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Groundwater Recharge Prospects for Sustainable *Rabi* Crop Planning in Semi-Arid Regions

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ABSTRACT: India experiences water scarcity though the average annual rainfall of the country is 1170 mm which is higher than the global average of 800 mm. Groundwater is utilized for irrigation in approximately 60% of the net irrigated area, with several districts classified under the over-exploited groundwater category. Hence, *in-situ* moisture conservation, critical irrigation using harvested rainwater, optimal groundwater management and recharging of aquifers are very essential for the sustainability of water resources. The planning of *rabi* crops depends upon the residual moisture content in the soil and the availability of surface and ground water. Since it is impossible to measure groundwater recharge directly and numerous methods which are complex, costly and needs huge data have been used to estimate recharge. In this study, an attempt was made to estimate groundwater recharge prospects by considering the spatial and temporal variability of rainfall in the selected region to support the sustainable planning of *rabi* crops such as rice, wheat, mustard and rapeseed. These crops are typically cultivated under well-irrigated systems. Significant spatial variation in groundwater recharge prospects was observed during 2022 and 2023. In comparison to 2022, the number of districts classified under the normal category decreased considerably in 2023 due to drought conditions.

Keywords: Crop planning, groundwater recharge, semi-arid regions, spatial, temporal

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Introduction

The rapid industrialization, population growth, climate change and agricultural activities resulted in over-utilization of the fresh water resources leading to reduction of groundwater level in many parts of India (Kadam *et al.,* 2012). India has a higher average annual rainfall of 1170 mm compared to the global average of 800 mm, in spite of this; the country faces water scarcity (Jasrotia, 2009). India is the largest user of groundwater for irrigation in the world, estimated as 210 billion cubic meters per year when compared to 105 billion cubic meters in China and 100 billion cubic meters in US (Shankar *et al.,* 2011). According to the 2005-06 Agricultural Census, 60.4% of the net irrigated area in India uses groundwater. According to the Central Ground Water Board (CGWB), ground water is over-exploited in 15% of the administrative blocks and that the rate of depletion is growing 5.5% per annum. Substantial decline in groundwater level was observed in North Western India over a period of 30 years (1980 to 2010) and this includes many parts of Gujarat and Rajasthan where the groundwater level fell more than 16 meters (Sheetal Sekhri, 2012). A decline of 1 to 4 meters was observed in states like Telangana and Andhra Pradesh. The depletion of groundwater resources has increased the cost of pumping, caused seawater intrusion in coastal areas and has raised questions about sustainable groundwater supply as well as environmental sustainability (Rejani *et al.,* 2009). Hence, optimal groundwater management and recharging of aquifers are very essential. Rainwater management is one of the most critical components of rainfed farming and the successful production of crops largely depends on how efficiently the soil and water are conserved *in-situ* and the surplus runoff is harvested and utilized (Srinivasarao *et al.,* 2013). Rainwater harvesting for groundwater recharge reduces the runoff, prevents soil erosion and thus controls the loss of fertile top soil, reduces the sedimentation in streams and rivers and clogging of water ways (Morgan, 2005; Labrière *et al.,* 2015; Rejani *et al.,* 2022).

Drylands in India are experiencing more frequent water scarcity events usually in summer months and in drought years. As rainfed agriculture is prime source of income for local inhabitants to meet their livelihood needs, today's environmental externality is a threat to agricultural sustainability. One of the major constraints for agricultural production is the availability of irrigation water during dry spells. Sometimes, droughts may generate severe water shortage even for drinking purpose due to decline of groundwater table. Precise estimation of groundwater recharge is very important for efficient management of groundwater systems (Healy and Cook, 2002). Many researchers reported that recharge depend on various parameters like rainfall, soil type, vegetation, land use and topography (Jyrkama *et al.,* 2002; Singhal and Goyal, 2012). It is very difficult to measure groundwater recharge because it will diffuse and varies both spatially and temporally (Cherkauer, 2004). Numerous methods ranging widely in complexity and cost and some methods which needs huge data have been used to estimate recharge (Lerner *et al.,* 2020). Some commonly used methods are based on unsaturated-zone drainage, water balance (Dripps and Bradbury, 2007; Lee *et al.,* 2006), water-table fluctuations, base flow separation from hydrographs (Risser *et al.,* 2005), GIS and remote sensing techniques etc. (Lakshminarayana and

Venkateswara Rao, 2014). Some norms are also available for estimating the groundwater recharge considering the districts as a whole and prediction and assessment of variability of recharge is probably one of the most difficult and important problems to overcome. Hence, by conserving moisture in the soil by *in-situ* and *ex-situ* measures, supplementary irrigation of harvested water and groundwater recharge are very essential to achieve optimal crop yield and for the sustainable management of aquifers (Rejani *et al.*, 2022). In this study, an attempt was made to estimate the groundwater recharge prospects considering the spatial and temporal variability of rainfall in the selected region for the sustainable planning of *rabi* crops.

Materials and Methods

Determination of groundwater recharge

The rainfall intensity, distribution and the total rainfall influences the groundwater recharge during the monsoon period. The precise estimation of groundwater recharge would require considerable time and large quantities of data. In this study, a simplified methodology is adopted and the criteria followed for groundwater recharge prospects are presented in Table 1. The weeks with rainfall ranged from -19 to -59% of the normal weekly rainfall is considered as deficit rainfall weeks and weeks with rainfall <= -59% of the normal weekly rainfall is considered as scanty rainfall weeks. After categorizing the rainfall weeks, the qualitative estimation of groundwater recharge prospects was attempted by interpreting the weekly rainfall received for each district. For example, if scanty rainfall is received in more than 65% of weeks or deficit rainfall is received are more than 80% of weeks on cumulative basis, the recharge possibility is considered to be extremely low.

Table 1: Criteria for groundwater recharge assessment

Percent of deficit rainfall weeks	Percent of scanty rainfall weeks	Groundwater recharge prospects
80	65	Extremely low
70	50	Very low
50	30	Low
30	10	Medium
10	0	Normal

Rainfall data from IMD (www.imd.gov.in) pertaining to different districts of India was utilized for the groundwater recharge analysis. The area under different crops in each district was used for finding the groundwater prospects of that particular crop. The prominent crops included in this study are rice, wheat, rapeseed and mustard. The groundwater recharge prospects were determined for the years 2022, 2023 and was plotted using ARCGIS for analyzing the spatial and temporal variability in recharging prospects.

Results and Discussion

Groundwater recharge prospects

The groundwater recharge prospects during 2022 and 2023 were determined. Based on the criteria given in Table 1, the groundwater recharge due to monsoon rainfall in 2022 was extremely low to very low in about 124 districts (16% of total districts). About 21% of total districts had low to extremely low prospects for groundwater recharge. About 44 districts each in Uttar Pradesh and Bihar, 11 districts in Punjab and 13 districts in Haryana were among these 124 districts. Less than normal rainfall in states like Kerala, Manipur, Mizoram and Nagaland affected the groundwater recharge prospects. Prospects for groundwater recharge were normal in about 260 districts with majority of them in Madhya Pradesh, Rajasthan, Bihar, Maharashtra, Odisha, West Bengal and Andhra Pradesh.

Based on the above criteria, the ground water recharge due to monsoon rainfall was extremely low to very low in about 145 districts during 2023. About 172 districts (27% of total districts) had low to extremely low prospects for groundwater recharge. About 401 districts seem to have medium prospects for recharge. Prospects for groundwater recharge were normal in about 126 districts distributed across the country. About 50% of districts in Assam, Arunachal Pradesh, Odisha and West Bengal, which were expected to be receiving less than normal rainfall, had the prospects of normal recharge. In western states of Rajasthan and Gujarat, the prospects for recharge vary from medium to normal in many districts. In southern states except for Kerala, prospects for groundwater recharge improved with rainfall during last week of August to September months. In Kerala, prospects for recharge in many districts varied from extremely low to low category.

Prospects of groundwater recharge in *rabi* cropped areas

Districts with significant area in *rabi* season for different crops were identified during 2022 and 2023. These districts cover 80% of *rabi* area under each crop. The crops considered for the study included wheat, rice, rapeseed and mustard. During 2022, out of 419 districts identified to be dominant for *rabi* areas, 59 districts had extremely low to low groundwater recharge prospects. Among the 59 districts, 39 districts were spread over in Uttar Pradesh, 8 districts in Bihar, 5 districts in Jharkhand, 7 districts in Telangana and one district each in Madhya Pradesh and Rajasthan.

During 2023, the crops considered for the study included wheat, rice, rapeseed and mustard. Out of 419 districts identified to be dominant for *rabi* areas, 58 districts had extremely low to very low groundwater recharge prospects. These 58 districts include 16 in Maharashtra, 13 in Uttar Pradesh, 10 in Assam, 6 in Assam, 4 in Rajasthan, 3 in Gujarat and Madhya Pradesh and one in Karnataka and remaining in other states.

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Prospects of groundwater recharge in rice growing areas

About 109 districts were identified for growing rice under *rabi* season and were spread out in Andhra Pradesh, Assam, Bihar, Jharkhand, Karnataka, Kerala, Odisha, Telangana, Uttarakhand and West Bengal. Based on the *rabi* cropped area, area with different sources of irrigation available in this district, these districts have been categorized into canal irrigated, well irrigated, dependent on residual moisture, etc. For the present analysis, the states of Andhra Pradesh, Bihar, Jharkhand, and Telangana were considered due to availability of irrigation information. Among these 4 states, about 11 districts are depending on canal irrigation system and 7 districts are in Andhra Pradesh and 4 districts in Bihar. Around 17 districts depend on well irrigation and 9 districts are spread in Bihar, 7 districts in Telangana and only one district in Andhra Pradesh.

Among the 17 districts dependents on well irrigation, the groundwater recharge prospects in 2022 were very low in 4 districts of Bihar (Table 2a & Fig. 1a). Attempts to grow rice during *rabi* season in these districts would deplete the available groundwater. The districts include Banka, Muzaffarpur, Siwan, and Nalanda in Bihar; Mahabubnagar, Nizamabad and Medak in Telangana and Kurnool in Andhra Pradesh. Attempt to grow rice in *rabi* season with residual moisture and/or with well irrigation could also suffer due to very low to low prospects of ground water recharge during the selected season.

Among these 17 districts, the groundwater recharge prospects during 2023 were very low in 5 districts i.e., Dharbanga, Gaya, Muzaffarpur, Siwanand Patna in Bihar (Table 2b & Fig. 1b). Attempts to grow rice during *rabi* season in these districts would deplete the available groundwater. In all other districts located in Andhra Pradesh, Bihar, Jharkhand and Telangana, the groundwater recharge prospects were medium to normal during the *kharif* season. Though districts of Andhra Pradesh and Telangana have the prospects for normal groundwater recharge, cultivation of rice could be dissuaded and crops such as *rabi* pulses and oilseeds could be promoted to enhance the cropping intensity. Compared to 2022, the number of districts under normal category of groundwater recharge prospects in rice was reduced considerably in 2023 due to drought.

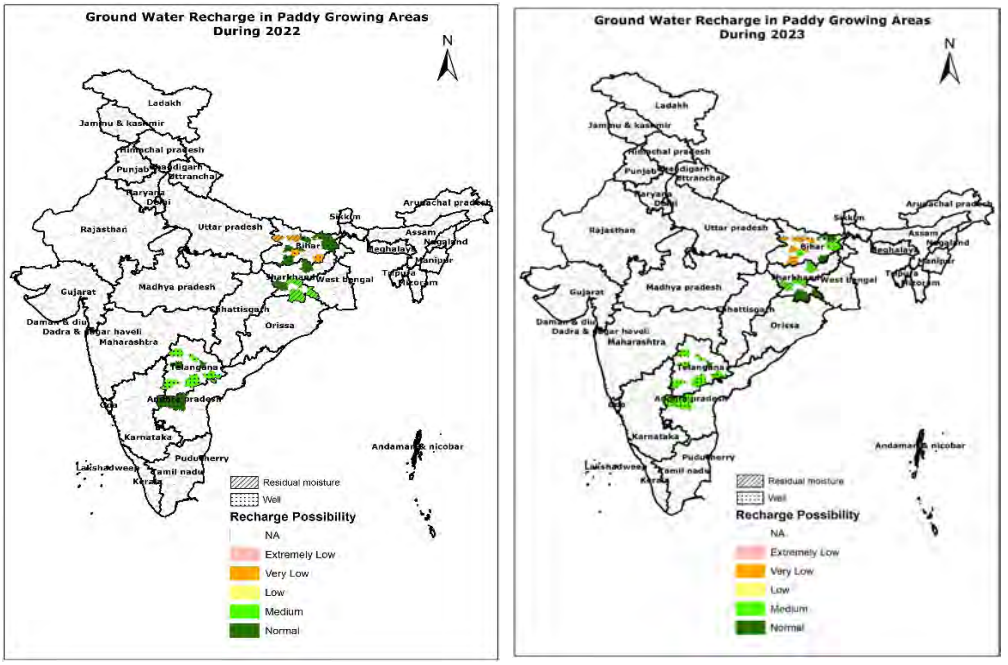

Fig. 1(a & b): Groundwater recharge prospects in rice growing areas during 2022 and 2023

Table 2a: Groundwater recharge prospects in rice growing areas during 2022

Recharge prospects	State	Districts
Very low	Bihar	Muzaffarpur, Nalanda, Swian
Medium	Jharkhand	East Singhbhum, West Singhbhum, Ranchi
	Telangana	Karimnagar, Khammam, Mahabubnagar, Nalgonda, Nizamabad

Normal	Andhra Pradesh	Kurnool
	Telangana	Medak, Warangal
	Jharkhand	Gumla, Giridish
	Bihar	Darbanga, Gaya, Katihar, Patna, Purnia, Saupal, Banka, Araria,

Table 2b: Groundwater recharge prospects in rice growing areas during 2023

Recharge prospects	State	Districts
Very low	Bihar	Darbhanga, Patna, Muzaffarpur, Siwan, Gaya
Medium	Andhra Pradesh	Kurnool
	Bihar	Katihar, Nalanda, Purnia,
	Telangana	Khammam, Karimnagar, Mahabubnagar, Medak, Nizamabad, Nalgonda
	Jharkhand	Giridish, Gumla, Ranchi
Normal	Telangana	Warangal
	Bihar	Saupal, Banka, Araria
	Jharkhand	East Singhbhum, West Singhbhum

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Prospects of groundwater recharge in wheat growing areas

About 170 districts were identified to be growing wheat crop. In that 62 districts were located in Uttar Pradesh, 32 in Madhya Pradesh, 16 districts each in Punjab, Haryana and Rajasthan, 13 in Bihar and others in states of Gujarat, Himachal Pradesh, Jammu & Kashmir etc. Among these 170 districts, canal irrigation is predominant in 45 districts of Punjab, Haryana, Rajasthan and Uttar Pradesh. Wheat grown under well irrigated systems in 95 districts and were located in Uttar Pradesh, Madhya Pradesh, Rajasthan, Bihar and Gujarat (Fig. 2a & b). Other systems include canals and residual moisture. Among the districts with canal irrigation facility for wheat crop, during 2022, a total of 21 districts had the possibility of low groundwater recharge prospects during the *kharif* season (Table 3a & Fig 2a). Around 50% of these districts were in Uttar Pradesh. Among the districts with canal irrigation facility for wheat crop, only 5 districts out of 45 districts had very low to low ground water recharge prospects. However, considering the storage available in the reservoirs, normal area could be sown during *rabi* crop. Out of 96 districts, in 19 districts groundwater plays a dominant role in wheat cultivation, and were spread in Uttar Pradesh (14 districts), Bihar (3 districts), one in Gujarat had very low ground water recharge prospects during the monsoon, which could impact the wheat cultivation and production. About 27 out of 96 districts, 16 were in Uttar Pradesh, 3 districts in Bihar, 2 districts in Madhya Pradesh and one district each in Gujarat and Rajasthan had very low prospects for groundwater recharge. About 24 out of 95 districts, 23 districts from Uttar Pradesh, one district in Bihar had low prospects. About 51 districts had a possibility of medium to normal recharge prospects which indicates opportunities for better wheat cultivation under well irrigated areas as well.

During 2023, a total of 24 districts, 12 in Uttar Pradesh, 4 in Bihar and 3 in Gujarat, 2 in Madhya Pradesh and Maharashtra and one in Rajasthan had the possibility of very low groundwater recharge prospects during the *kharif* season (Table 3b & Fig. 2b). Among the districts with canal irrigation facility for wheat crop, 9 districts out of 45 districts had extremely low to very low ground water recharge prospects. However, considering the storage available in the reservoirs which support these districts, there may not be any deficiency in availability of canal irrigation and normal area could be sown during *rabi* crop. About 96 districts, where groundwater plays a dominant role in wheat cultivation, 68 districts spread 32 were in Uttar Pradesh, 3 in Bihar, 18 in Madhya Pradesh, 11 in Rajasthan, 3 districts each in Gujarat and Bihar and one district in Maharashtra had medium to normal ground water recharge prospects during the monsoon. Nearly 4 of 95 districts, 2 were in Uttar Pradesh, 2 districts in Bihar had low prospects for groundwater recharge. With better prospects of groundwater recharge in 68 districts, the cropped area under wheat could substantially go up during the *rabi* season. In 11 districts, where the groundwater recharge prospects were extremely low to very low, *rabi* pulses could be

promoted. Compared to 2022, the number of states with districts under very low category of groundwater recharge prospects in wheat was increased considerably in 2023 due to the prevalent drought situations.

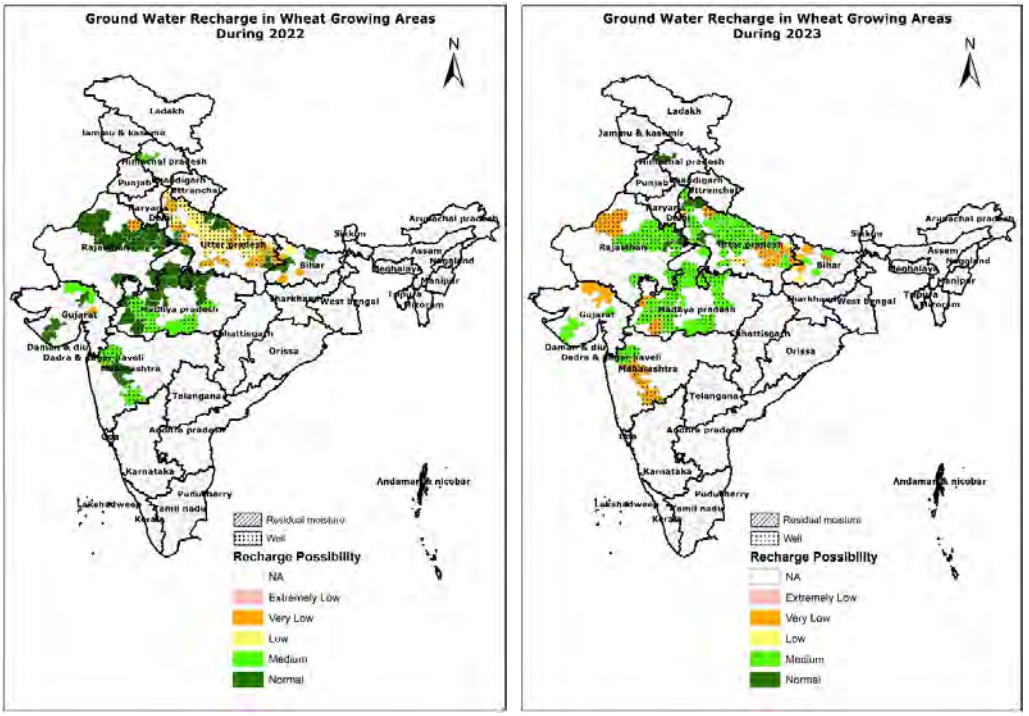

Fig. 2 (a & b): Groundwater recharge prospects in wheat growing areas during 2022 and 2023

Table 3a: Groundwater recharge prospects in wheat growing areas during 2022

Recharge prospects	State	Districts
Very low	Bihar	Aurangabad, Nalanda, Siwan
	Rajasthan	Jhunjhunun
	Gujarat	Kheda
	Uttar Pradesh	Aligarh, Azamgarh, Bahraich, Ballia, Balrampur, Barabanki, Deoria, Etah, Fatehpur, Firozabad, Gorakhpur, Hamirpur, Jaunpur, Meerut, Muzaffarnagar, Sant Kabir Nagar
Low	Bihar	Champaran (East)
	Uttar Pradesh	Amdedkarnagar, Badaun, Bareilly, Basti, Bijnor, Bulandshar, Faizabad, Farrukhabad, Gauttam Budd Nagar, Gonda, Hardoi, Kannauj, Khanpur Dehat, Kushinagar, Lucknow, Moradabad, Rampur, Meerut, Rampur, Saharanpur, Shahjahanpur, Siddharth Nagar, Sitapur, Sulthanpur, Unnao
Medium	Gujarat	Banaskantha, Rajkot
	Himachal Pradesh	Hamirpur
	Madhya Pradesh	Betul, Chhindwara, Dewas, East Nimar, Indore, Jabalpur, Ujjain
	Maharashtra	Nasik, Solapur
Normal	Bihar	Bhojpur, Buxar, Saran, Darbhanga, Madhubani
	Gujarat	Junagarh, Mahesana, Rajkot.
	Madhya Pradesh	Ashoknagar, Bhindi, Bhopal, Chhatarpur, Damoh, Dhar, Guna, Rajgarh, Ratlam, Khargone (West Nimar), Shajapur, Shivpuri, Tikamgarh.
	Rajasthan	Alwar, Baran, Bharatpur, Bikaner, Chittorgarh, Dausa, Jaipur, Karauli Nagaur, Sikar

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Maharashtra	Ahmadnagar
Uttar Pradesh	Agra, Ghazipur, Kheri, Lalitpur, Hathras, Mau, Pilibit

Table 3b: Groundwater recharge prospects in wheat growing areas during 2023

Recharge prospects	State	Districts
Very low	Bihar	Bhojpur, Darbhanga, Purab Champran, Siwan
	Gujarat	Banaskanta, Mahesana, Sabarkanta
	Madhya Pradesh	Ratlam, West Nimar
	Maharashtra	Ahmadnagar, Sholapur
	Rajasthan	Bikaner
	Uttar Pradesh	Ambedkarnagar, Azamnagar, Ballia, Balarampur, Deoria, Faizabad, Ghazipur, Gorakhpur, Jaunpur, Moradabad, Rampur, Sulthanpur
Low	Bihar	Aurangabad, Buxar
	Uttar Pradesh	Fatehpu, Kushinagar
Medium	Bihar	Saran, Madhubani, Muzaffarpur
	Gujarat	Junagadh, Kheda, Rajkot
	Madhya Pradesh	Ashoknagar, Betul, Bhind, Bhopal, Chhatarpur, Chindwara, Damoh, Dewas, Dhar, Guna, Indore, Jabalpur, Khandwa (East Nimar), Rajgarh,Shajapur, Shivpuri, Tikamgarh, Ujjain
	Maharashtra	Nasik
	Rajasthan	Alwar, Baran, Chittorgarh, Jaipur, Jhunjhunun, Karauli, Nagaur, Sikar
	Uttar Pradesh	Agra, Aligarh, Badaun, Bahraich, Barabanki, Bareilly, Basti, Balandshar, Farrukhabad, Gazipur, Gonda, Hamirpur, Hardoi, KhanpurDehat, Kheri, Lalitpur, Lucknow, Hathras, Mau, Meerut, Phlibhit, Saharanpur, Sant kabirdasnagar, Shahjahanpur, Siddarthnagar, Sitapur, Unnao
Normal	Himachal Pradesh	Kangra
	Rajasthan	Bharatpur, Dausa
	Uttar Pradesh	Bijnor, Etah, Firozabad, Kannauj, Muzaffarnagar

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Prospects of groundwater recharge in rapeseed and mustard growing areas

More than 80% of rapeseed & mustard is being cultivated in 70 districts spread in Rajasthan, Madhya Pradesh, Haryana, West Bengal, Uttar Pradesh etc. Among these 70 districts, well and canal irrigation systems were dominant in 45 and 11 districts, respectively. In about 9 districts, residual moisture plays a dominant role. About 11 districts with canal irrigation system spread in Haryana, Rajasthan and Uttar Pradesh had the possibility for low to normal groundwater recharge prospects and the cropped area may not reduce as the storage in reservoirs which support the canal systems is sufficient. During 2022, among 45 districts, where well irrigation is dominant, only one district in Madhya Pradesh had extremely low prospects for ground water recharge (Fig. 3a & Table 4a). About 6 districts, spread in Rajasthan, Uttar Pradesh and West Bengal had very low prospects for groundwater recharge and 3 districts, each in Bihar, Uttar Pradesh and West Bengal had low ground water recharge prospects. About 47 districts had medium to normal prospects for groundwater recharge. With 24 districts in Rajasthan having normal recharge prospects, better production of rapeseed and mustard could be realized. Among the districts (9) which were dependent on residual moisture for crop production, only one district had extremely low to low prospects for groundwater recharge and remaining 6 districts had medium to normal prospects for groundwater recharge.

During 2023, among 45 districts, where well irrigation is dominant, 8 districts spread in 3 districts each in Gujarat and Rajasthan, one district each in Bihar and Uttar Pradesh had the possibility of very low groundwater recharge prospects (Fig. 3b & Table 4b). The remaining 49 districts spread in Rajasthan (20), West Bengal (5), Madhya Pradesh (7), Assam (4), Telangana and Uttar Pradesh (3), one district each Jammu & Kashmir and Haryana had the prospects of groundwater recharge varying from medium to normal. With 19 districts in Rajasthan having normal recharge prospects, better production of rapeseed and mustard could be realized. Among the districts (9) which were dependent on residual moisture for crop production, only 3 districts had very low to low prospects for groundwater recharge and remaining 6 districts had medium to normal prospects for groundwater recharge. Thus, better area and production of rapeseed and mustard was realized. Compared to 2022, the number districts under normal category of groundwater recharge prospects in mustard were decreased from 38 districts to 10

districts in 2023 due to the prevalent drought situations. Similarly, the numbers of districts under very low groundwater recharge prospects in mustard were increased considerably in 2023 due to drought.

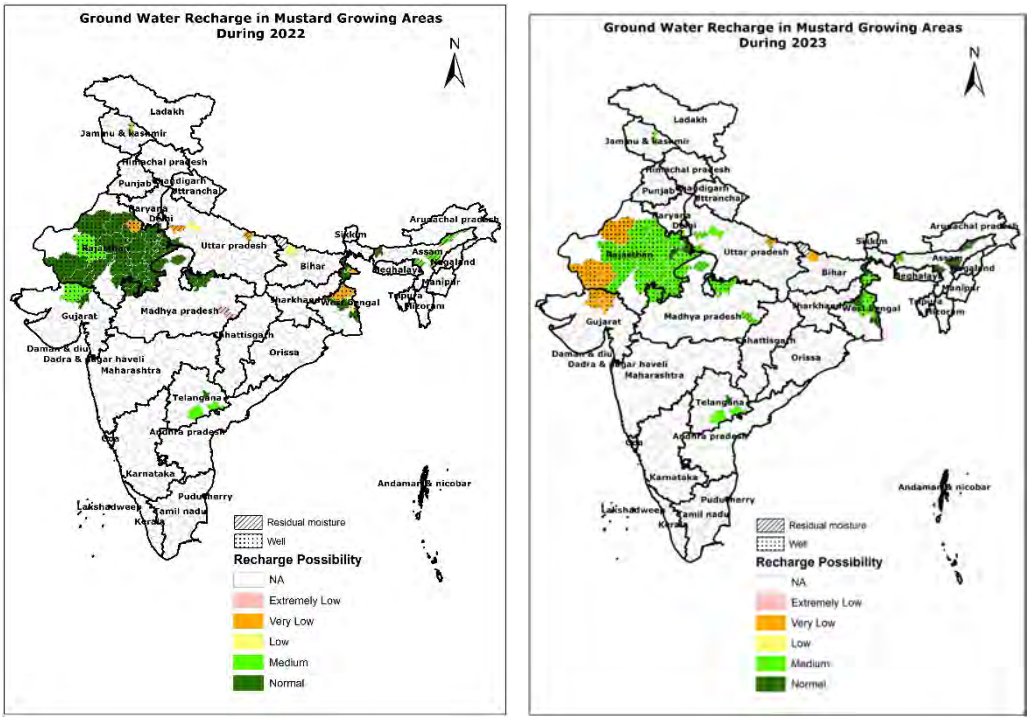

Fig. 3 (a & b): Groundwater recharge prospects in mustard and rapeseed growing areas during 2022 and 2023

Table 4a: Groundwater recharge prospects in mustard and rapeseed growing areas during 2022

Recharge prospects	State	Districts
Extremely low	Madhya Pradesh	Dindori
Very low	Rajasthan	Junjhunun
	Uttar Pradesh	Aligarh, Balarampur
	West Bengal	Birbhum, Murshidabad, South Dinajpur
Low	Bihar	Purab Champaran
	Uttar Pradesh	Baudan
	West Bengal	Nadia
Medium	Assam	Dhemaji, Karbi Analong, Lakhimpur
	Gujarat	Banaskantha, Patan
	Jammu and Kashmir	Ananthnag
	Rajasthan	Jodhpur
	Telangana	Khammam, Nalgonda
Normal	Assam	Kokrajhar
	Gujarat	Mahesana
	Haryana	Mewat
	Telangana	Warangal
	Madhya Pradesh	Chattarpur, Gawlior, Mansaur, Neemuch, Sheopur, Tikamgarh
	Rajasthan	Ajmer, Alwar, Baran, Barmer, Bharatpur, Bilwara, Bikaner, Bundi, Chittorgarh, Churu, Dausa, Dhaulpur, Jaipur, Jalore, Jhalawar, Karauli, Kota, Nagaur, Pali, Sawai Madhopur, Sikar, Sirohi, Tonk
	Uttar Pradesh	Agra

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	West Bengal	Bankura, 24-Parganas (North), Malda, North Dijajpur

Table 4b: Groundwater recharge prospects in mustard and rapeseed growing areas during 2023

Recharge prospects	State	Districts
Very low	Bihar	Purab Champaran
	Gujarat	Banaskanta, Mahesana, Patan
	Rajasthan	Barmer, Bikaner, Jalor
	Uttar Pradesh	Balarampur
Medium	Assam	Kokrajhar
	Haryana	Mewat
	Jammu & Kashmir	Anantnag
	Madhya Pradesh	Chattarpur, Dindori, Gwalior, Mandsaur, Neemuch, Sheopur, Tikamgarh
	Rajasthan	Ajmer, Alwar, Baran, Bhilwara, Bundi, Chittorgarh, Churu, Dhaulpur, Jaipur, Jhalawar, Junjhunun, Jodhpur, Karauli, Kota, Nagaur, Pali, Sawi Madhopur, Sikar, Sirohi, Tonk
	Telangana	Khamam, Nalgonda
	Uttar Pradesh	Agra, Aligarh, Badaun
	West Bengal	Bardhaman, Maldha, Murshidabad, Nadia, South Dinajpur
Normal	Assam	Dhemaji, karbi Anglong, Lakimpur
	Rajasthan	Bharatpur, Dausa
	Telangana	Warangal
	West Bengal	Birbhum, 24-Parganas (North), North Dinajpur

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Conclusion

Based on the classification of deficient and scanty rainfall weeks, the groundwater recharge prospects for *rabi* crop planning were assessed during 2022 and 2023. The ground water recharge potential due to monsoon rainfall in 2022 was extremely low to very low in about 124 districts and about 21% of total districts had low to extremely low prospects for groundwater recharge. During 2022, out of 419 districts identified to be dominant regions for *rabi* crops, 59 districts had extremely low to very low groundwater recharge prospects. During 2023, out of 419 districts identified to be dominant for *rabi* crops cultivation areas, 58 districts had extremely low to very low groundwater recharge prospects. The rice, wheat, mustard and rapeseed were generally grown under well irrigation systems. Considerable spatial variation in groundwater recharge prospects in different crop growing areas was noticed in 2022 and 2023. Compared to 2022, the number of states with districts under normal category of groundwater recharge prospects in rice, wheat, mustard and rapeseed had decreased considerably in 2023 due to the prevalent drought situations. Hence, for all the three crops under cultivation in various districts compared to 2022, there were very low prospects for groundwater recharge in 2023 due to drought.

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