability of surface water (690 BCM/year) is greater than groundwater (433 BCM/year). However, groundwater, being available almost everywhere through bore wells, is easily accessible and thus, forms the largest share of agriculture and drinking water supply. Of the extracted groundwater around 89 per cent is used in the irrigation sector, 9 per cent is used for the domestic purposes and the remainder 2 per cent goes into industrial use. Groundwater also fulfils 50 per cent of urban water requirements and 85 per cent of rural domestic water requirements.

1.2 Irrigation through Groundwater

Major means of irrigation in the country are canals, tanks and wells, including tube-wells. Of all these sources, groundwater contributes the largest share. Wells – dug wells, shallow tube-wells and deep tube wells – provide about 62 per cent of water for irrigation, followed by canals with around 25 per cent.

The over-exploitation of groundwater has created a series of problems, particularly in the agriculture-intensive belts across India. The situation is becoming particularly acute in the Northwest, where the groundwater levels have plunged from 8m to 16m below ground. As the levels fall, rising pumping costs ultimately makes extraction uneconomical; small formers and labourers get directly impacted. The average farmer in Punjab, Rajasthan and Haryana faces the prospect of having no groundwater left for irrigation by 2025.

2. METHODOLOGY

The present study was conducted in three districts of Northern Karnataka *viz.,* Belagavi, Vijayapur and Uttar Kannada based on the highest number of observation wells. The study is based on secondary data collected from 1999 to 2018 for achieving the objectives of the study. Secondary data was collected from various sources like Central Groundwater Department and district Groundwater department.

2.1 Analytical Tools

For the purpose of evaluating the objectives of the study, the following analytical tools were used for analyzing the data to draw meaningful results and conclusions. District-wise data on groundwater level has been collected and analyzed by using standard statistical tools like arithmetic mean and coefficient of variation, compound growth rates and graphical representations to know the trends in depletion of groundwater in the study area.

2.2 Compound Annual Growth Rate Analysis

To study the annual growth rate in quantity and value of export of coir products, the compound growth rate was computed using semi-log or exponential model [5].

$$\ln Y_t = \alpha + \beta_t + u_t$$

Where,

Y_t = Quantity (tonnes) of coir products exported in year t.

t = Time element which takes the value 1, 2 .. n for various years.

α = Intercept

β_t= Regression co-efficient

u_t= Error term

Compound Annual Growth Rate (CAGR) = [(Antilog β_t-1) x100]

3. RESULTS AND DISCUSSION

Trends in depletion of groundwater level in Belagavi district is presented in Table 1. It is evident from the table that in the year 1999 the level of groundwater was highest in Bailhongal among the talukas of Belagavi district (11.27 MBGL) followed by Khanapur, Ramdurg, Raybag, Chikkodi, Saudatti, Hukkeri, Belagavi, Atani and Gokak with 10.13, 9.38, 7.43, 7.09, 6.77, 6.52, 6.04, 5.88 and 5.85 MBGL respectively. In 2018 the depth of water level was highest in Bailhongal with 31.75 MBGL followed by Belagavi, Chikkodi, Khanapur, Saudatti, Atani, Hukkeri, Gokak, Raybag and Ramdurg with 24.38, 23.96, 23.13, 21.75, 20.01, 18.32, 16.63, 13.67 and 10.63 MBGL respectively.

It is observed that depth of water level has increased over the years in all the taluka, the rate of increase in the depth of water level was highest in Belagavi and Atani with 4.82 and 3.72 per cent per year respectively which are significant at one per cent level of probability followed by Saudatti (3.66%), Khanapur (3.38%), Chikkoddi (2.98%), Gokak (2.55%) which are significant five per cent level of probability. Among all talukas of Belagavi district Ramdurg taluka recorded least growth in the depth of water level with 0.43 per cent per year. On an average in Belagavi district as a whole in the 1999 depth of groundwater level was 7.62 MBGL and it increased to 20.22 MBGL in 2018 at a rate of 2.72 percent per year. Similar results were obtained by Pennan, C. [6].

The depletion of groundwater table is mainly due to over extraction of groundwater for irrigation and domestic purposes. Belagavi district is the major sugarcane growing area, as sugarcane crop requires more water farmers extracting excessive groundwater than its rechargeable rate. The fluctuations in increase in depth of water level from 1999 to 2018 as highest in Saudatti and Khanapur with 42.57 and 34.99 per cent respectively. It is due to uneven distribution of rainfall leads to lowering groundwater recharge. Then it leads to the depletion of groundwater level.

Trends in depletion of groundwater level in Vijayapur district is presented in Table 2. It is evident from the table that in the year 1999 the level of groundwater was highest in Vijayapur among the talukas of Vijayapur district (12.96 MBGL) followed by Indi, Basavana Bagevadi Muddebihal and Sindagi with 7.54, 5.75, 5.64 and 4.94 MBGL respectively. In 2018 the depth of water level was highest in Vijayapur with 22.11 MBGL followed by Indi, Sindagi, Basavana Bagevagi and Muddebihal with 21.48, 18.27, 17.13 and 16.47 MBGL respectively.

It is observed that depth of water level has increased over the years in all the taluka, the rate of increase in the depth of water level was highest in Sindagi and Muddebihal with 2.29 and 2.61 per cent per year respectively which are significant at five per cent level of probability followed by Basavana Bagevadi (2.65 %). Among all talukas of Vijayapur district Vijayapur and Indi talukas recorded least growth in the depth of water level with 0.10 and 0.45 per cent per year respectively. On an average in Vijayapur district as a whole in the 1999 depth of groundwater level was 7.37 MBGL and it increased to 19.09 MBGL in 2018 at a rate of 1.62 per cent per year. Similar results were obtained by Singh, O., Kasana, A., Singh, K. and Sarangi, A. [7].

Table 1. Trends in level of groundwater in Belagavi district (1999-2018) (MBGL)

Year	ATN	BLHNGL	BLGV	CKD	GKK	HKR	KNPR	RMDRG	RYBG	SDT	Overall
1999	5.88	11.27	6.04	7.09	5.85	6.52	10.13	9.38	7.43	6.77	7.64
2000	11.94	19.22	11.24	13.95	10.51	11.69	14.16	19.67	11.97	15.58	13.99
2001	18.28	21.40	17.06	17.78	19.33	18.20	17.06	25.98	15.75	23.77	19.46
2002	19.78	41.53	20.45	31.92	18.31	24.51	27.71	19.46	24.60	35.15	26.34
2003	18.02	41.96	17.67	28.01	19.27	21.45	20.69	23.22	21.19	26.04	23.75
2004	23.51	33.29	20.51	30.28	17.43	20.03	26.08	22.19	24.87	37.14	25.53
2005	20.15	25.97	17.00	23.54	11.92	16.37	17.28	19.16	21.31	20.22	19.29
2006	21.50	34.02	22.15	29.11	15.12	19.35	23.53	25.32	19.68	19.10	22.89
2007	19.50	26.91	14.18	21.96	13.64	16.20	25.14	16.23	17.35	13.35	18.45
2008	21.68	32.47	21.93	25.00	14.16	20.51	23.84	21.22	18.89	18.95	21.87
2009	24.17	38.52	23.79	28.29	19.25	20.84	33.02	18.34	21.75	23.27	25.12
2010	20.53	24.36	24.45	23.39	14.81	21.26	24.86	20.00	21.00	21.54	21.62
2011	22.48	33.04	20.29	21.49	20.96	16.61	25.95	23.03	17.59	32.63	23.41
2012	24.08	27.36	20.78	22.73	18.53	17.72	27.06	23.24	17.72	24.36	22.36
2013	26.78	45.28	25.45	30.52	21.68	20.75	36.70	36.15	29.98	32.00	30.53
2014	22.54	30.53	28.39	23.64	14.94	13.34	24.21	18.03	13.53	28.16	21.73
2015	24.37	31.70	29.23	31.15	25.61	21.45	43.12	25.56	30.87	55.32	31.84
2016	28.87	30.84	31.24	32.65	20.86	23.34	42.78	26.31	18.43	44.34	29.97
2017	22.13	27.21	23.49	25.75	15.04	19.60	14.39	16.16	12.69	21.20	19.77
2018	20.01	31.75	24.38	23.96	14.63	18.32	23.13	10.63	13.67	21.75	20.22
CAGR (%)	**3.73****	**2.04**	**4.82****	**2.98***	**2.55***	**1.98**	**3.38***	**0.43**	**1.02**	**3.66***	**2.72***
CV (%)	**23.93**	**26.55**	**28.83**	**25.80**	**26.83**	**22.78**	**34.99**	**27.91**	**30.72**	**42.57**	**13.99**

*Note-1 *indicates significance at five per cent level of probability, ** indicates significance at one per cent level of probability*

2. ATN= Athani, BLHNGL= Bailahonagal, BLGV= Belagavi, CKD= Chikkodi, GKK= Gokak, HKR= Hukkeri, KNPR= Khanapur, RMDRG= Ramadurg, RYBG= Raybag, SDT= Saudatti

3. MBGL= Meter Below Ground Level

Table 2. Trends in level of groundwater in Vijayapur district (1999-2018) (MBGL)

Year	BASAVANA BAGEVADI	INDI	MUDDEBIHAL	SINDAGI	VIJAYAPUR	OVERALL
1999	5.75	7.54	5.64	4.94	12.96	7.37
2000	12.88	16.21	11.47	10.83	18.70	14.02
2001	18.56	24.23	17.22	16.14	18.36	18.90
2002	24.27	32.16	20.09	20.01	17.35	22.77
2003	25.11	30.35	18.26	17.44	16.98	21.63
2004	29.27	28.64	23.78	22.37	16.32	24.07
2005	20.67	19.70	16.73	14.15	15.96	17.44
2006	22.31	30.51	21.32	18.93	16.26	21.87
2007	14.90	23.03	15.51	16.51	17.63	17.52
2008	20.78	27.27	17.68	15.34	18.96	20.00
2009	20.57	28.18	19.83	15.63	19.36	20.71
2010	26.20	25.54	26.68	16.43	20.36	23.04
2011	29.84	26.33	24.21	13.64	18.36	22.48
2012	28.24	23.51	23.67	19.87	19.69	22.99
2013	33.55	16.46	24.59	17.12	16.33	21.61
2014	16.44	19.20	15.84	16.97	11.80	16.05
2015	26.56	19.58	15.67	17.25	14.33	18.68
2016	20.92	18.87	22.15	21.07	15.50	19.70
2017	22.15	22.35	20.45	21.52	16.34	20.56
2018	17.13	21.48	16.47	18.27	22.11	19.09
CAGR (%)	**2.65**	**0.45***	**2.61***	**2.79***	**0.10**	**1.62**
CV (%)	**29.94**	**25.85**	**26.26**	**23.61**	**14.39**	**19.71**

*Note-1 *indicates significance at five per cent level of probability, ** indicates significance at one per cent level of probability*

Table 3. Trends in level of groundwater in Uttar Kannada district (1999-2018) (MBGL)

Year	ANKL	BTKL	HYL	HNVR	KRWR	KMT	MNDGD	SDPR	SRS	SUPA	YLPR	Overall
1999	6.88	5.99	6.42	6.57	3.86	7.34	7.06	8.12	8.29	6.79	9	6.94
2000	10.57	9.47	10.43	11.10	5.61	11.7	13.10	13.53	15.51	4.71	6.45	10.20
2001	13.36	16.29	14.92	13.26	7.88	18.19	19.70	25.06	26.98	5.44	6.47	15.23
2002	22.32	18.64	22.50	14.54	8.42	22.61	20.03	27.49	28.77	5.85	6.57	17.98
2003	20.22	18.24	17.43	16.32	9.36	19.86	22.01	24.03	25.33	4.84	5.70	16.67
2004	23.96	26.58	20.98	19.75	8.30	15.70	25.46	21.00	33.65	5.11	7.46	18.90
2005	23.72	12.72	16.29	22.59	9.36	17.30	16.89	17.69	28.54	6.80	9.23	16.47
2006	19.84	17.28	30.99	19.86	10.54	16.17	22.45	25.45	43.91	5.99	7.91	20.04
2007	21.68	22.06	25.23	20.36	6.65	19.69	21.35	22.42	41.66	5.31	8.24	19.51
2008	22.25	21.57	20.46	21.65	6.84	20.71	25.00	23.02	38.55	6.30	8.59	19.54
2009	21.31	23.70	38.20	22.69	6.40	20.99	24.25	20.86	47.81	5.16	7.83	21.75
2010	20.51	22.54	20.82	24.65	6.13	20.21	20.62	22.28	31.52	4.63	8.15	18.37
2011	19.06	23.16	25.84	18.14	5.34	18.92	22.36	22.96	40.67	5.38	6.69	18.96
2012	22.22	16.28	10.42	17.30	6.87	18.29	19.88	25.34	30.47	5.73	8.52	16.48
2013	18.39	20.80	17.98	15.42	5.17	21.16	24.24	26.47	46.04	5.56	8.49	19.07
2014	18.35	22.95	11.95	13.25	11.20	14.80	38.70	26.56	26.9	6.08	9.28	18.18
2015	18.59	21.34	13.64	15.16	10.36	17.88	22.60	26.47	38.86	6.05	8.99	18.18
2016	18.46	22.41	16.91	15.43	10.12	18.64	24.96	25.89	33.51	6.12	8.79	18.29
2017	23.66	12.10	23.35	14.12	12.88	17.95	19.00	24.61	42.99	5.80	8.37	18.62
2018	21.21	16.21	12.11	13.54	11.95	14.78	19.23	25.19	42.80	6.13	8.35	17.41
CAGR (%)	**2.53***	**2.53**	**0.88**	**1.09**	**2.58***	**1.41**	**2.84***	**2.80****	**4.51****	**0.36**	**1.26***	**2.38***
CV (%)	**22.87**	**28.52**	**40.39**	**26.65**	**30.54**	**20.17**	**27.78**	**21.09**	**30.43**	**10.93**	**13.23**	**19.41**

*Note-1 *indicates significance at five per cent level of probability, ** indicates significance at one per cent level of probability*
2. ANK= Ankola, BTKL= Bhatkal, HYL= Haliyal, HNVR= Honnavar, KRWR= Karwar, KMT= Kumta, MNDGD= Mundagod, SDPR= Siddapur, SRS= Sirsi, YLPR= Yallapur

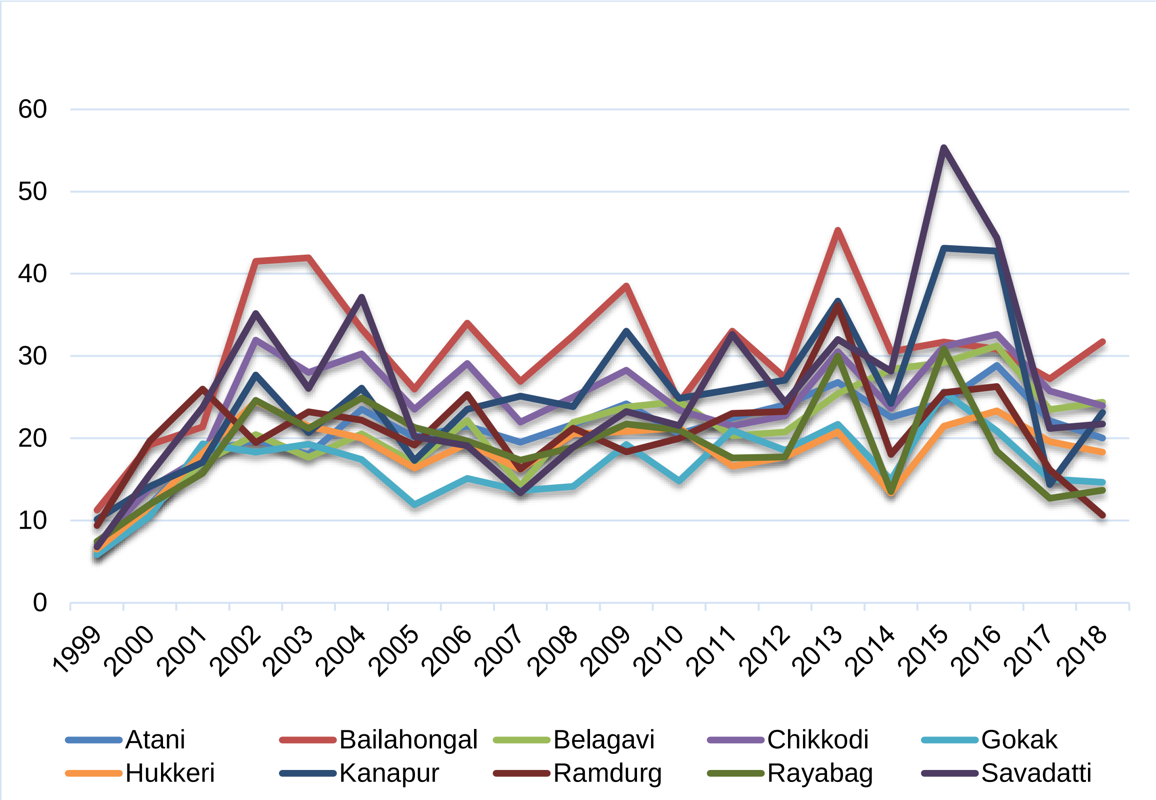

Fig. 1. Trends in level of groundwater in Belagavi district (1999-2018)

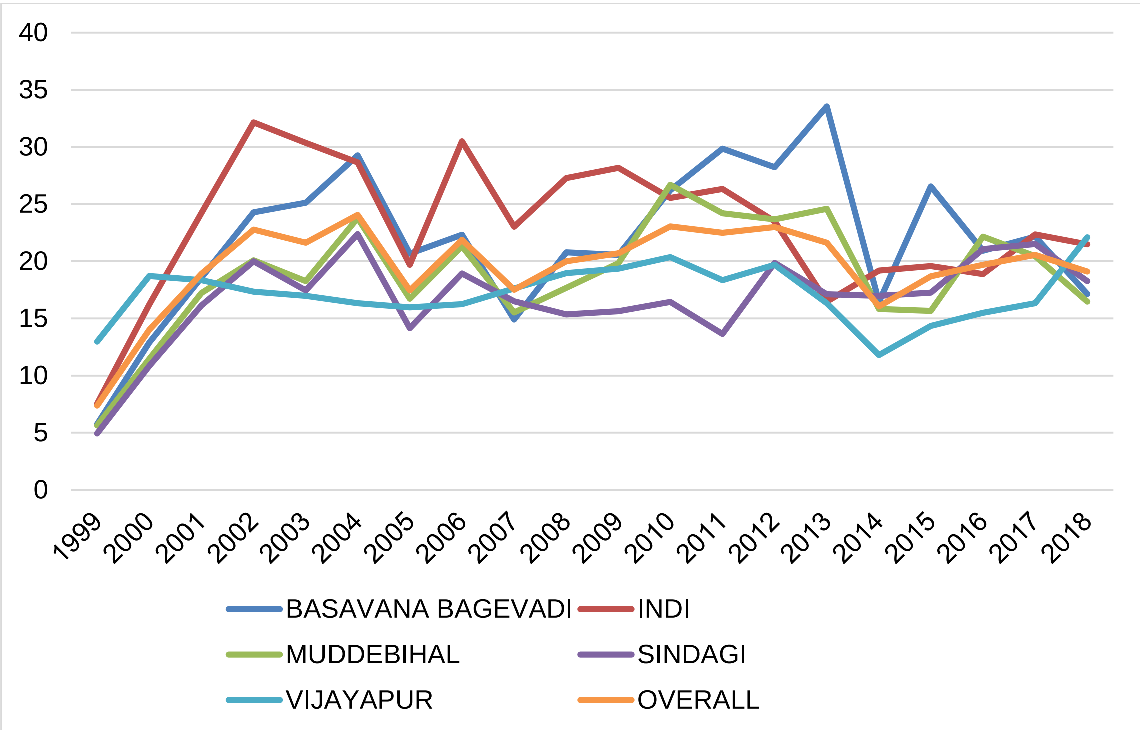

Fig. 2. Trends in level of groundwater in Vijayapur district (1999-2018)

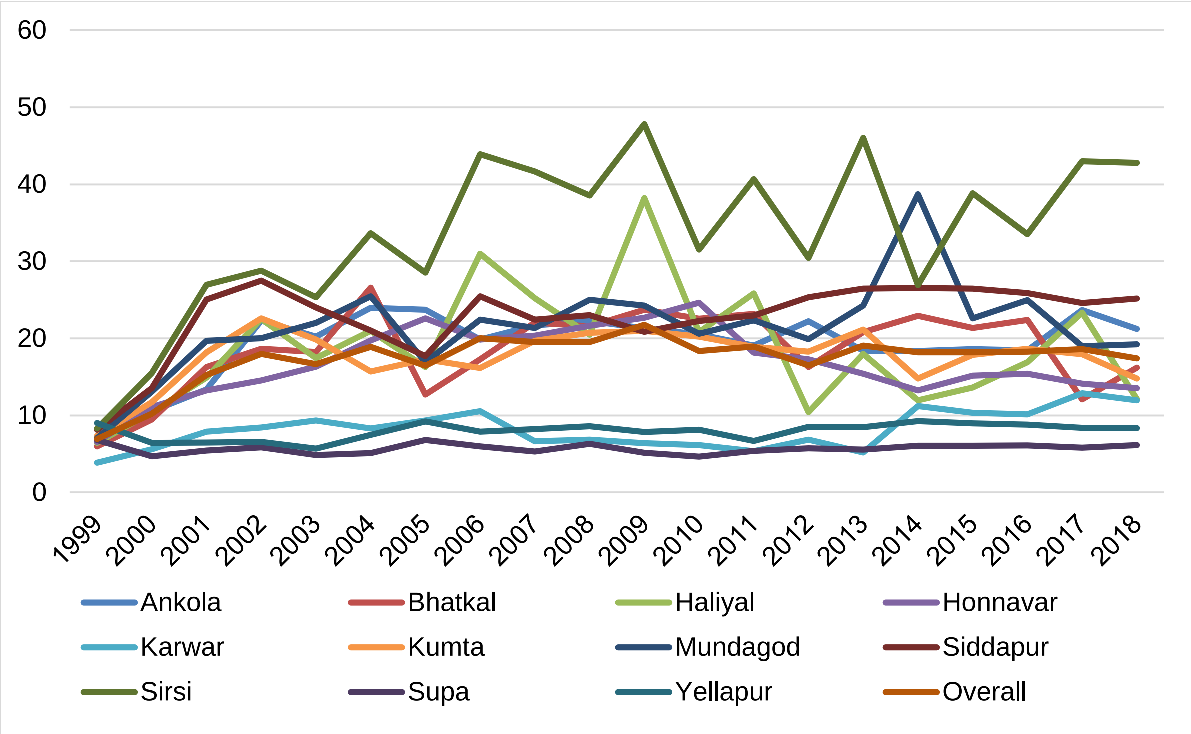

Fig. 3. Trends in level of groundwater in Uttar Kannada district (1999-2018)

The depletion of groundwater table is mainly due to scarcity of rainfall and over extraction of groundwater for irrigation and domestic purposes. The fluctuation in increase in depth of water level from 1999 to 2018 is highest in Basavana Bagevadi and Muddebihal with 29.94 and 26.26 per cent respectively. It is due to uneven distribution of rainfall leads to lowering groundwater recharge. Then it leads to the depletion of groundwater level.

Trends in depletion of groundwater level in Uttar Kannada district is presented in Table 3. It is evident from the table that in the year 1999 the level of groundwater was highest in Yellapur among the talukas of Uttar Kannada district (9.00 MBGL) followed by Sirsi, Siddapur, Kumta, Mundagod, Ankol, Supa, Honnavar, Haliyal, Bhatkal and Karwar with 8.29, 8.12, 7.34, 7.06, 6.88, 6.79, 6.57, 6.42, 5.99 and 3.86 MBGL respectively. In 2018 the depth of water level was highest in Sirsi with 42.80 MBGL followed by Siddapur, Ankol, Mundagod, Bhatkal, Kumta, Honnavar, Haliyal, Karwar, Yellapur and Supa with 25.19, 21.21, 19.23, 16.21, 17.78, 13.54, 12.11, 11.95, 8.35 and 6.13 MBGL respectively.

It is observed that depth of water level has increased over the years in all the taluka, the rate of increase in the depth of water level was highest in Ssirsi and Siddapur with 4.51and 2.80 per cent per year respectively which are significant at one per cent level of probability followed by Mundagod (2.84%), Karwar (2.58%) and Ankola (2.53%), which are significant at five per cent level of probability. Among all talukas of Uttar Kannada district Supa and Haliyal talukas recorded least growth in the depth of water level with 0.36 and 0.88 per cent per year respectively. On an average in Uttar Kannada district as a whole in the 1999 depth of groundwater level was 6.94 MBGL and it increased to 17.41 MBGL in 2018 at a rate of 2.38 which is significant at five per cent level of probability.

The depletion of groundwater table is mainly due to over extraction of groundwater for irrigation and domestic purposes. The fluctuations in increase in depth of water level from 1999 to 2018 as highest in Haliyal, Karwar and Sirsi with 40.39, 30.54 and 30.43 per cent respectively. It is due to uneven distribution of rainfall leads to lowering groundwater recharge. Then it leads to the depletion of groundwater level. Similar results were obtained by Sengupta, S. [8].

4. CONCLUSION AND POLICY RECOMMENDATION

The study revealed that over the years depth of groundwater level goes on increasing significantly *i.e.* groundwater table is decreasing in all the districts of study area. The main reason for decline in groundwater availability is over exploitation of groundwater over its recharge rate and inadequacy of rainfall. So it is necessary;

- To maintain scientific spacing between two bore wells.
- To adopt conjunctive use techniques of ground water and surface water that can improve the ground water scenario.
- To create awareness among ground water users about the conditions of water and its availability and encourage its judicious and economical use so as to make sustainable use.
- To grow crops that require less amount of water.
- To further suggest adopting ground water recharge and rain water harvesting techniques, especially in over-exploited areas so as to avoid further groundwater depletion.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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