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Trend Analysis of Groundwater Status in NICRA-AICRPAM Domain Districts and Crop Planning Strategies

Mukesh Dewangan, Bhumika Chandrakar, Vidya Charan Ratre, J. L. Chaudhary

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ABSTRACT

The present study was carried out at the Department of Agrometeorology, College of Agriculture, IGKV, Raipur (CG) during 2019-20. The research was conducted for the two (Bemetara and Kanker) NICRA-AICRPAM districts of the Chhattisgarh. For systematic study 23 years (1996-2018) long term groundwater depth data were collected from Central Ground Water Board, Raipur. The trend analysis of groundwater depth is computed with the help of linear trend line graph method. Outcome of linear trend graph analysis for annual groundwater depth indicates significantly increasing trend for Bemetara and Saja tehsils of Bemetara district and koelibeda tehsil of Kanker district and Durgkodal tehsil of Kanker district is showing significantly decreasing trend. Some tehsils of Bemetara district i.e. Nawagarh, Berla and some tehsils of Kanker district i.e Kanker, Charama are showing non significant decreasing trends while Antagarh, Bhanupratapur and Narharpur tehsils are showing non-significant increasing trends. District wise trend analysis of groundwater depth analysis is showing significant increasing trend of Bemetara district while Kanker district is showing non-significant increasing trend. Significant decreasing trend of Durgkondal teshil of Kanker district indicates that groundwater level is in recharging pattern which is a highly significant feature. The outcome of research will be helpful to determine how much groundwater decreases or increases over the period of twenty-three years (1996-2018). It will help ultimately to decide cropping patterns and accordingly what should be our cropping strategies based on groundwater status and extreme events (Dry and wet spells). On the basis of outcome of trend analysis of groundwater depth crop plans are to be prepared which suggested that the two districts i.e. Bemetara and Kanker have shown depletion of groundwater. Cropping strategies are suggested to grow low water requirement crops instead of existing crops such as maize, rice and sugarcane to cope with groundwater decline. Otherwise we have to prepare groundwater recharge plan fairly so that there is no chronic shortage of even drinking water in near future.

Keywords Trend analysis, Dry and wet spells, Groundwater depth, Cropping pattern.

Mukesh Dewangan[1], Bhumika Chandrakar[2], Vidya Charan Ratre[3], L. Chaudhary[4]*

[2]Field Assistant (AICRP-AM), [3]Assistant Professor
[4]Senior Scientist

[1,2,3,4] Dept of Agricultural Meteorology, IGKV, Krishak Nagar, Raipur (CG) 492012, India

Email: jlcagromet@gmail.com
*Corresponding author

INTRODUCTION

According to Economic survey 2018, extreme weather effects in un-irrigated lands are more detrimental compared to irrigated fields. Extreme disturbances have extremely different consequences between irrigated and un-irrigated areas and crops, almost twice high than irrigated. Long-term forecasts of climate change have indicated that it can reduce annual agriculture incomes by an average of 15-18% and up to 20-25% in un-irrigated areas. Extreme temperatures have been mainly felt in the North-East India, Gujarat, Rajasthan, Tamil Nadu and Kerala states (Anonymous 2018). In order to overcome these issues, some basic and applied research are required that will support the development of a sustainable rainfed farming system.

Chhattisgarh is the 26th state of the Indian Union which came into existence on November 1, 2000. The climatic conditions of state are predominately hot sub- humid type with the average annual rainfall of approximately 1200 mm (Chaudhary *et al.* 2015). The state total geographical area is about 136 lakh ha, where 60.76 lakh ha of the area comes under forest region (43.8%) and 58.81 lakh ha (43% arable land) are used for cultivation. About 80% of state population is engaged in agriculture. Chhattisgarh agriculture is mainly monocropped where cereal crops especially rice is extensively cultivated during the monsoon season. Rice yield in the state of Chhattisgarh is about 1597 kg/ha, which is well below the average of 2404 kg/ha of India (Anonymous 2016). Chhattisgarh agriculture is highly dependent on monsoon rainfall, near about 70% area comes under rainfed condition, therefore weather conditions becoming quite important for good crop production. The onset of monsoon first occur in southern part of Chhattisgarh around 10 June and covering the entire state by around 20 June. Rainfall during July and August is usually high (350 to 400 mm) but the pattern has changed during last few years. Heavy rainfall also occuring during month of September. Generally cyclonic activity is occuring in month of October and it causes heavy rainfall. Under such situation, the farmers tend to follow rice – wheat, rice – mustard, rice – pulses and rice – winter vegetables cropping pattern in partially irrigation availability whereas rice – fallow and rice – utera (Lathyrus, chickpea and linseed) are generally followed under rainfed situation.

Chhattisgarh state with such climate dependence and irregular weather conditions has been amongst the states with lower agricultural productivity, low income and poverty concentration. In such situation, the studies of weather condition and their extremes becomes very important. Taking into consideration these facts the present study has been carried out with the objective of finding out the trend of ground water level in Kanker and Bemetara districts. Groundwater is a very precious commodity of future generation. It should be used in judicious way and its proper recharge plan is requirement of present climate change scenario, otherwise we will have to face the very chronic situation in future. Kanker district has 07 tehsils i.e. Antagarh, Bhanupratapur, Durgkondal, Charama, Koelibeda, Kanker, Narharpur. Bemetara district has 04 tehsils i.e. Saja, Nawagarh, Berla, Bemetara.

MATERIALS AND METHODS

The groundwater data recorded by Central Ground Water Board (CGWB), Raipur during 1996 to 2018 were collected and classified into four seasons i.e. Non-monsoon (January-February), Pre-monsoon (April-May), Monsoon (July-August) and Post-monsoon (November-December). The seasonal groundwater depths are averaged out to obtain the annual groundwater depth. Districts and tehsils average is shown in this Table 1.The data about groundwater level shows the depth at which water is available and unit for the data is mbgl (meter below ground level). It is very important to understand the meaning of trend of groundwater i.e. increasing trend shows that the groundwater level is going down. Decreasing trend shows groundwater level is showing positive trend, moving upward and there is recharging pattern.

RESULTS AND DISCUSSION

Groundwater depth with annual trend analysis tehsil wise for Bemetara district

Data belonging to annual groundwater depth of 23-years for Bemetara district is presented in Table 1. Data revealed that maximum depth of groundwater

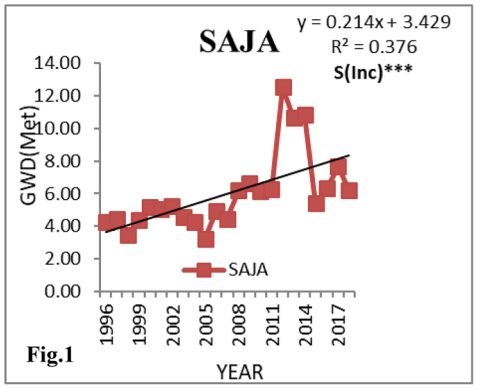

Fig.1

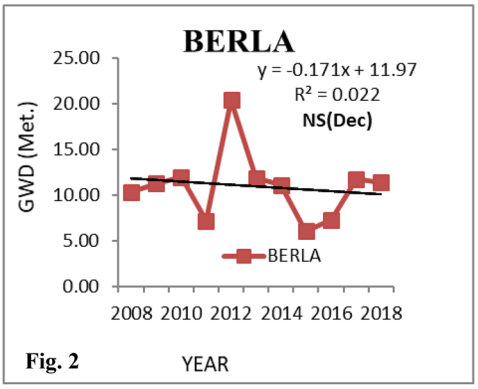

Fig. 2

* Significant at 10% level ** Significant at 5% level *** Significant at 1% level

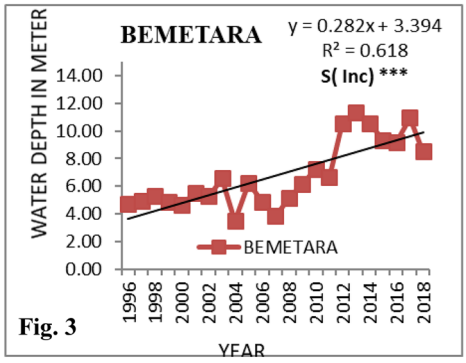

Fig. 3

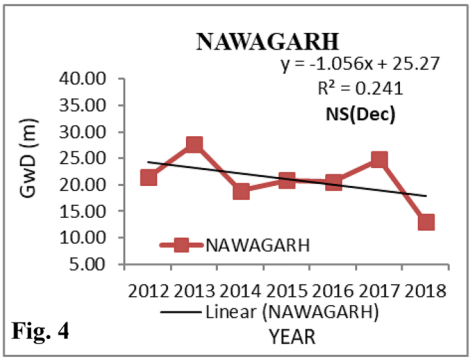

Fig. 4

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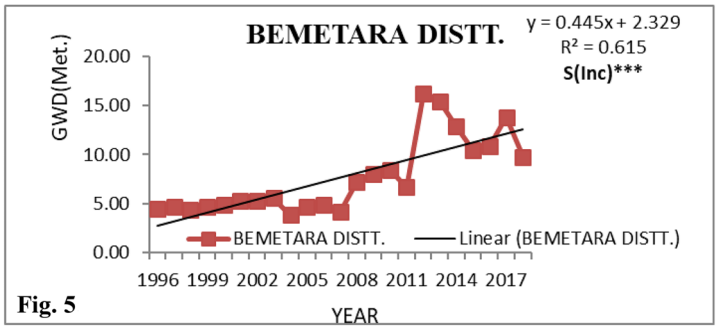


Fig. 5

* Significant at 10% level ** Significant at 5% level *** Significant at 1% level

Fig.1. Ground water trend of Saja tehsil, district Bemetara. **Fig. 2.** Ground water trend of Berla tehsil, district Bemetara. **Fig. 3.** Ground water trend of Bemetara tehsil, district Bemetara. **Fig. 4.** Ground water trend of Nawagarh tehsil, district Bemetara. **Fig. 5.** Ground water trend of Bemetara district.

was 16.24 mbgl in the year 2012 followed by 15.4 mbgl in the year 2013 and 13.8 mbgl in the year 2017, whereas the lowest depth of groundwater recorded 4.5 mbgl in the year 1998. It was observed that there was depletion in groundwater depth up to 16.24 mbgl as compared to 1996 groundwater depth of 4.5 mbgl. Outcome of linear trend graph analysis Figs. 1-5 for annual groundwater depth indicates significantly increasing trend with variable increasing rates and analysis carried out through Mann-Kendall method.

Table 1. Annual groundwater depth in mbgl (meter below ground level) of different tehsils in Bemetara districts (1996 to 2018).

District →	Saja	Berla	Bemetara	Nawagarh	Average of Bemetara district
Year ↓	GWD (mbgl)	GWD (mbgl)	GWD (mbgl)	GWD (mbgl)	GWD (mbgl)
1996	4.28	NA	4.75	NA	4.52
1997	4.43	NA	4.97	NA	4.70
1998	3.46	NA	5.33	NA	4.39
1999	4.40	NA	4.87	NA	4.64
2000	5.17	NA	4.66	NA	4.92
2001	5.04	NA	5.52	NA	5.28
2002	5.22	NA	5.29	NA	5.26
2003	4.55	NA	6.58	NA	5.56
2004	4.24	NA	3.49	NA	3.87
2005	3.23	NA	6.24	NA	4.73
2006	4.93	NA	4.89	NA	4.91
2007	4.47	NA	3.83	NA	4.15
2008	6.18	10.34	5.13	NA	7.22
2009	6.61	11.26	6.17	NA	8.01
2010	6.13	11.96	7.24	NA	8.45
2011	6.27	7.18	6.64	NA	6.70
2012	12.52	20.40	10.58	21.45	16.24
2013	10.65	11.85	11.37	27.75	15.40
2014	10.81	11.07	10.57	18.88	12.83
2015	5.41	6.00	9.34	20.88	10.41
2016	6.30	7.26	9.16	20.58	10.82
2017	7.66	11.72	10.98	24.84	13.80
2018	6.20	11.36	8.52	12.96	9.76

Trend analysis of annual groundwater depth tehsil wise for Kanker district

Data of annual groundwater is presented in Table 2 which reveals that groundwater depth for Kanker district was observed to be 6.39 mbgl in the year 2010 followed by 6.28 mbgl in the year 2012 and 6.11 mbgl in the year 2013. Groundwater depth of Kanker district is showing no- significant increasing pattern as compared to base period i.e. 1996.

The annual groundwater depth analysis has been done for different tehsils of Kanker district through Linear Graph Method. This analysis is showing different result i.e. Charama and Kanker tehsils are showing non-significant decreasing trend while Narharpur, Bhanupratappur and Antagarh tehsils are showing non-significant increasing trend, Koelibeda tehsil is showing significant increasing pattern and Durgkondal tehsil is showing significant decreasing pattern. Graphical representation has been shown in Figs. 6-13 for different tehsils of Kanker district.

Although there was non-significant annual increasing trend of groundwater depth in the Kanker district, it was found that groundwater depth was going down day by day as compared to 1996 base year which might be due to non judicious utilization of groundwater without effective recharge plans.

The statistical analysis of long term data of two NICRA districts viz. Bemetara and Kanker of Chhattisgarh indicates that there was significantly depleting trend of groundwater in one NICRA district Bemetara at various level of significance as indicated by increasing trend of groundwater level. Tehsils with depletion groundwater are generally in Bemetara

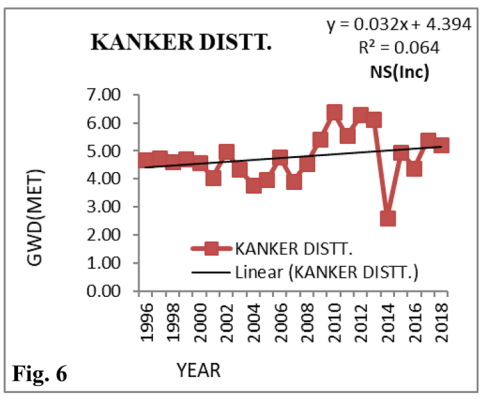


Fig. 6

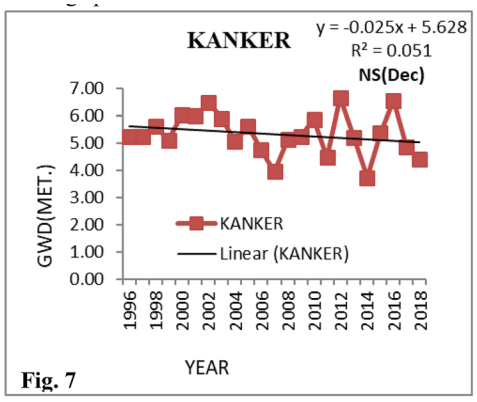


Fig. 7

* Significant at 10% level ** Significant at 5% level *** Significant at 1% level

Fig. 6. Ground water trend of Kanker district. **Fig. 7.** Ground water trend of Kanker tehsil, district Kanker.

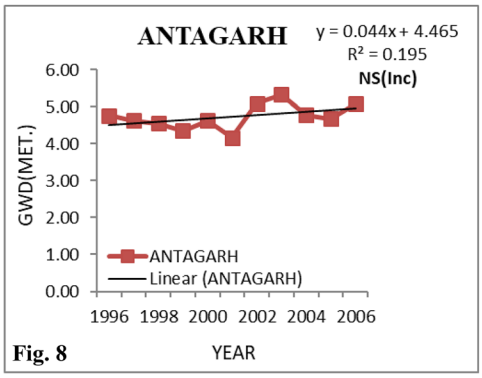


Fig. 8

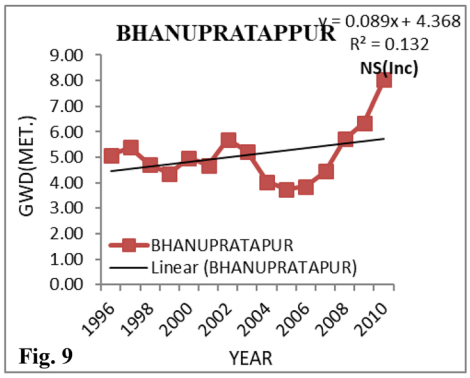


Fig. 9

* Significant at 10% level ** Significant at 5% level *** Significant at 1% level

Fig. 8. Ground water trend of Antagarh tehsil, district Kanker. **Fig. 9.** Ground water trend of Bhanupratappur tehsil, district Kanker.

district while Kanker district is not showing any significant trend. Only Koelibeda tehsil is showing significant increasing trend and Durgkodal tehsil is found to be having decreasing trend. Similar studies conducted by the Kumar *et al*. (2018) suggests that there is enormous extraction of groundwater to meet out the demand of various sectors in Lucknow district, Brocque *et al.* (2018) and Asoka *et al*. (2017) study proposed that depletion of groundwater is because of irrigation purposes in high crop intensity and high water demanding crop area, while Chinnasamy and Agoramoorthy (2015) reports suggested that groundwater is extremely dependent on rainfall, decreasing rainfall leads to depletion of groundwater. Table 3

Table 2. Annual groundwater depth in mbgl (meter below ground level) of different tehsils in Kanker districts (1996 to 2018).

Teshil → Year ↓	Antagarh GW (mbgl)	Charama GW (mbgl)	Kanker GW (mbgl)	Durkoudul GW (mbgl)	Bhanupratappur GW (mbgl)	Koelibeda GW (mbgl)	Narharpur GW (mbgl)	Average of Kanker district GW (mbgl)
1996	4.77	5.97	5.24	4.25	5.08	3.89	3.52	4.67
1997	4.63	6.82	5.22	3.43	5.39	3.84	3.92	4.75
1998	4.55	6.47	5.62	3.38	4.69	3.64	3.88	4.60
1999	4.36	6.42	5.11	4.46	4.35	4.47	3.79	4.71
2000	4.63	6.78	6.02	2.85	4.97	2.92	3.96	4.59
2001	4.17	4.09	5.98	1.70	4.69	3.51	4.27	4.06
2002	5.09	6.54	6.47	2.42	5.69	4.73	3.86	4.97
2003	5.33	5.86	5.90	0.41	5.22	4.91	2.76	4.34
2004	4.78	4.43	5.05	1.85	4.03	3.81	2.53	3.78
2005	4.68	5.20	5.62	0.40	3.75	5.21	2.95	3.97
2006	5.08	4.88	4.74	NA	3.85	5.44	4.65	4.77
2007	NA	4.80	3.94	NA	4.45	NA	2.48	3.92
2008	NA	4.09	5.12	NA	5.71	NA	3.26	4.54
2009	NA	6.04	5.24	NA	6.34	NA	4.10	5.43
2010	NA	5.35	5.86	NA	8.04	NA	6.31	6.39
2011	NA	6.62	4.46	NA	NA	NA	NA	5.54
2012	NA	5.90	6.66	NA	NA	NA	NA	6.28
2013	NA	7.02	5.20	NA	NA	NA	NA	6.11
2014	NA	1.50	3.73	NA	NA	NA	NA	2.61
2015	NA	3.64	5.37	NA	NA	NA	4.20	4.95
2016	NA	4.06	6.55	NA	NA	NA	2.55	4.39
2017	NA	4.72	4.83	NA	NA	NA	5.40	5.38
2018	NA	4.49	4.40	NA	NA	NA	5.28	5.23

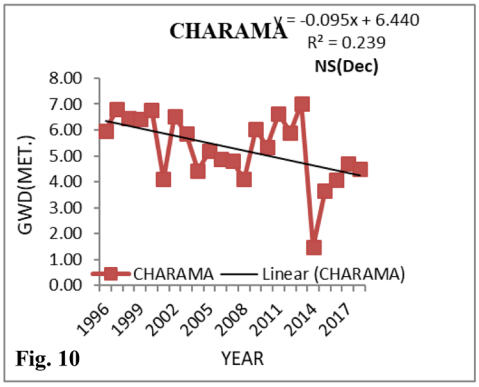


Fig. 10

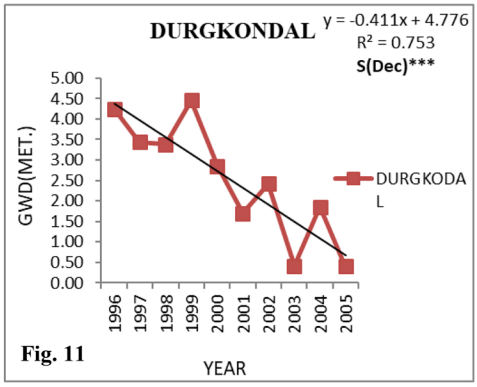
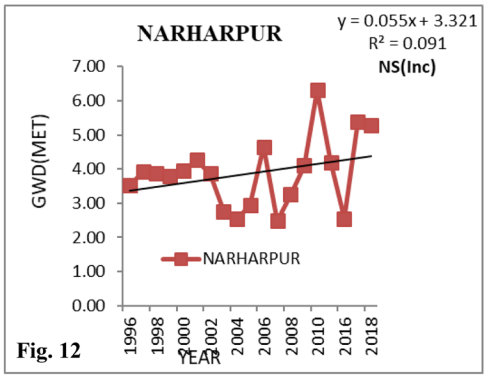


Fig. 11

* Significant at 10% level ** Significant at 5% level *** Significant at 1% level



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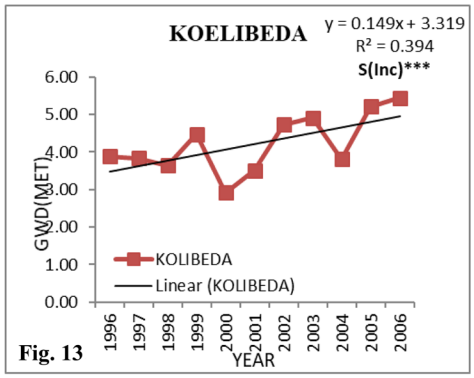

Fig. 13

* Significant at 10% level ** Significant at 5% level *** Significant at 1% level

Fig. 10. Ground water trend of Charama tehsil, district Kanker. **Fig. 11.** Ground water trend of Durgkondal tehsil, district Kanker. **Fig. 12.** Ground water trend of Narharpur tehsil, district Kanker. **Fig. 13.** Ground water Trend of Koelibeda Tehsil, district Kanker.

Table 3. Mann-Kendall trend analysis of annual groundwater depth of 11 tehsils of two districts (Bemetara and Kanker) of Chhattisgarh from 1996-2018.

Sl. No.	Tehsil	Years	Mann-Kendall Trend result	Remarks
1	Bemetara	1996-2018	S (Inc)***	Depletion pattern
2	Nawagarh	2012-2018	NS (Dec)	-
3	Saja	1996-2018	S (Inc) ***	Depletion pattern
4	Berla	2008-2018	NS (Dec)	-
5	Kanker	1996-2018	NS (Dec)	-
6	Charama	1996-2018	NS (Dec)	-
7	Narharpur	1996-2018	NS (Inc)	-
8	Bhanupratappur	1996-2010	NS (Inc)	-
9	Durgkondal	1996-2005	S (Dec)***	Recharging pattern
10	Antagarh	1996-2006	NS (Inc)	-
11	Koelibeda	1996-2006	S (Inc)***	Depletion pattern
Sl. No.	District	Years	Mean-Kendal Trend result	Remarks
1	Bemetara	1996-2018	S (Inc)***	Depletion pattern
2	Kanker	1996-2018	NS (Inc)	-

(NS (no significant), S (significant), * 10% significant level, ** 5% significant level and *** 1% significant level, Inc (increase), Dec (decrease) for Mann-Kendal trend).

also shows significantly increasing trend of annual groundwater depth for Bemetara tehsil and Saja tehsil of Bemetara district while Berla and Nawagarh tehsil are showing non significant decreasing trend.

Bemetara district recorded significantly increasing trend of groundwater depth on annual basis which reveals that the groundwater table is going down. This might be due to the fact that the district of Bemetara shows negative trends of annual rainfall. To deteriorate the situation vegetable farmers are utilizing groundwater through pumping without any systematic recharge plans.

Crop plan strategy for Bemetara district

The irrigation percentage of the district is 46.4% Groundwater (bore/tube well) is the main source of irrigation which contributes 94% of total source of irrigation.

The district showing decreasing trend of annual rainfall and groundwater depth trend indicates increasing depth with significant downfall in groundwater level. The down fall in the groundwater depth might be due to existing cropping pattern in which majority of the areas are belongs to rice, gram, soybean, wheat and vegetables which need more water throughout the year. Based on groundwater condition the crop plan strategies for the district are shown in the Table 4 along with the existing cropping pattern.

Table 4. Existing cropping system and suggested crop plan strategies for Bemetara district.

Land situation	Existing cropping system	Crop plan strategies
Un bunded upland	Mung/Urd/Pigeon pea – fallow groudnut – fallow	Over exploitation of the groundwater in the district needs sound recharge plan and its effective implementation with structured time formed Watershed management program should be implemented with effective monitoring system. Adaptation of new shor duration and low water demanding varieties with new irrigation methodology is needed to be implemented Area under soybean should be decreased and sunflower can be introduced
Bunded upland	Rice – fallow	
Midland	Rice/ Soybean– fallow Rice/Soybean – fallow	
Shallow lowland	Rice – Lathyrus/Linseed (relay) Soybean – Gram/Wheat	
Bahra lowland	Rice – fallow Soybean/Rice– Gram/ Wheat Rice – Lathyrus/ Linseed (relay)	

Table 5. Existing cropping system and suggested crop plan strategies for Kanker district.

Land situation	Existing cropping system	Crop plan strategies
Un bunded upland	Pigeon pea+Maize – fallow Rice – fallow Rice– fallow	Short duration high yielding variety of Pigeon pea, Wheat, Mung and Rice should be adopted Adaptation of modern irrigation should be made compulsory in the district
Bunded upland	Rice – fallow Maize – fallow	
Land situation	Existing cropping system	Crop plan strategies
Shallow lowland	Rice – fallow Maize – fallow Rice – fallow	Watershed management program should be implicated essentially
Bahra lowland	Rice – Lathyrus/Gram Maize – Lathyrus	

In Bemetara district existing cropping pattern need to be reallocated at village level. In district large area is in under vegetable cultivation, which requires large amount of irrigation throughout the year, so there should be policy on water management and their rational use.

Crop plan strategy for Kanker district

In Kanker district very less area is under irrigation i.e. 14.3% where the main source of irrigation is groundwater (bore/tube well) which is about 78% of total irrigation resource.

The district is not showing any significant trend in rainfall and groundwater depth but the groundwater depth fallen down in 2018 from 1996 status. The district has sloppy lands, low irrigation (through canals) and high groundwater use has been observed. Based on the situation existing cropping pattern and crop plan strategies for the district are given in the Table 5.

CONCLUSION

On the basis of trend results of groundwater it was concluded that in most of the tehsils groundwater is

falling down. The matter of concern is for district Bemetara which requires immediate attention. There is also need to change the existing cropping. Effective implementation of watershed management plan and groundwater recharge plan are the primary needs. Durgkondal tehsil of Kanker district groundwater level is found to be in significant decreasing pattern. It indicates that groundwater recharging is taking place in this tehsil. The crop plan strategies have to be reframed based on the trend analysis of extreme events (dry and wet spells) and groundwater depth. The existing crop plan should be changed in Bemetara district adopting high yielding crop varieties and their cropping sequences is suggested as different situations.

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