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An Assessment of Ground Water Level in Tamil Nadu State - GIS Approach

P C Abdul Muhimin¹, J V Remya¹, Sruthy Vijay¹, Emayavaramban²

¹ Student, Department of Geography, Madurai Kamaraj University

² Professor & Head, Department of Geography, Madurai Kamaraj University

Abstract

Groundwater is an essential resource that is used for drinking water, agriculture, ecosystem maintenance, and other purposes. It is also important for the environment. The groundwater level is highly affected by the monsoon season, and as our study area is a semi-arid region, the fluctuation in rainfall has a high effect on its groundwater level. For this study, we used 29 years of rainfall data collected from the Tamil Nadu Water Supply and Drainage Board (TWAD) and the Tamil Nadu State Environment and Related Issues (TNENVIS), and to find the drought prone areas, we used the Standardised Ground Water Index method. The results of our study indicated that certain areas in the region are highly susceptible to drought conditions due to the variability in rainfall patterns and overexploitation. This information can be valuable for policymakers and stakeholders in implementing strategies to manage and conserve groundwater resources effectively.

Keywords: Ground water level; Drought; Pre-monsoon; Post-monsoon

Introduction

The treasure buried beneath our feet is groundwater. Subterranean fissures and gaps in rocks, sand, and soil are filled with fresh water. It can be compared to an enormous, wet subterranean sponge. With its ongoing movement and interaction with surface water in the form of lakes, rivers, and streams, groundwater is a vital component of the Earth's water cycle. It is essential to our existence because it irrigates crops, sustains healthy ecosystems, and provides drinking water to millions of people worldwide. The level of groundwater can vary depending on a number of factors, including rainfall, the type of rock or soil beneath the surface, and the rate of groundwater withdrawal.

In general, groundwater levels are highest in areas with high rainfall and permeable soils, and they are lowest in areas with low rainfall and impermeable soils.

Methodology

For the study of ground water level of Tamil Nadu State we used data of 29 years (1991-2019). Secondary data are used for this study and they are collected from Tamil Nadu Water Supply And Drainage Board (TWAD), Tamil Nadu State Environment and Related Issues (TNENVIS) and to find the drought prone areas we used the method Standardized Ground Water Index and the equation for this is $SGI = (W - W_m) / SD$.

Study Area

Study area is located along 13.09°N and 80.27°E. Tamil Nadu is bordered by Eastern Ghats in north, Kerala in the west, Bay of Bengal in east and Indian Ocean in south. It covers an area of 130,058 km sq. With more than a thousand km of coastline, sandy beaches, rocky cliffs, and lagoons can be found across Tamil Nadu. The Eastern Ghats are located to the north, and the Western Ghats rise along the western boundary. Fertile plains created by enduring rivers like the Cauvery and Palar dominate the centre areas.

Observations

Groundwater Level in Pre-Monsoon Season

Ariyalur

As per the analysis of 29 years of groundwater level in Ariyalur district (Figure 1) during pre-monsoon season (may), the lowest level of groundwater is shown in the year 2005 with a value of 5.7, followed by 1994 (7), 1995 and 1998 (8.4), 2004 (8.5), 2006 (8.7) respectively. During this time span the highest amount of groundwater level in 2017 (31.7), followed by 2018 (31.3), 2019 (30), 2016 (28.7), 2015 (25.66) respectively. Upto 2009 the ground water level shows high fluctuations, from 2010 to 2014 a constant drop in ground water level is shown, the value depicted by 2015 is as same as 2014, from 2016 to 2018 it again depicts continuous drop in ground water level and in 2019 it denotes a rise in ground water level.

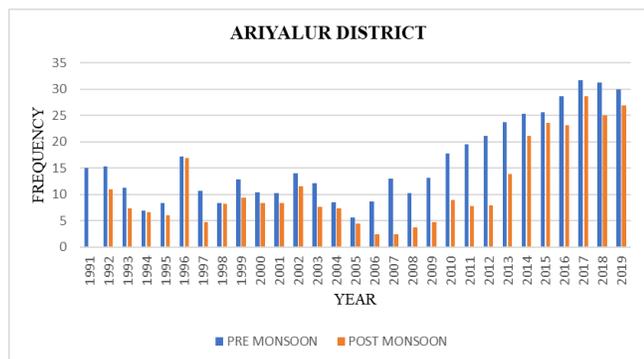


Fig. 1. Ariyalur District

Coimbatore. As per the analysis of groundwater level in Coimbatore district during pre-monsoon season, the highest level of groundwater is shown in the year 2012 with a value of 12.2, followed by 2006 (12.7), 1999(13), 2011(13.2), 2000(13.5), 1997(13.8) respectively.

From the observation (Figure 2) we come to an inference that 1991 to 1999 depict high variations in the ground water level. during the year 2000 and 2001, it shows a slight drop in the ground water level. A steep drop in ground water level

is represented by 2002 and 2004, among which the lowest ground water level is marked by 2004. From 2005 to 2016, it represents high fluctuations. In the year 2017, it shows a steep drop in ground water level and after that it rises slowly.

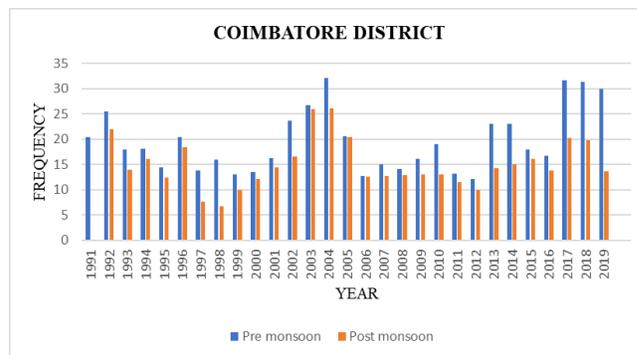


Fig. 2. Coimbatore District

Cuddalore. The lowest ground water level during pre-monsoon in Cuddalore district (Figure 3) was denoted in the year 2019 with the value 36.6 followed by 36.1 in 2017 and 35 in 2018. The highest ground water level values during pre-monsoon were recorded in the year 2011 with the value 13.1 followed by 13.6 in 2019 and 13.9 in 2008&2012. The ground water level of Cuddalore shows high fluctuation all over the study period.

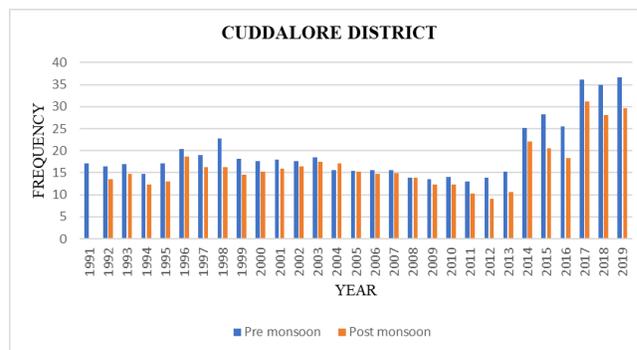


Fig. 3. Cuddalore district

Dharmapuri. The lowest ground water level during pre-monsoon in Dharmapuri district (Figure 4) was denoted in the year 2014 with the value 21.2 followed by 20.9 in 2003 and 17.9 in 2004. The highest ground water level values during pre-monsoon were recorded in the year 2012 with the value 6.6 followed by 7 in 2011 and 7.4 in 2006.

The ground water level shows high fluctuations in 1991 and 1992. Year 1993 shows a drop in ground water level and after that it shows slight rise in the level from 1994 and 1995. From the year 1996 to 2002, it depict small fluctuations in the



ground water level. During 2003 the ground water level falls steeply. From 2003 itself the ground water level shows high variations.

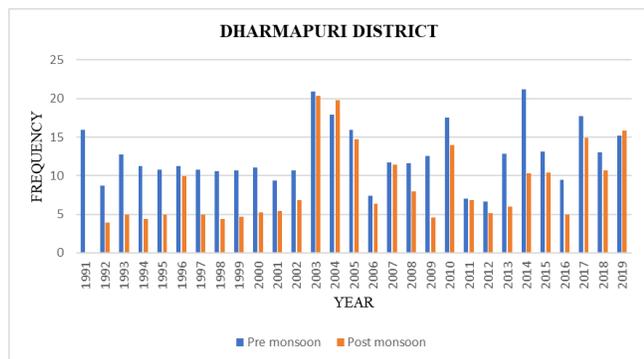


Fig. 4. Dharmapuri district

Dindigul. The lowest ground water level during pre-monsoon in Dindigul district (Figure 5) was denoted in the year 2017 with the value 21.5 followed by 16.3 in 2019 and 14.3 in 2014. The highest ground water level values during pre-monsoon were recorded in the year 2008 with the value 3.8 followed by 4.7 in 2006 and 5.5 in 1994.

During the year 1991 to 1993 shows slight variations in the ground water level, 1994 and 1995 depicts rise in the ground water level. Again in 1996 there is a fall in the groundwater level, from 1997 it again shows a rise in groundwater level upto 1999. Year 2000 onwards it shows a highly irregular groundwater level upto 2019.

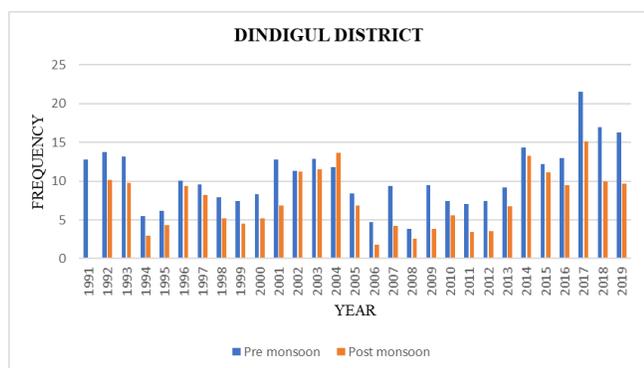


Fig. 5. Dindigul district

Erode. The lowest ground water level during pre-monsoon in Erode district (Figure 6) was denoted in the year 2004 with the value 30.2 followed by 28.9 in 2017 and 24.9 in 2003. The highest ground water level values during pre-monsoon were recorded in the year 2011 with the value 6.2 followed by 7.1 in 2012 and 7.4 in 2006.

From the year 1992 to 1995 shows rise in ground water level. In the year 1996 the groundwater level falls slightly, and it continuous in the year 1997 also. During the year 1998 the groundwater level began to rise upto the year 2000. From the year 2001 onwards it shows high fluctuation in the groundwater level upto 2019.

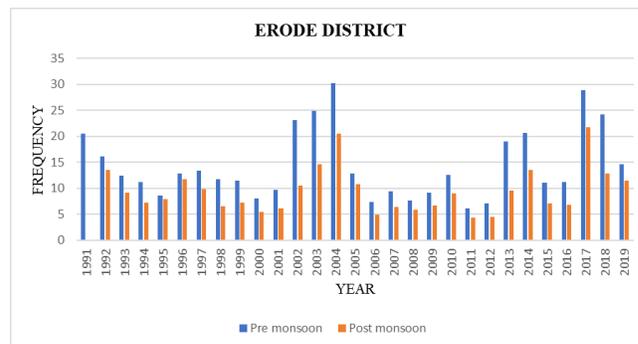


Fig. 6. Erode district

Kanchipuram. The lowest ground water level during pre-monsoon in Kanchipuram district (Figure 7) was denoted in the year 2014 with the value 12.5 followed by 10.4 in 2010 and 10.1 in 2015. The highest ground water level values during pre-monsoon were recorded in the year 1995 with the value 4.4 followed by 5.2 in 1996 and 5.3 in 2006. The groundwater level of Kanchipuram shows high fluctuation all over the study period.

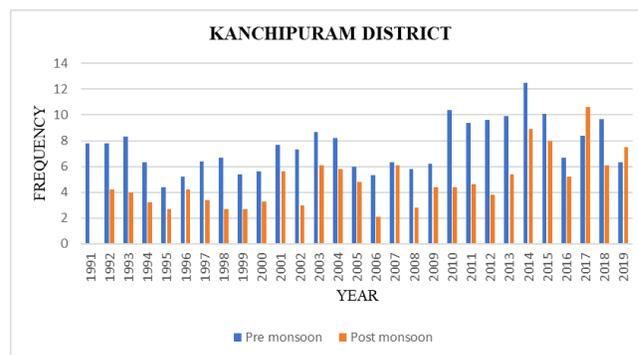


Fig. 7. Kanchipuram district

Kanyakumari. From the observation from the Figure 8, the lowest ground water level during pre-monsoon in Kanyakumari district was denoted in the year 2014 with the value 9.1 followed by 8.7 in 2013 and 7.9 in 2003. The highest ground water level values during pre-monsoon were recorded in the year 1999 with the value 4.4 followed by 4.6 in 2008 and 4.7 in 1995.

During the study we come to an observation that, from the year 1991 to 1999 shows slight variations in the groundwater



level. Year 2000, 2001 and 2002 depict almost constant groundwater level, 2003 represent a fall in the ground water level. From 2004 to 2006 the ground water rises slowly. From 2007 onwards the ground water level shows rapid raise and fall.

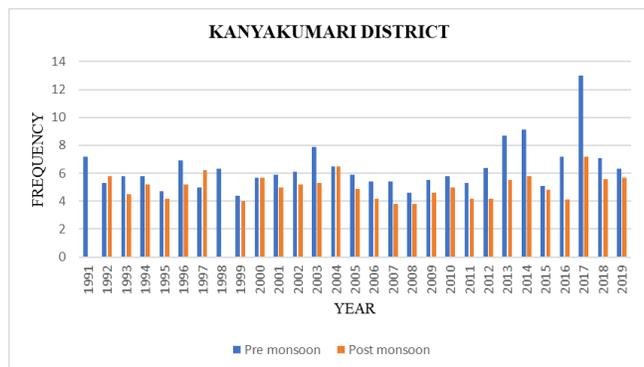


Fig. 8. Kanyakumari district

Karur. The lowest ground water level during pre-monsoon in Karur district was denoted in the year 2017 with the value 31.3 followed by 25.5 in 2014 and 22.9 in 2018. The highest ground water level values during pre-monsoon were recorded in the year 1994 with the value 3.7 followed by 4.9 in 2006 and 6.9 in 1995.

From the Figure 9 we come to an observation that, upto 1996 the ground water level shows slight fluctuations. From the year 1997 to 2000, it represents rise in the ground water level. During the year 2001 to 2004, it depicts drop in the ground water level. From 2005 it shows highly irregular ground water level.

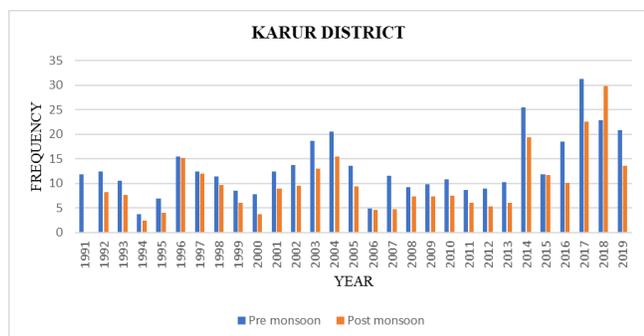


Fig. 9. Karur district

Krishnagiri. The lowest ground water level during pre-monsoon in Krishnagiri district was denoted in the year 2014 with the value 29.5 followed by 25.5 in 2015 and 23.2 in 1991. The highest ground water level values during pre-monsoon were recorded in the year 2012 with the value 8.4 followed by 8.5 in 2006 and 10.2 in 2001. From the Figure 10 we come

to an assumption that the groundwater level of Krishnagiri shows high fluctuation all over the study period.

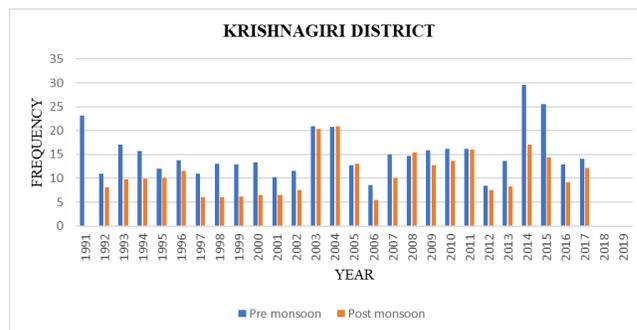


Fig. 10. Krishnagiri district

Madurai. From the survey of 28 years (1991-2017), the lowest ground water level of Madurai district during pre-monsoon was recorded during the year 2014 with the value 14.2 followed by 11.5 in 2013 and 11.1 in 2004. The highest ground water level values during pre-monsoon are recorded in the year 2012 with the value 4.0 followed by 4.9 in 2008 and 5.3 in 2011.

From the analysis of Figure 11, upto the year 1996 the ground water level is varies rapidly. From 1997 the ground water level began to rise slowly upto 1999. From the year 2000 to 2002, it represents a drop in the level an 2003 represent a relatively high fall in the ground water level and it continuous upto the year 2004. After 2004 it depicts a highly fluctuating ground water level.

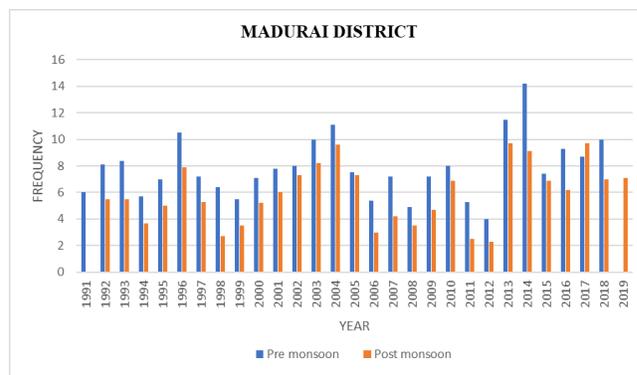


Fig. 11. Madurai district

Nagapattinam. The lowest ground water level during pre-monsoon in Nagapattinam district was denoted in the year 2018 with the value 16.1 followed by 8.7 in 2017 and 6.7 in 2019. The highest ground water level values during pre-monsoon were recorded in the year 1999 with the value 2.0 followed by 2.1 in 1998,2000&2009 and 2.4 in 2002.



From the observation of Figure 12 we can say that, Nagapattinam shows almost uneven ground water level upto the year 1997. During the year 1998 the ground water level shows a rise, it continuous upto the year 2000. From the year 2005 to 2008, it depicts almost even ground 1water level and from 2009 itself started to represent the fluctuations

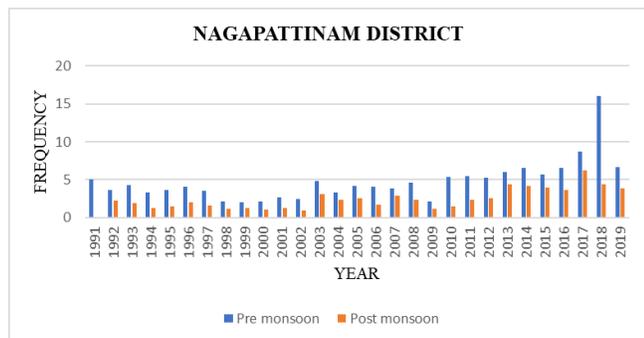


Fig. 12. Nagapattinam district

Namakkal. The lowest ground water level during pre-monsoon in Namakkal district was denoted in the year 1996 with the value 36.6 followed by 20.9 in 1991 and 16.5 in 2002. The highest ground water level values during pre-monsoon were recorded in the year 2006 with the value 5.3 followed by 8.0 in 2009 and 8.2 in 2008. From the observation of Figure 13 we can say that, the groundwater level of Namakkal shows high fluctuation all over the study period.

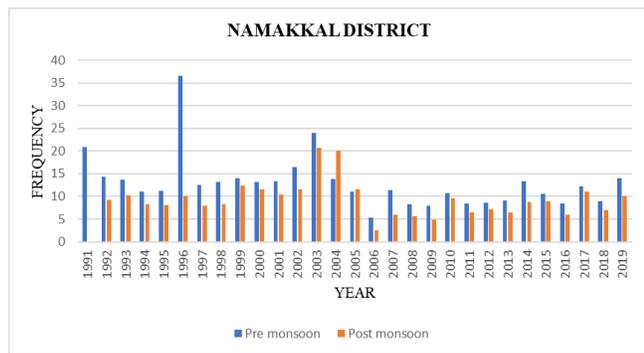


Fig. 13. Namakkal district

Perumbalur. The analysis of Figure 14 we can come to an assumption that the lowest ground water level during pre-monsoon in Perumbalur district was denoted in the year 2019 with the value 16.4 followed by 15.8 in 1996 and 13.6 in 2003&2017. The highest ground water level values during pre-monsoon were recorded in the year 1998 with the value 2.3 followed by 3.4 in 2000 and 3.5 in 1994. The groundwater level of Perumbalur shows high fluctuation all over the study period.

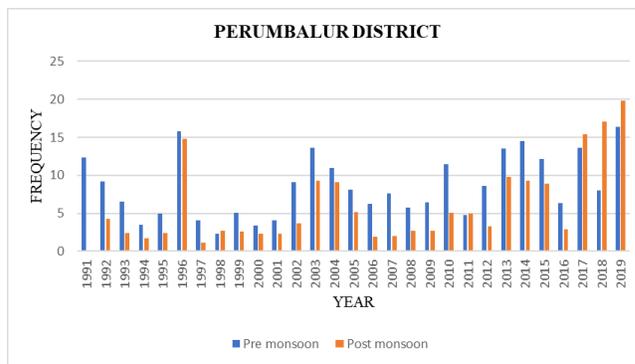


Fig. 14. Perumbalur district

Pudukkottai. The lowest ground water level during pre-monsoon in Pudukkottai district was denoted in the year 2019 with the value 43.9 followed by 35.5 in 2017 and 32.2 in 2018. The highest ground water level values during pre-monsoon were recorded in the year 1994 with the value 4.0 followed by 4.6 in 2001 and 5.4 in 2006.

From the observation of Figure 15 we can understand that, the groundwater level of Pudukkottai shows high fluctuation all over the study period and the fluctuation on its peak in 2019.

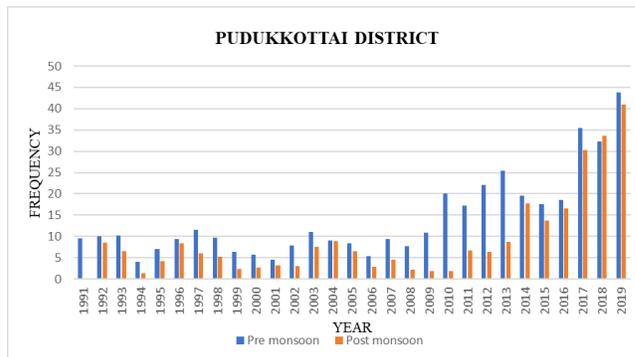


Fig. 15. Pudukkottai district

Ramanathapuram. The lowest ground water level during pre-monsoon in Ramanathapuram district (Figure 16) was denoted in the year 2018 with the value 20.4 followed by 19.7 in 2019 and 17.7 in 2017. The highest ground water level values during pre-monsoon were recorded in the year 1999 with the value 5.5 followed by 5.7 in 2009 and 5.9 in 1991.

The study area (Ramanathapuram) also shows fluctuation in its ground water level. Upto the year 2003 ground water level of Ramanathapuram shows small variations or fluctuations. The year 2004 depict comparatively a high drop / fall in the ground water level. From 2005 onwards it represents small fluctuations upto 2015 and afterwards it depicts high



fluctuations.

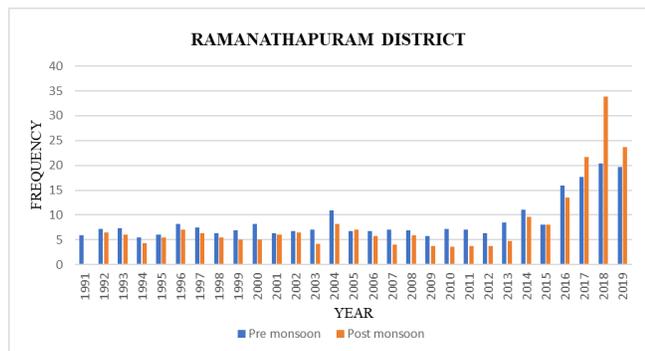


Fig. 16. Ramanathapuram district

Salem. The lowest ground water level during pre-monsoon in Salem district (Figure 17) was denoted in the year 2003 with the value 35.6 followed by 30.0 in 2002 and 19.8 in 1991. The highest ground water level values during pre-monsoon were recorded in the year 2006 with the value 7.1 followed by 8.4 in 2008 and 9.5 in 2004&2007.

Salem shows high variations in ground water level. From 1991 to 1998 there is small variations in the ground water level. The year 1999 and 2000 shows raise in the ground water level. During the period 2001 to 2003, the ground water level falls steeply and the lowest ground water level is depicted by the year 2003. From the year 2003 onwards, the ground water level shows high fluctuations.

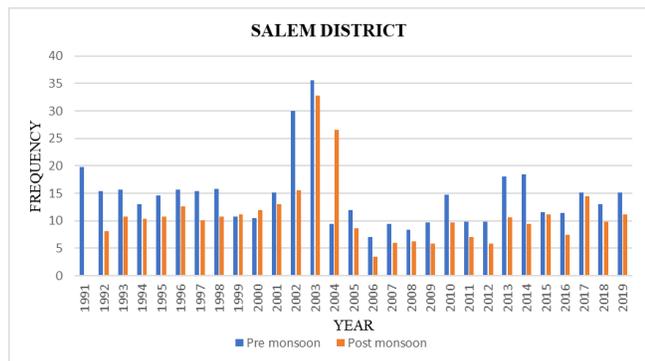


Fig. 17. Salem district

Sivagangai. The lowest ground water level during pre-monsoon in Sivagangai district was denoted in the year 2019 with the value 26.3 followed by 25.7 in 2017 and 25.5 in 2018. The highest ground water level values during pre-monsoon were recorded in the year 1995 with the value 4.7 followed by 5.3 in 1994 and 6.5 in 1998.

From the observation of the Figure 18 we can say that, the Sivagangai region shows a drop / fall in the ground water level

throughout the studying period. Some years like 1994, 1995, 1998, and 1999 shows the rise in ground water level.

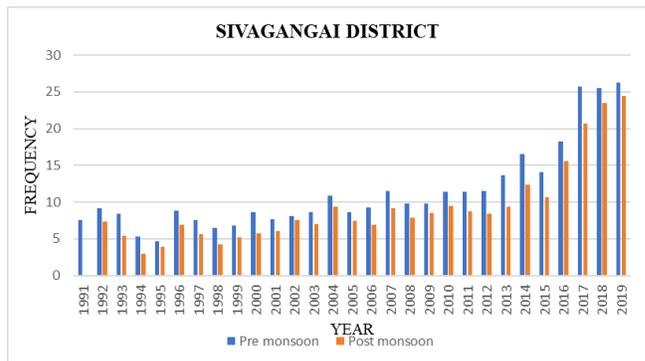


Fig. 18. Sivagangai district

Thanjavur. The lowest ground water level during pre-monsoon in Thanjavur district was denoted in the year 2017&2019 with the value 22.2 followed by 21.5 in 2016 and 20.6 in 2018. The highest ground water level values during pre-monsoon were recorded in the year 1998 with the value 3.9 followed by 4.0 in 1999 and 4.3 in 1994.

Thanjavur (Figure 19) depicts high variation in ground water level. From the year 1991 to 2002, it represent slight fluctuation or variation in ground water level. The year 2003, depict a steep fall in the ground water level. From 2004 onward, the ground water level shows slight variations. From the year 2014 onwards, it shows high fluctuations.

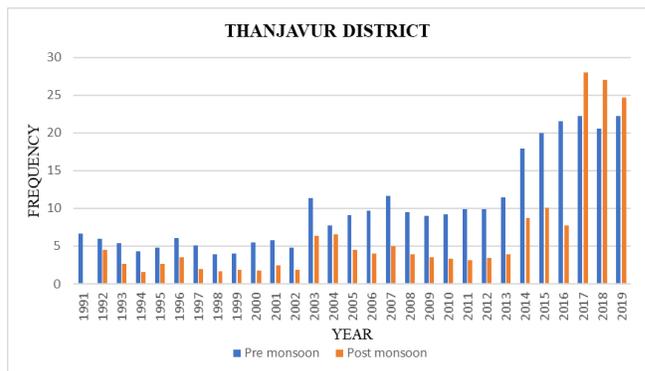


Fig. 19. Thanjavur district

Theni. From the assessment of Figure 20, the lowest ground water level during pre-monsoon in Theni district was denoted in the year 2017 with the value 21.3 followed by 19.1 in 2003 and 17.6 in 2004. The highest ground water level values during pre-monsoon were recorded in the year 2011 with the value 11.3 followed by 12.1 in 2000 and 13.1 in 2012. The ground water level of Theni shows high fluctuations all around the study period.



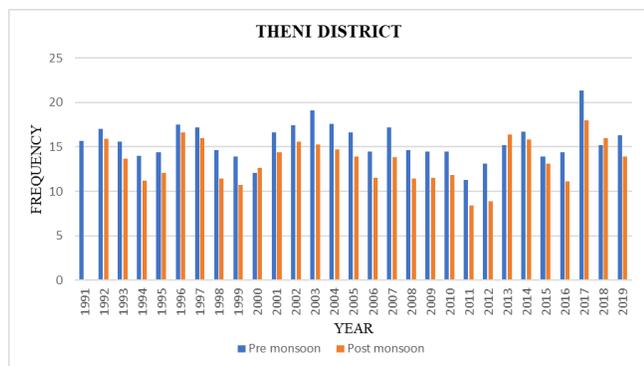


Fig. 20. Theni district

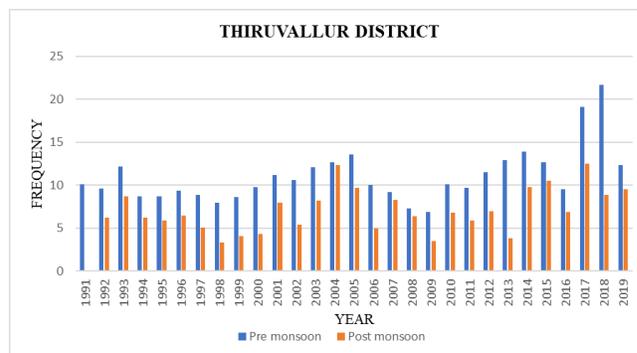


Fig. 22. Thiruvallur district

Thiruvarur. The lowest ground water level during pre-monsoon in Thiruvarur district was denoted in the year 2018 with the value 21.7 followed by 13.9 in 2014&2017 and 13.6 in 2005. The highest ground water level values during pre-monsoon were recorded in the year 2009 with the value 6.9 followed by 7.3 in 2008 and 8.0 in 1998.

From the observation of Figure 21 we can come to an assumption that, this area / district experience low ground water level all the studying period. It falls very steep in 2018.

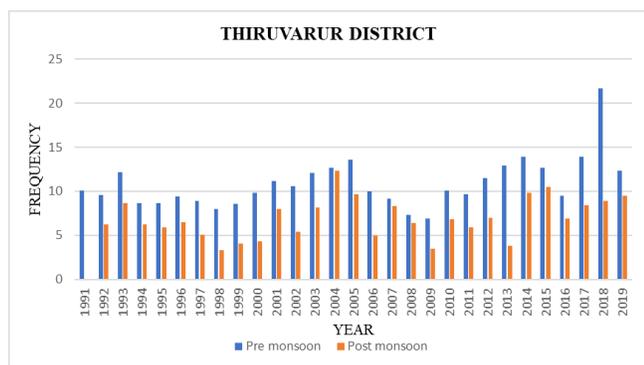


Fig. 21. Thiruvarur district

Thiruvallur. The lowest ground water level during pre-monsoon in Thiruvallur district was denoted in the year 2018 with the value 21.7 followed by 19.1 in 2017 and 13.9 in 2014. The highest ground water level values during pre-monsoon were recorded in the year 2009 with the value 6.9 followed by 7.3 in 2008 and 8.0 in 1998.

From the observation of Figure 22 we can come to an assumption that, this area / district experience low ground water level all the studying period. It falls very steep in 2018.

Thoothukudi. The lowest ground water level during pre-monsoon in Thoothukudi district was denoted in the year 2004 with the value 11.3 followed by 9.9 in 2003 and 8.9 in 2009. The highest ground water level values during pre-

monsoon were recorded in the year 2008 with the value 4.2 followed by 5.5 in 2011,2016&2019 and 5.6 in 2018.

From the observation of Figure 23 we can come to an assumption that, this area / district experience low ground water level all the studying period. It falls very steep in the year 2004.

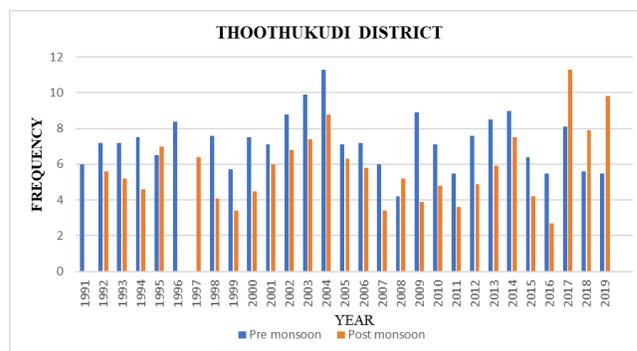


Fig. 23. Thoothukudi district

Tiruchirappalli. The lowest ground water level during pre-monsoon in Tiruchirappalli district was denoted in the year 2019 with the value 23.1 followed by 19.1 in 2018 and 18.5 in 2017. The highest ground water level values during pre-monsoon were recorded in the year 1994 with the value 4.8 followed by 5.4 in 2006 and 6.5 in 1999.

From the observation of the Figure 24 we can understand that, the groundwater level of Tiruchirappalli shows high fluctuation all over the study period and the fluctuation on its peak in 2019.

Tirunelveli. The lowest ground water level during pre-monsoon in Tirunelveli district was denoted in the year 2017 with the value 23.9 followed by 21.8 in 2014 and 20.8 in 2013. The highest ground water level values during pre-monsoon were recorded in the year 2016 with the value 3.7 followed by 3.9 in 2008 and 4.7 in 1994.



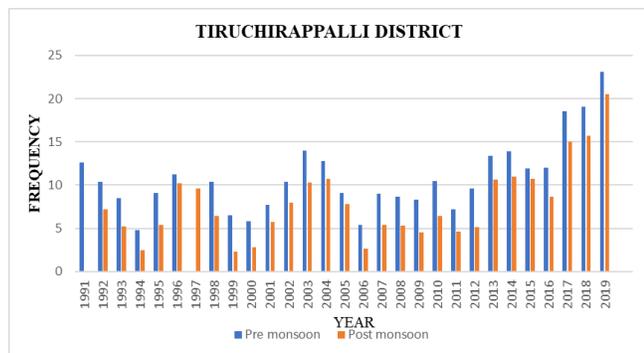


Fig. 24. Tiruchirappalli district

From the assessment of Figure 25 year 1991 to 1993, it depict fall in ground water level. The year 1994 and 1995, represent rise in the ground water level. From the year 2017 onwards it shows high fluctuation.

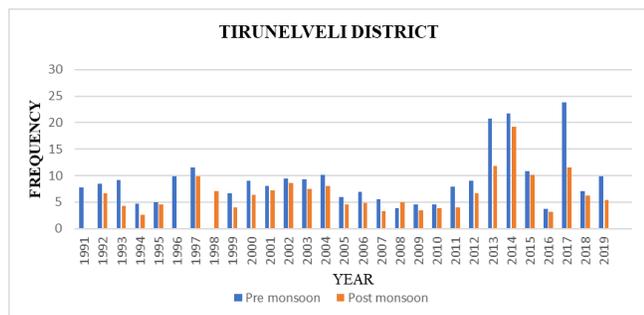


Fig. 25. Tirunelveli district

Tiruppur. The lowest ground water level during pre-monsoon in Tiruppur district was denoted in the year 2004 with the value 30.5 followed by 26.4 in 2017 and 25.2 in 2014. The highest ground water level values during pre-monsoon were recorded in the year 2011 with the value 5.8 followed by 6.1 in 2012 and 9.8 in 2018. The study area shows (Figure 26) high fluctuation in the ground water level. Here the highest ground water level depicted in the year 2011 and lowest level in 2004.

Tiruvannamalai. The study area shows high fluctuation in the ground water level. Here the highest ground water level depicted in the year 1995 and lowest level in 2019.

Vellore. The lowest ground water level during pre-monsoon in Vellore district was denoted in the year 2003 with the value 26.9 followed by 22.1 in 2005 and 21.3 in 2019. The highest ground water level values during pre-monsoon were recorded in the year 1997 with the value 5.3 followed by 7.7 in 1999 and 7.9 in 1995.

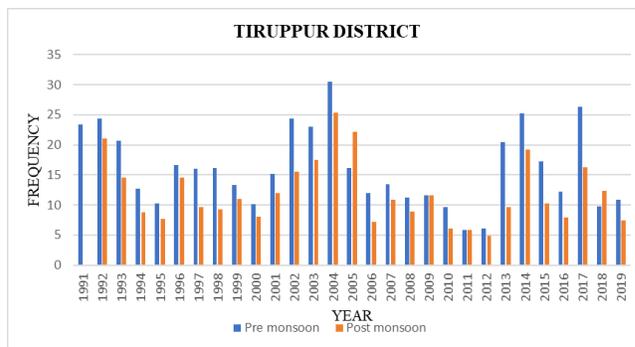


Fig. 26. Tiruppur district

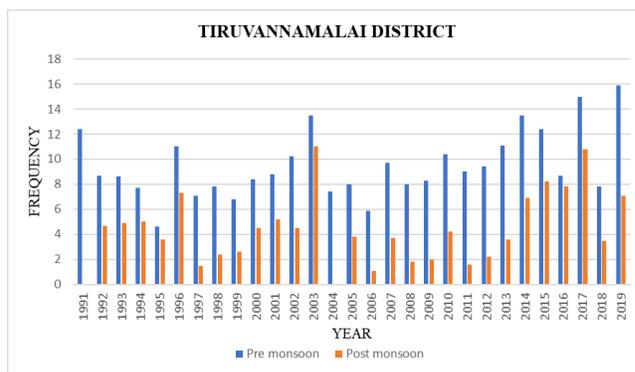


Fig. 27. Tiruvannamalai district

From the observation of Figure 28 we can say that, the study area depicts high fluctuation all the study period. The lowest level of ground water level is in 2003 and highest ground water level is in 1997.

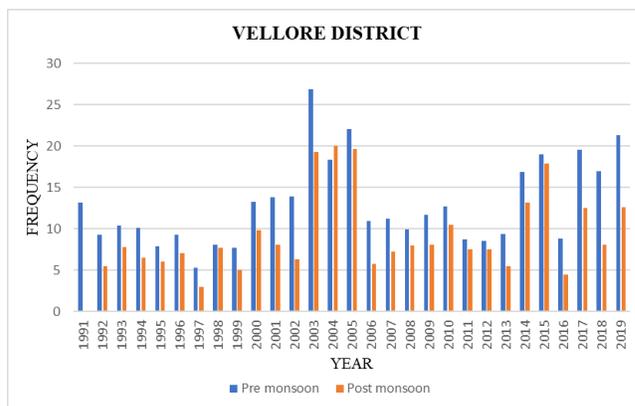


Fig. 28. Vellore district

Villupuram. The lowest ground water level during pre-monsoon in Villupuram district was denoted in the year 2018 with the value 18.3 followed by 12.1 in 2019 and 11.7 in 1996.



The highest ground water level values during pre-monsoon were recorded in the year 2008 with the value 4.6 followed by 4.8 in 2006 and 5.2 in 2007.

From the observation of Figure 29 we can come to an assumption that, this area / district experience low ground water level all the studying period. It falls very steep in 2018.

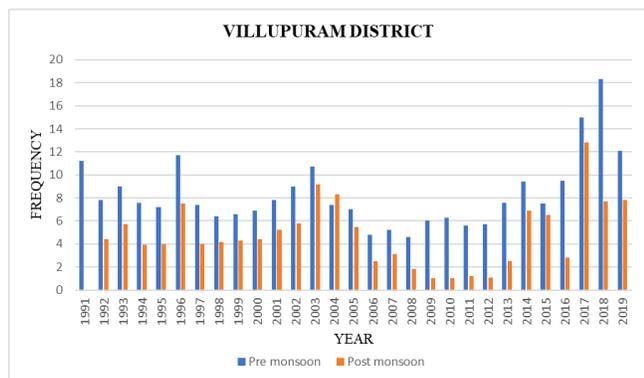


Fig. 29. Villupuram district

Virudhunagar. The lowest ground water level during pre-monsoon in Virudhunagar district was denoted in the year 2013 with the value 13.1 followed by 12.9 in 2004 and 11.5 in 2014&2017. The highest ground water level values during pre-monsoon were recorded in the year 2008 with the value 3.8 followed by 4.4 in 2007 and 5.4 in 2006.

From the observation of Figure 30 we can come to an assumption that, this area / district experience low ground water level all the studying period.

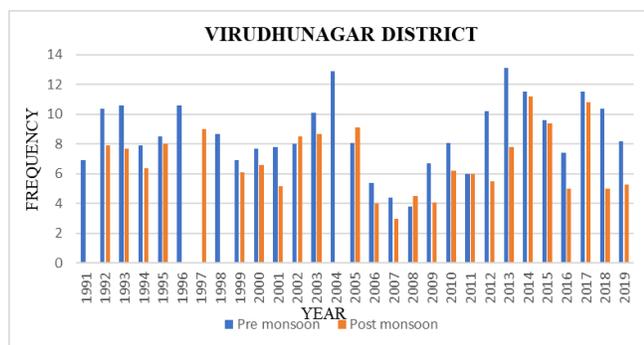


Fig. 30. Virudhunagar district

Nilgiri & Chennai – data not available.

Groundwater Level in Pre-Monsoon Season

Ariyalur

The lowest ground water level during post monsoon in Ariyalur district is denoted in the year 2017 with the value 28.7 followed by 26.9, 23.6 during the years 2019, 2015

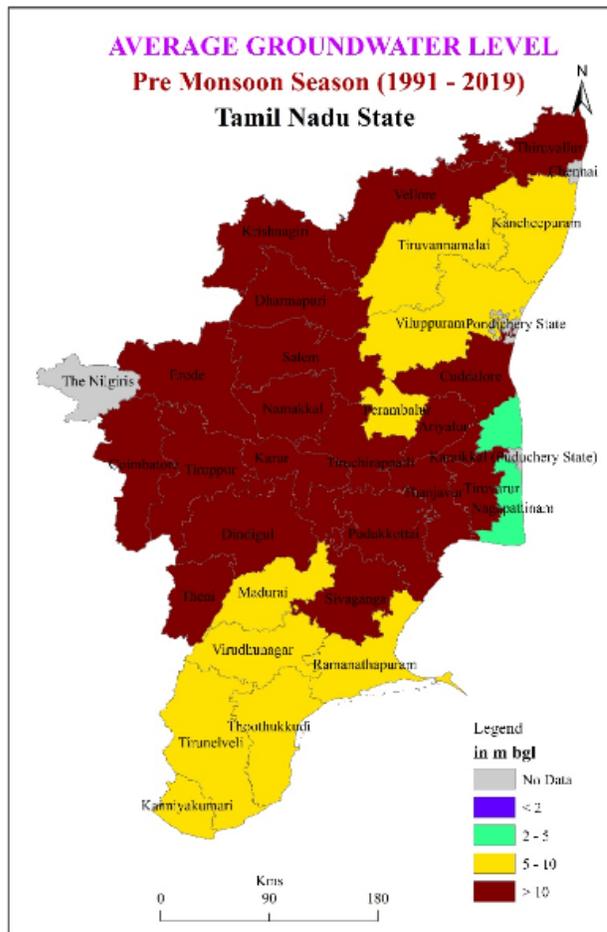


Fig. 31. Groundwater Level in Pre-Monsoon Season

respectively. The highest ground water level values during post monsoon are 2.4, 2.5, 3.7 during the year 2006, 2007, 2008 respectively. The ground water level (Figure 1) shows high fluctuations throughout the study period. The steep drop in ground water level is recorded in the year 2017. The highest level of ground water level recorded in 2006.

Coimbatore

The lowest groundwater level during post monsoon in Coimbatore district is recorded in the year 2004 (26.2) is followed by the year 2003 (26) and 1992 (22) respectively. The highest ground water level values during post monsoon are 6.8 (1998), 7.6 (1997), 9.9 (2012) and so on. From the observation of Figure 2 we come to an inference that 1991 to 1996 depict high variations in the ground water level. During the year 1997 and 1998, it shows a slight drop in the ground water level. A steep drop in ground water level is represented by 2003 and 2004, among which the lowest ground water level is marked by 2004. From 2005, it represents high fluctuations.



Cuddalore

From the assessment of Figure 3, the lowest ground water level during post monsoon in Cuddalore district is denoted in the year 2017 with the value 31.1 followed by 29.7 in 2019 and 28.1 in 2018. The highest ground water level values during post monsoon are recorded in the year 2012 with the value 9.1 followed by 10.3 in 2011 and 10.7 in 2013.

The ground water level of Cuddalore shows high fluctuation all over the study period.

Dharmapuri

The lowest ground water level during post monsoon in Dharmapuri district is denoted in the year 2003 with the value 20.3 followed by 19.8 in 2004 and 15.8 in 2019. The highest ground water level values during post monsoon are recorded in the year 1992 with the value 3.9 followed by 4.4 in 1994&1998 and 4.7 in 1999. The ground water level shows (Figure 4) slight fluctuations from 1992 and 1995. The year 1996, it depicts steep drop in the ground water level. During 2003 the ground water level falls steeply. From 2003 onwards the ground water level shows high variations.

Dindigul

The lowest ground water level during post monsoon in Dindigul district (Figure 5) is denoted in the year 2017 with the value 15.1 followed by 13.7 in 2004 and 13.3 in 2014. The highest ground water level values during post monsoon are recorded in the year 2006 with the value 1.8 followed by 2.6 in 2008 and 3.0 in 1994. During the year 1992 and 1993 shows slight variations in the ground water level, 1994 and 1995 depicts rise in the ground water level. Again in 1996 there is a fall in the groundwater level, from 1998 it again shows a rise in groundwater level upto 1999. Year 2000 onwards it shows a highly irregular groundwater level up to 2019.

Erode

The lowest groundwater level during post monsoon in Erode district is denoted in the year 2017 with the value 21.7 followed by 20.6 in 2004 and 14.6 in 2003. The highest ground water level values during post monsoon are recorded in the year 2011 with the value 4.3 followed by 4.5 in 2012 and 4.9 in 2006.

From the assessment of Figure 6, the year 1993 to 1995 shows rise in ground water level. In the year 1996 the groundwater level falls slightly. During the year 1998 the groundwater level began to rise up to the year 2000. From the year 2001 onwards it shows high fluctuation in the groundwater level up to 2019.

Kanchipuram

The lowest ground water level during post monsoon in Kanchipuram district is denoted in the year 2017 with the value 10.6 followed by 8.9 in 2014 and 8.0 in 2015. The

highest ground water level values during post monsoon are recorded in the year 2006 with the value 2.1 followed by 2.7 in 1995, 1998&1999 and 2.8 in 2008. The groundwater level of Kanchipuram (Figure 7) shows high fluctuation all over the study period.

Kanyakumari

The lowest ground water level during post monsoon in Kanyakumari district (Figure 8) is denoted in the year 2017 with the value 7.2 followed by 6.5 in 2004 and 6.2 in 1997. The highest ground water level values during post monsoon are recorded in the years of 2007&2008 with the value 3.8 followed by 4.0 in 1999 and 4.1 in 2016. During the study we come to an observation that, from the year 1991 to 1997 shows slight variations in the groundwater level. From the year 1998, it depicts high fluctuations.

Karur

The lowest ground water level during post monsoon in Karur district (Figure 9) is denoted in the year 2018 with the value 29.8 followed by 22.6 in 2017 and 19.4 in 2014. The highest ground water level values during post monsoon are recorded in the year 1994 with the value 2.5 followed by 3.7 in 2000 and 4.0 in 1995. Up to 1996 the ground water level shows slight fluctuations. From the year 1997 to 2000, it represents rise in the ground water level. During the year 2001 to 2004, it depicts drop in the ground water level. From 2005, it shows highly irregular ground water level.

Krishnagiri

The lowest ground water level during post monsoon in Krishnagiri district is denoted in the year 2004 with the value 20.9 followed by 20.4 in 2003 and 17.1 in 2014. The highest ground water level values during post monsoon are recorded in the year 2006 with the value 5.4 followed by 6.1 in 1997&1998 and 6.2 in 1999. The groundwater level of Krishnagiri (Figure 10) shows high fluctuation all over the study period.

Nagapattinam

The lowest ground water level during post monsoon in Nagapattinam district is denoted in the year 2017 with the value 6.2 followed by 4.4 in 2013&2018 and 4.2 in 2014. The highest ground water level values during post monsoon are recorded in the year 2002 with the value 0.9 followed by 1.0 in 2000 and 1.1 in the years of 1998&2009. From the observation of Figure 12 we can say that, Nagapattinam shows almost even ground water level up to the year 1997. During the year 1998 the ground water level shows a rise, it continuous up to the year 2002. From the year 2005 to 2008, it depicts almost even ground water level and from 2009 itself started to represent the fluctuations.



Namakkal

The lowest ground water level during post monsoon in Namakkal district is denoted in the year 2003 with the value 20.7 followed by 20.1 in 2004 and 12.4 in 1999. The highest ground water level values during post monsoon are recorded in the year 2006 with the value 2.6 followed by 4.9 in 2009 and 5.6 in 2008. From the observation of Figure 13 we can say that, the groundwater level of Namakkal shows high fluctuation all over the study period.

Perumbalur

The lowest ground water level during post monsoon in Perumbalur district is denoted in the year 2019 with the value 19.8 followed by 17.1 in 2018 and 15.4 in 2017. The highest ground water level values during post monsoon are recorded in the year 1997 with the value 1.1 followed by 1.7 in 1994 and 1.9 in 2006. The groundwater level of Perumbalur (Figure 14) shows high fluctuation all over the study period.

Pudukottai

The lowest ground water level during post monsoon in Pudukottai district is denoted in the year 2019 with the value 41 followed by 33.7 in 2018 and 30.2 in 2017. The highest ground water level values during post monsoon are recorded in the year 1994 with the value 1.4 followed by 1.8 in 2010 and 1.9 in 2009. From the observation of Figure 15 we can understand that, the groundwater level of Pudukkottai shows high fluctuation all over the study period and the fluctuation on its peak in 2019.

Ramanathapuram

The lowest ground water level during post monsoon in Ramanathapuram district is denoted in the year 2018 with the value 33.8 followed by 23.7 in 2019 and 21.7 in 2017. The highest ground water level values during post monsoon are recorded in the year 2007 with the value 4.1 followed by 4.2 in 2003 and 4.3 in 1994. From the Figure 16, the study area (Ramanathapuram) also shows fluctuation in its ground water level. Up to the year 2003 ground water level of Ramanathapuram shows small variations or fluctuations. The year 2019 depict a high drop / fall in the ground water level. From 2005 onwards it represents small fluctuations up to 2015 and afterwards it depicts high fluctuations.

Salem

The lowest ground water level during post monsoon in Salem district is denoted in the year 2003 with the value 32.8 followed by 26.5 in 2004 and 15.6 in 2002. The highest ground water level values during post monsoon are recorded in the year 2006 with the value 3.4 followed by 5.8 in 2009 and 5.9 in 2012. From the assessment of Figure 17, Salem shows high variations in ground water level. From 1991 to 1998 there is small variations in the ground water level. The year 1999

and 2000 shows raise in the ground water level. During the period 2001 to 2003, the ground water level falls steeply and the lowest ground water level is depicted by the year 2003. From the year 2003 onwards, the ground water level shows high fluctuations.

Sivagangai

The lowest ground water level during post monsoon in Sivagangai district is denoted in the year 2019 with the value 24.4 followed by 23.5 in 2018 and 20.7 in 2017. The highest ground water level values during post monsoon are recorded in the year 1994 with the value 3 followed by 3.9 in 1995 and 4.2 in 1998. From the observation of Figure 18 we can say that, the Sivagangai region shows a drop / fall in the ground water level throughout the studying period. Some years like 1994, 1995, 1998, and 1999 shows the rise in ground water level.

Thanjavur

The lowest ground water level during post monsoon in Thanjavur district is denoted in the year 2017 with the value 28 followed by 27 in 2018 and 24.7 in 2019. The highest ground water level values during post monsoon are recorded in the year 1994 with the value 1.6 followed by 1.7 in 1998 and 1.8 in 2000. From the study of Figure 19, up to the year 2013 the ground water level shows slight variations. From the year 2014, it shows high fluctuation in ground water level.

Theni

The lowest ground water level during post monsoon in Theni district is denoted in the year 2017 with the value 18 followed by 16.4 in 2013 and 16.0 in 2018. The highest ground water level values during post monsoon are recorded in the year 2011 with the value 8.4 followed by 8.9 in 2012 and 11.1 in 2016. The ground water level of Theni (Figure 20) shows high fluctuations all around the study period.

Thiruvarur

The lowest ground water level during post monsoon in Thiruvarur district is denoted in the year 2004 with the value 12.3 followed by 10.5 in 2015 and 9.8 in 2014. The highest ground water level values during post monsoon are recorded in the year 1998 with the value 3.3 followed by 3.5 in 2009 and 3.8 in 2013. From the observation of Figure 21 we can come to an assumption that, this area / district experience low ground water level all the studying period.

Thiruvallur

The highest ground water level during post monsoon in Thiruvallur district is denoted in the year 2017 with the value 12.5 followed by 12.3 in 2004 and 10.5 in 2015.

The lowest ground water level values during post monsoon are recorded in the year 1998 with the value 3.3 followed by 3.5 in 2009 and 3.8 in 2013. From the observation of Figure 22 we

can come to an assumption that, this area / district experience low ground water level all the studying period.

Thoothukudi

The lowest ground water level during post monsoon in Thoothukudi district is denoted in the year 2017 with the value 11.3 followed by 9.8 in 2019 and 8.8 in 2004. The highest ground water level values during post monsoon are recorded in the year 2016 with the value 2.7 followed by 3.4 in 1999 and 3.6 in 2011. From the assessment of Figure 23 we can come to an assumption that, this area / district experience low ground water level all the studying period. It falls very steep in the year 2017.

Tiruchirappalli

The lowest ground water level during post monsoon in Thiruchirappally district is denoted in the year 2019 with the value 20.5 followed by 15.7 in 2018 and 15 in 2017. The highest ground water level values during post monsoon are recorded in the year 1999 with the value 2.3 followed by 2.5 in 1994 and 2.8 in 2000. From the observation of Figure 24 we can understand that, the groundwater level of Tiruchirappalli shows high fluctuation all over the study period and the fluctuation on its peak in 2019.

Tirunelveli

The lowest ground water level during post monsoon in Tirunelveli district is denoted in the year 2014 with the value 19.2 followed by 11.8 in 2013 and 11.5 in 2017. The highest ground water level values during post monsoon are recorded in the year 1994 with the value 2.6 followed by 3.3 in 2007 and 3.5 in 2009. From the assessment of Figure 25 we can come to a conclusion that, the year 1992 and 1993, it depicts fall in ground water level. The year 1994 and 1995, represent rise in the ground water level. From the year 2014 onwards it shows high fluctuation.

Tiruppur

The lowest ground water level during post monsoon in Tiruppur district (Figure 26) is denoted in the year 2004 with the value 25.4 followed by 22.2 in 2005 and 21.1 in 1992. The highest ground water level values during post monsoon are recorded in the year 2012 with the value 4.9 followed by 5.9 in 2011 and 6.1 in 2010. The study area shows high fluctuation in the ground water level. Here the highest ground water level depicted in the year 2012 and lowest level in 2004.

Thiruvannamalai

The lowest ground water level during post monsoon in Thiruvannamalai district (Figure 27) is denoted in the year 2003 with the value 11 followed by 10.8 in 2017 and 8.2 in 2015. The highest ground water level values during post monsoon are recorded in the year 2006 with the value 1.1

followed by 1.5 in 1997 and 1.6 in 2011.

Vellore

The lowest ground water level during post monsoon in Vellore district (Figure 28) is denoted in the year 2005 with the value 19.7 followed by 19.3 in 2003 and 17.9 in 2015. The highest ground water level values during post monsoon are recorded in the year 1997 with the value 3.0 followed by 4.5 in 2016 and 5.0 in 1999. The study area shows high fluctuation in the ground water level. Here the highest ground water level depicted in the year 1997 and lowest level in 2005.

Villupuram

The lowest ground water level during post monsoon in Villupuram district is denoted in the year 2017 with the value 12.8 followed by 9.2 in 2003 and 8.3 in 2004. The highest ground water level values during post monsoon are recorded in the year 2009&2010 with the value 1.0 followed by 1.1 in 2012 and 1.2 in 2011. From the observation of Figure 29 we can come to an assumption that, this area / district experience low ground water level all the studying period. It falls very steep in 2009 and 2010.

Virudhunagar

The lowest ground water level during post monsoon in Virudhunagar district is denoted in the year 2014 with the value 11.2 followed by 10.8 in 2017 and 9.4 in 2015. The highest ground water level values during post monsoon are recorded in the year 2007 with the value 3.0 followed by 4.0 in 2006 and 4.1 in 2009.

From the observation of Figure 30 we can come to an assumption that, this area / district experience low ground water level all the studying period.

Chennai & Nilgiri - data not available.

Fluctuation of Groundwater Level in Premonsoon

As per the analysis of Table 1 [Pre monsoon (May)] data we can come to a conclusion that the groundwater level of Tamil Nadu is fluctuating during all these years, such as raising and falling of groundwater level happens rapidly and it shows that the rainfall received by the state is also fluctuating.

Table 1. Fluctuation of Groundwater Level in Premonsoon

Sl.no	District	Pre Monsoon (May)			
		1992	2002	2012	2019
1	Ariyalur	15.3	14	21.2	30
2	Coimbatore	25.5	23.7	12.2	30
3	Cuddalore	16.5	17.6	13.9	36.6
4	Dharmapuri	8.7	10.7	6.6	15.2
5	Dindigul	13.8	11.3	7	16.3
6	Erode	16.1	23.1	7.1	14.6
7	Kanchipuram	7.8	7.3	9.6	6.3
8	Kanyakumari	5.3	6.1	6.4	6.3
9	Karur	12.5	13.7	8.9	20.8
10	Krishnagiri	10.9	11.5	8.4	0
11	Madurai	8.1	8	4	11
12	Nagapattinam	3.6	2.4	5.2	6.7
13	Namakkal	14.4	16.5	8.6	14
14	Nilgiri	0	0	0	0
15	Perumbalur	9.2	9.1	8.6	16.4
16	Pudukkottai	10.1	7.8	22.1	43.9
17	Ramanathapuram	7.2	6.7	6.4	19.7
18	Salem	15.4	30	9.9	15.1
19	Sivagangai	9.2	8.1	11.5	26.3
20	Thanjavur	6	4.8	9.9	22.2
21	Theni	17	17.4	11.3	16.3
22	Thiruvarur	9.6	10.6	11.5	12.3
23	Thiruvallur	9.6	10.6	11.5	12.3
24	Thoothukudi	7.2	8.8	7.6	5.5
25	Tiruchirappalli	10.4	10.4	9.6	23.1
26	Tirunelveli	8.4	9.4	9	9.8
27	Tiruppur	24.4	24.4	6.1	10.9
28	Tiruvannamalai	8.7	10.2	9.4	15.9
29	Vellore	9.3	13.9	8.5	21.3
30	Villupuram	7.8	9	5.7	12.1
31	Virudhunagar	10.4	8	10.2	8.2

Fluctuation Of Groundwater Level In Postmonsoon

As per the Table 2 [post monsoon (January)] data we can come to a conclusion that the groundwater level of Tamil Nadu is fluctuating during all these years, such as raising and falling of groundwater level happens rapidly and it shows that the rainfall received by the state is also fluctuating.

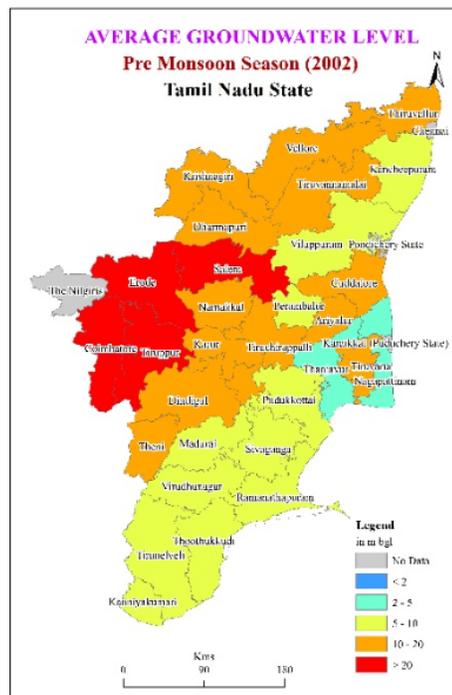


Fig. 32. Average ground water level pre monsoon season 2002, Tamil nadu

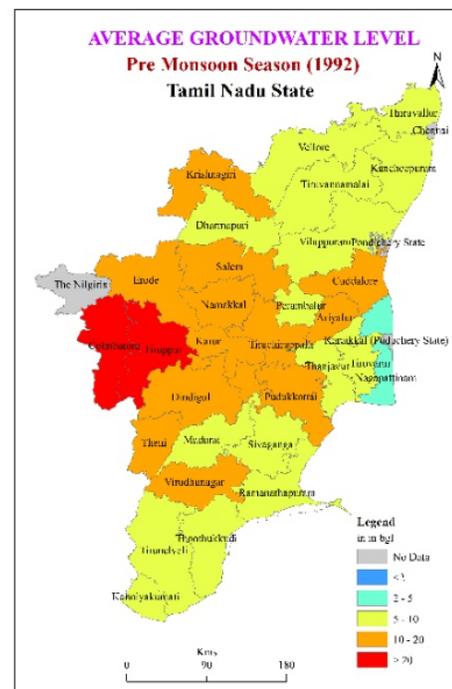


Fig. 33. Average ground water level pre monsoon season 1992, Tamil nadu



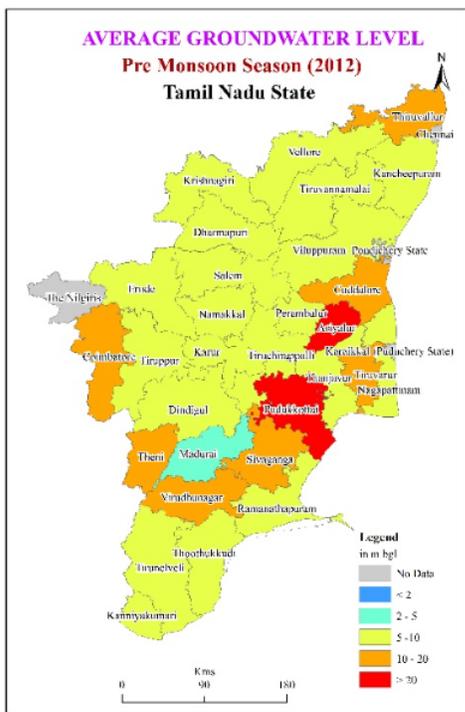


Fig. 34. Average ground water level in pre monsoon season 2012, Tamil nadu

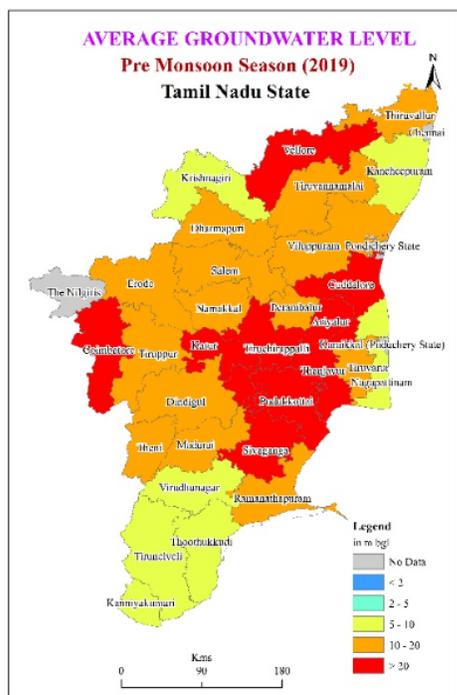


Fig. 35. Average ground water level in pre monsoon season 2019, Tamil nadu

Table 2. Fluctuation Of Groundwater Level In Postmonsoon

Sl.no	District	PostMonsoon (January)			
		1992	2002	2012	2019
1	Ariyalur	11	11.5	8	26.9
2	Coimbatore	22	16.6	9.9	13.6
3	Cuddalore	13.5	16.5	9.1	29.7
4	Dharmapuri	3.9	6.8	5.1	15.8
5	Dindigul	10.2	11.2	3.5	9.7
6	Erode	13.6	10.6	4.5	11.5
7	Kanchipuram	4.2	3	3.8	7.5
8	Kanyakumari	5.8	5.2	4.2	5.7
9	Karur	8.3	9.5	5.3	13.6
10	Krishnagiri	8.1	7.5	7.6	0
11	Madurai	5.5	7.3	2.3	7.1
12	Nagapattinam	2.2	0.9	2.5	3.8
13	Namakkal	9.3	11.5	7.2	10
14	Nilgiri	0	0	0	0
15	Perambalur	4.3	3.7	3.3	19.8
16	Pudukottai	8.6	3	6.4	41
17	Ramanathapuram	6.5	6.5	3.7	23.7
18	Salem	8.1	15.6	5.9	11.2
19	Sivagangai	7.3	7.6	8.4	24.4
20	Thanjavur	4.5	1.9	3.4	24.7
21	Theni	15.9	15.6	8.9	13.9
22	Thiruvavur	6.2	5.4	7	9.5
23	Thiruvallore	6.2	5.4	7	9.5
24	Thoothukudi	5.6	6.8	4.9	9.8
25	Tiruchirapalli	7.2	8	5.1	20.5
26	Tirunelveli	6.7	8.6	6.6	5.4
27	Tiruppur	21.1	15.6	4.9	7.5
28	Tiruvannamalai	4.7	4.5	2.2	7.1
29	Vellore	5.5	6.3	7.5	12.6
30	Villupuram	4.4	5.8	1.1	7.8
31	Virudhunagar	7.9	8.5	5.5	5.3

Drought In Pre Monsoon Season

As per the analysis of Table 3 we can come to an assumption about the drought during pre-monsoon season (May) that all places in Tamil Nadu are prone to drought.

The data set of Chennai and Nilgiris are unavailable.

Table 4. Drought In Post Mon

Standardized Ground Water Index				
Post Monsoon				
SGI=(W-Wm)/SD				
SD= $\sqrt{(W-Wm)^2/N-1}$				
Wm=222.43				
Sl.no	District	Post Monsoon(W)	SD	SGI
1	Ariyalur	9.5	40.97	-5.19
2	Coimbatore	15.1	39.9	-5.19
3	Cuddalore	15.1	39.9	-5.19
4	Dharmapuri	8.7	41.13	-5.19
5	Dindigul	7.5	41.36	-4.37
6	Erode	9.5	40.97	-5.19
7	Kanchipuram	4.5	41.94	-5.19
8	Kanyakumari	5.1	41.82	-5.19
9	Karur	8.6	41.15	-5.19
10	Krishnagiri	10.9	40.7	-5.19
11	Madurai	5.7	41.7	-5.19
12	Nagapattinam	2.4	42.34	-5.19
13	Namakkal	9.3	41.01	-5.19
14	Nilgiri	0	0	0
15	Perambalur	6.1	41.63	-5.19
16	Pudukottai	9.4	40.99	-5.19
17	Ramanathapuram	8.1	41.24	-5.19
18	Salem	11.1	40.67	-5.19
19	Sivagangai	9.3	41.01	-5.19
20	Thanjavur	6.4	41.57	-5.19
21	Theni	13.3	40.24	-5.19
22	Thiruvarur	7	41.45	-5.19
23	Thiruvellore	6.7	41.51	-5.19
24	Thoothukudi	5.3	41.78	-5.19
25	Tiruchirapalli	7.9	41.28	-5.19
26	Tirunelveli	6.7	41.51	-5.19
27	Tiruppur	12	40.49	-5.19
28	Tiruvannamalai	4.5	41.94	-5.19
29	Vellore	9.1	41.05	-5.19
30	Villupuram	4.3	41.97	-5.19
31	Virudhunagar	7	41.45	-5.19

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