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Abbreviations

AR5	Fifth Assessment Report
BCM	Billion Cubic Meter
BL	Base Line
CCCDM	Centre for Climate Change and Disaster Management
CGWB	Center Ground Water Board
CO2	Carbon di oxide
CORDEX	Coordinated Regional Climate Downscaling Experiment
CSR	Corporate Social Responsibility
CVI	Cumulative Vulnerability Index
CWC	Central Water Commission
DoLR	Department of Land Resources
DRIP	Dam Rehabilitation and Improvement Project
EC	End Century
GCM	Global Climate Model
GHG	Green House Gas
GIS	Geographical Information System
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit GmbH
Ha	Hectare
HDI	Human Development Index
IAMP	Irrigated Agriculture Modernisation Project
IAMWARM	Irrigated Agriculture Modernisation and Water Bodies Management
IMD	India Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
IWDP	Integrated Wastelands Development Programme

IWRM	Integrated Water Resource Management
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
MaxT	Maximum Temperature
MC	Mid Century
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MinT	Minimum Temperature
mm	Millimeter
MoEF & CC	Ministry of Environment, Forest and Climate Change
MoRD	Ministry of Rural Development
NABARD	National Bank for Agriculture and Rural Development
NAPCC	National Action Plan on Climate Change
NCIWRD	National Commission on Integrated Water Resource Development
NDC	Nationally Determined Contribution
NGO	Non-Governmental organizations
NHP	National Hydrology Project
NWM	National Water Mission
PRECIS	Providing Regional Climate Information System
PWD	Public Works Department
RCP	Representative Concentration Pathways
RDPR	Rural Development and Panchayat Raj
SAPCC	State Action Plan on Climate Change
SHG	Self Help Group
Sq. km	Square Kilometer
TANGEDCO	Tamil Nadu Generation and Distribution Corporation Limited
TMC	Thousand Million Cubic Feet
TNAU	Tamil Nadu Agriculture University
TWAD	Tamil Nadu Water and Drainage

Executive Summary

It is an undeniable fact that the world's climate is changing. The fluctuating rainfall patterns, extreme rainfall and temperatures are creating shorter rainy seasons and longer dry seasons. These shifts have severe impact on natural resources such as water resources, agriculture, coastal, forest, biodiversity, livelihoods, etc. The availability of water is an essential component for ecosystems and affects many of mankind's social and economic actions. Hence, water security is one of the major challenges that the society faces today at both global and local level. Water security and climate change are cross-cutting issues of recent global agreements, such as the Sustainable Development Goals and the Paris Agreement on Climate Change. ***The UN Water*** (United Nation's inter-agency coordination mechanism for all water-related issues) defined ***water security*** as ***"the capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development"*** for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability. The availability and access to water are the pre-eminent issues affecting global economic development, in particular, livelihoods of the poor as they often suffer the most when resources are scarce. ***India is not isolated from these drivers, with water security emerging as an issue of extreme urgency for the country.*** As part of its bilateral collaboration, Government of India and GIZ Germany have undertaken the Water Security and Climate Adaptation in Rural India (WASCA) project that aims to improve water resource management at the national level and in the states of Rajasthan, Madhya Pradesh and Tamil Nadu.

'Scoping study for Indo-German Project on Water Security and Climate Adaptation in Rural India (WASCA) in the State of Tamil Nadu' a rapid assessment on potential water security and climate adaptation, has been carried out in the state of Tamil Nadu, which has become one of the water starved states of the country. The scoping study carefully scrutinizes state's rural water security through a systematic analysis via availability, accessibility of water and its governance through climate lens.

The per capita availability of water in Tamil Nadu is fast declining and well below national average . In the recent decades, the water demand is rising at a faster rate due to rapid increase in population, and industrial and economic growth. The assessment used in this study starts with an analysis of basin-wise surface and groundwater resources and its potential, groundwater extraction, changes in land use, irrigation and cropping patterns, and land holdings of the state. Basin-wise (Except Cauvery Basin) water availability, sectoral demand and gap are intensely explored. Then, current and future climate change scenarios are assessed using high resolution Indian Meteorological Department (IMD) gridded data and Coordinated Regional Climate Downscaling Experiment (CORDEX) Asia's global climate model data. The significant increase in maximum and minimum temperature have been observed in the past during 1951- 2015 and under future climate change scenarios till 2100. Later, the district-wise cumulative vulnerability index is derived using IPCC protocol in order to identify the vulnerable districts in terms of water security enabling possible interventions. Both primary and secondary data collected from authorised sources are carefully analysed and overall 18 indicators (climate, water, agriculture and socio economic) that reflect/influence state's rural water security through four interconnected sectors namely, climate extremities, water resources, agriculture and socio-economic are selected to assess climate vulnerability. These data are normalised, aggregated and composite vulnerability index (CVI) values are calculated using a robust statistical tool. The composite vulnerability index values of each district are spatially mapped using geospatial techniques. Based on the cumulative vulnerability index score, four hot spot districts namely Ramanathapuram, Dharmapuri, Perambalur and Thiruvannamalaiand and corresponding basins and sub-basins are prioritised for demonstrating pilot project.

Finally, the existing schemes and projects related to the state's water security are explored and gap areas are conceived for future plausible adaptation strategies. The exact gap to implement the project could be fine-tuned with the help of local officials and community, for which this study strongly recommends a detailed Participatory Rural Appraisal at the village level to augment water resources, and climate proof sustainable water resource management.

1 Overview of the Project

WASCA, a bi-lateral project commissioned by the German Federal Ministry for Economic Cooperation and Development in partnership with the Ministry of Rural Development (MoRD) and Ministry of Jal Shakti (MoJS) is implemented by GIZ in four states namely, Tamil Nadu, Rajasthan, Madhya Pradesh and Uttar Pradesh, and at the national level. The project aims to improve water resource management with respect to water security and climate adaptation. The project period is from April 2019 - March 2022. Project WASCA seeks to address planning, financing and implementation mechanisms developed in the field of rural water resource management and climate change adaptation. the project has three output areas:

- Improved convergence of existing planning and financing approaches to strengthen water security
- Demonstration of convergent planning, financing and implementation at the sub-basin level
- Cooperation with the private sector for integrated and climate adapted management of water resources at state and local levels

The holistic pilot measures at sub-basin level were taken up in selected districts, and successful approaches were scaled-up at the state and national levels.

With its focus on water-related climate action and integrated water resource management (IWRM), the project aims to significantly contribute towards Sustainable Development Goals for ensuring efficient, sustainable, and inclusive water outcomes. Through its implementation, WASCA also supports the National Water Mission, one of the eight missions under the National Action Plan for Climate Change (NAPCC) to achieve their objective of promoting basin level IWRM. While India's Nationally Determined Contributions (NDC) are currently focused on mitigation, outputs from Project WASCA aims to explore possible contributions towards the larger goals of climate adaptation through its work on improving water efficiency in agriculture, allied sectors and industries, waste water management, ecosystem development and disaster risk reduction.

2 Overview of the Study

Scoping study for WASCA project in the State of Tamil Nadu was done by Centre for Climate Change and Disaster Management, Anna University India (Contract No: 83326949; Project No:18.2052.1-001.00) during the period 24 June to 30 September 2019. The main aim of the project is to have a rapid assessment report on potential and scope of water security and climate adaptation in the state of Tamil Nadu.

2.1 Objectives:

i. Preliminary state-level scoping of water security and climate adaptation in the respective states in all river basins including the groundwater context, looking at both demand and supply sides

ii. Identifying climate and water security hotspots through a scientific criteria in the state

iii. Identifying potential geographical areas for project demonstration for water security and climate adaptation and relevant interventions

iv. Mapping of existing schemes, projects and policies related to water security and climate adaptation for the purpose of scoping

v. Documenting gap areas related to water security and climate adaptation in the identified areas

vi. Identifying potential private sector presence in the select areas

2.2 Outputs

- Prioritised list of geographical areas/sub basins for undertaking demonstration project
- Spatial Map of high priority sub basins
- Specific areas of work including key action areas
- Potential private partners

2.3 Methodology

The objective wise methods and the source of data collection is tabulated in Table 1. Secondary data from published records, reports, articles, research publications, and authorised websites were taken for analysing land use, irrigation, surface and ground water parameters, and existing schemes related to water security. IMD gridded data and CORDEX data were analysed to observe the changes in past and future climate. Inputs from key officials of state government departments and stakeholders were also considered. The data were segregated and analysed, and geospatially mapped using GIS Tools.

Table 1 : Objective wise Methodology & Data Source

S.No.	Objective	Source & Method	Output
1	Preliminary state-level scoping of water security and climate adaptation in the respective states in all river basins	Secondary data from published records, reports, articles, research publications, and authorised websites	River basin's profile-Tables/ Charts/ Geospatialmaps
2	Climate hot spots	IMD observed gridded data; CORDEX Representative Concentration Pathways (RCP) 4.5 and 8.5 scenarios	Climate profile Geospatial maps
3	Identifying potential geographical areas for project demonstration for water security and climate adaptation and relevant interventions	Both primary and secondary data; Ranking of districts based on climate and water related data	Potential geographi-calareas for projectdemon-stration- Maps
4	Spatial mapping on existing schemes, projects and policies related to water security	Secondary data-Government Departments	Existing schemes/ projects in Tables
5	Documenting gap areas related to Water Security and Climate Adaptation in the select areas	Expert opinions, Ground info	Potential areas to work
6	List of private sectors involved in water-related projects	Secondary data	Potential private partnerslist

3 Literature Review

Climate change is projected to reduce renewable surface water and groundwater resources significantly in the driest subtropical regions, intensifying competition for water among sectors over the 21st century. In many regions, increase in temperature along with changing precipitation patterns alters hydrological systems and affects the quantity and quality of water resources (IPCC AR5). The same has been observed in the state of Tamil Nadu where the day and night time temperatures are at an increasing trend from 1969 to 2015, and the increase is more pronounced in recent decades (Jeganathan & Andimuthu 2013; 2019). The state is experiencing more dry days than wet days every year (Guhathakurta et al., 2011). However, there has been a significant increase in heavy precipitation events. Due to high spatial variability, collecting water where it falls and transferring to water starved areas and collecting the sparse rainfall will be a challenge. (TNSAPCC, 2013). The regional climate change projection for the state of Tamil Nadu simulated by Hadley Centre's regional climate model PRECIS indicated an increase in the maximum and minimum temperature under future near-, mid- and end century scenarios. The annual rainfall projections for the same periods indicate a general decrease in rainfall of about 2-7 per cent, 1-4 per cent and 4-9 per cent, respectively. However, significant exceptions are noticed over some pockets of western hilly areas and high rainfall areas where increases in rainfall are seen. There are also indications of increasing heavy rainfall events during the northeast monsoon season and a slight decrease during the southwest monsoon season. (Bal et al., 2016). Climate change will affect water resources, its supply demand and its quality. Any shortfall in water supply will enhance competition for water use in water-stressed regions.

As a monsoon dependent state, Tamil Nadu's agriculture in a particular season depends predominantly on the corresponding season's rainfall because the state has inter-state rivers and have a more closed water system than the other states (Gumma et al., 2014). An increasing population and failure in monsoons put more pressure on water resources in the state. The age old structures, inadequate maintenance, encroachment in the catchments and foreshore areas, large-scale siltation, the practice of fragmentation of land holdings, lack of institutional arrangements for the water supply, widespread deviations from the intended cropping pattern, seepage, percolation, evaporation, conversion of ayacut for non-agricultural purposes, excessive drawl in the upper reaches, unauthorised drawl, etc. have caused a wide gap in the potential created and its utilisation in the case of surface flow sources of irrigation in the state. (DoLR Report, 2012). Surface irrigation was mainly practiced in the districts adjacent to river Cauvery (Thiruvurur, Thanjavur, Nagapattinam, and Erode), and tank-irrigated areas are predominant in Tirunelveli and Pudukkottai. Groundwater-irrigated areas are spread across the state mainly in Coimbatore, Salem, Villupuram, and Thiruvannamali districts (Gumma et al., 2014). In Tamil Nadu, most of the surface water has already been tapped primarily for irrigation (Kuttimani et al., 2017). A significant decrease in irrigated area (30-40 per cent) was observed during the water-stressed years of 2002-03, 2003-04, and 2009-10 and groundwater in Tamil Nadu cannot serve as a secure water source in the case of scarcity of surface water and rainfall(Gumma et al., 2014). Some studies indicate that the water balance components would be affected by future climate change scenarios. The decrease in total water yield and ground water flow component was observed under IPCC AR4 scenario for mid-century and end-century period in the Chennai basin (Jeganathan & Andimuthu, 2015). There is lack of awareness about the risks related to climate change among decision-makers, planners and residents (Samuel et al., 2015). They also pointed out that the fragmented governance structure and lack of integrated analyses of hazards and socio-economic vulnerabilities are the primary causes of water-related deficiencies in Chennai. Sustainable use of water resource gets increasingly difficult as the demand for water far exceeds the availability, and the discounting rates for the future tend to increase under such circumstances. Therefore, in order to make our water utilisation more sustainable, both these approaches will have to be followed. (Lal 2001). In this context, adaptation strategies are of key significance. Adaptation to climate change, briefly put, involves the adjustment of practices, processes and structures to reduce the negative effects of change (UNDP, 2008). Adaptation options with improved irrigation methods/crop varieties along with infrastructural investments may yield better results.

4 Tamil Nadu State Profile

Tamil Nadu is one of the most water-stressed states in India. The state accounts for 6 per cent of population (Census 2011) that are endowed with only 3 per cent of water resources in India. The state's climate is semi-arid, tropical monsoon. Due to its topographical features and geographical area, the climate of Tamil Nadu is strikingly different from the general climate of the country. The state receives maximum rainfall during the months of October, November, and December (post-monsoon), whereas in the rest of the country, the maximum rainfall is received in the months of June, July, August, and September months (monsoon). The major part of the state is rain-fed and approximately 43 per cent of its area is used for agricultural cultivation. Since the state is entirely dependent on rains for recharging its water resources, monsoon failures lead to acute water scarcity and severe droughts. Drainage system of Tamil Nadu can be grouped into 17 major river basins, and majorities are water stressed. Most of the rivers which drain into Tamil Nadu originate from Western Ghats uplands and Eastern Ghats. Tamil Nadu has no perennial river; they are all rain-fed. These rivers have to cross state boundaries before they irrigate the fields downstream. Tamil Nadu has a total of 126 large dams and serve multiple purposes such as in in the field for irrigation, production of hydro-electricity, fisheries and drinking water, etc. There are several lakes/tanks in Tamil Nadu, that contribute in boosting the state's agricultural economy. The state has a rich tradition of tank irrigation with tanks being used for harvesting and preserving local rainfall and water from streams and rivers for later use, primarily for agriculture and drinking water, and for sacred bathing and ritual.

The current total water potential in Tamil Nadu is assessed to be 42,748 MCM (1510 TMC) out of which surface water potential contribute to 24160 MCM (853) and ground water potential of about 18588 MCM (657 TMC) (https://www.twadboard.tn.gov.in/content/tamilnadu). Almost 95 per cent surface water and 80 per cent ground water have already been in use. Major uses of water include irrigation, human/animal consumption, and industrial use.

4.1 Per Capita Water Availability

In recent decades, the water demand is increasing at a fast rate due to population rise, and industrial and economic growth. There is about 15.6 per cent increase in population between 2001 and 2011. The per capita need is larger and triggered by increasing population growth (Figure 1). The per capita availability of water in Tamil Nadu has come down from 1492 cubic meter in 1951 to 723 cubic meter in 2001 (Palanisami et al., 2011) and 590 cubic meter in recent period (Natarajan et al., 2017).

As per the Falkenmark Water Stress Indicator, 'a country or region is said to experience "water stress" when annual water supplies drop below 1,700 cubic meter per person per year. Countries with per-capita water availability less than 1,700 cubic meter per year are categorised as water-stressed. India has also now become a water stressed country with per capita available water of 1,545 cubic meter (NITI Aayog, 2018).

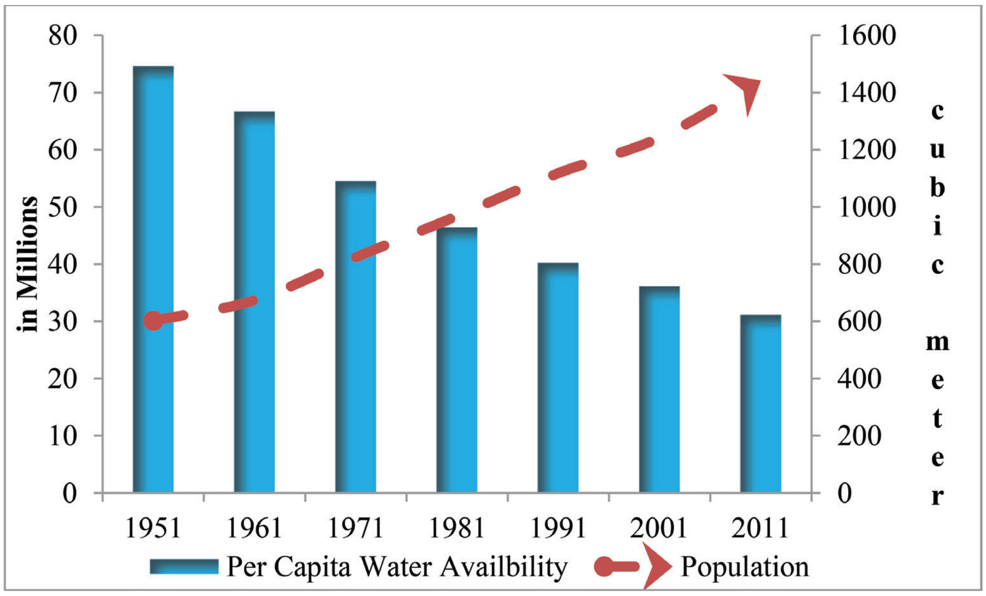


Figure 1 : Per capita water availability in Tamil Nadu

While the Tamil Nadu State's per capita water availability based on Census 2011 is against the international water stress indicator, and far lower than its standard. The state's per capita deficit befalls 923 cubic meters (59 per cent) from national annual per capita water availability. Due to population growth (projected population of 81.5 million in 2019) and increase in usage of water in domestic and industrial sectors, the per capita water availability is at an alarming decreasing trend.

4.2 Changes in Land Use Pattern

Booming economics, population growth and rapid urbanisation have considerable impact on water availability and demand. Changes in food consumption, lifestyle and land-use pattern also play a major role in water requirement. The land use pattern in Tamil Nadu has also witnessed significant structural changes due to rapid urbanisation and economic development. Figure 2 depicts land use changes from 2000-01 to 2015-16. Approximately 37 per cent of the state's total geographical area is used under net sown area in 2015-16. The land put to non-agricultural purposes have significantly gone up from 15.3 per cent in 2000-01 to 16.8 per cent in 2015-16. Wasteland comprising cultivable waste, current fallows and other fallows have increased from 20.1per cent in 2000-01 to 23.1 per cent in 2015-16. Its share in the geographical area has gone up to 23.1 per cent indicating its potential to be tapped. There is a steady decline in the extent of land under barren and uncultivable lands in the state. With the increase in wasteland, the relative share of net area sown in total geographical area of the state has come down from 40.8 per cent in 2000-01 to 37 per cent in 2015-16.

Area under permanent pastures and grazing lands are shrinking; it is a sign of a decline in village common land due to encroachment and neglect. However, total area under these categories is very small. The area under miscellaneous tree crops and groves has also decreased from 2 to 1.8 per cent in 2015-16. The decline in the net area sown was mainly attributed to increasing conversion of agricultural land into non-agricultural purposes including housing sites and other developmental purposes. A combination of factors such as increasing industrialisation, urbanisation, housing activities and infrastructure development triggered the conversion of agricultural land into non-agricultural uses. This has resulted in a decline of the area under cultivation.

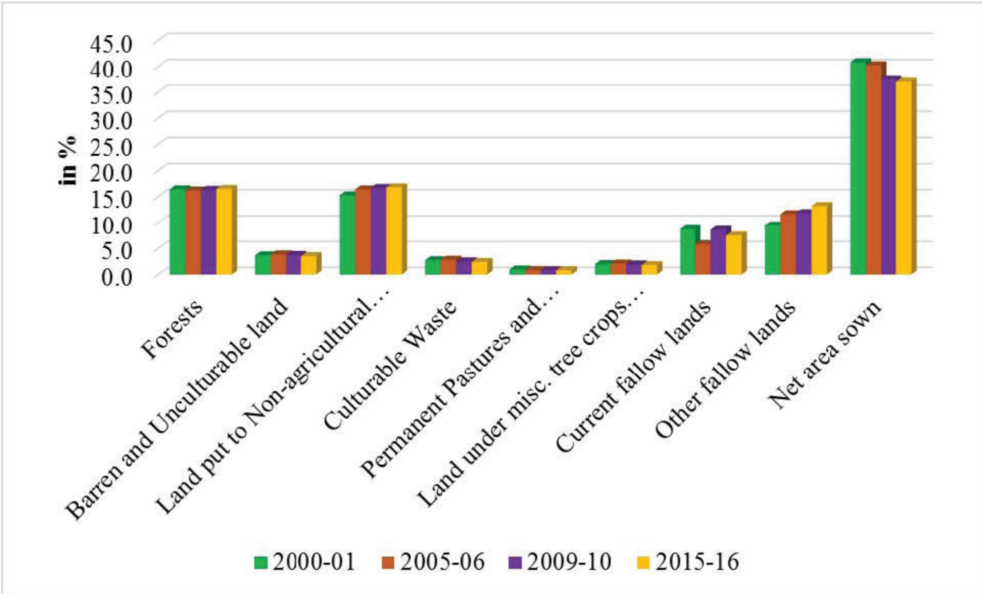


Figure 2 : Changes in land use pattern during 2000-01 to 2015-16

4.3 Land holdings

Together with rising demography and shrinking area under cultivation, the pattern of land ownership has also changed. As per the agriculture census of 2010-11, the marginal and small farm holdings account for 91 per cent of the total holdings and operated 60.6 per cent of the total area (Table 2). The shares of land operated by marginal farmers are 35.32 per cent, small farmers are 25.33 per cent, semi medium farmers are 20.89 per cent, medium farmers are 13.07 per cent and large farm holders account for 5.39 per cent. Even though the total number of operational holdings decreased from 8,192,973 to 8,118,224 in 2010-11, the marginal and small farm holdings have increased from 91.07 to 91.7 per cent (Figure 3)

Table 2 : Operational Holdings in 2005-06 to 2010-11

S. No.	Size Class	Number of Operational Holdings		Area of Operational Holdings in Hec.	
		2005-06	2010-11	2005-06	2010-11
1	Below 0.5	4491747	4536869	1052264	1065882
2	0.5 - 1.0	1735958	1729686	1234106	1225820
	Marginal (1+2)	6227705	6266555	2286370	2291702
3	1.0 - 2.0	1234054	1181344	1720819	1643697
	SMALL (3)	1234054	1181344	1720819	1643697
4	2.0 - 3.0	384502	359469	926612	864840
5	3.0 - 4.0	157523	142839	541085	490669
	Semi Medium (4+5)	542025	502308	1467697	1355509
6	4.0 - 5.0	76162	68321	338413	303223
7	5.0 - 7.5	69541	61646	415840	368716
8	7.5 - 10.0	23896	20679	203468	175872
	Medium (6+7+8)	169599	150646	957721	847811
9	10.0 - 20.0	16376	14363	216046	188412
10	Above 20.0	3214	3008	175294	161240
	Large (9+10)	19590	17371	391339	349652
	All Size Classes	8192973	8118224	6823947	6488370

(Source : Statistical Hand Book 2017, Department of Economics & Statistics, Government of Tamil Nadu)

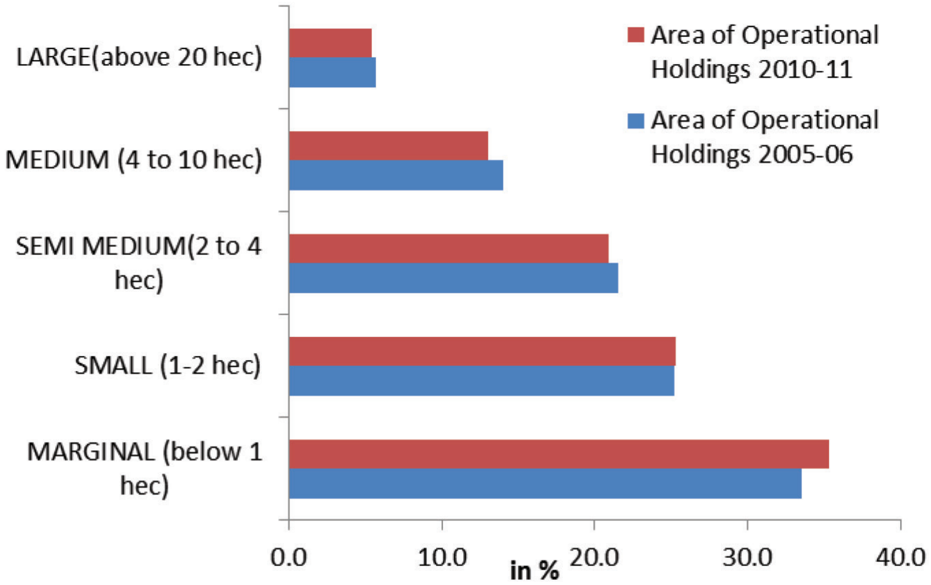


Figure 3 : Area of Operational Holdings in 2005-06 and 2010-11

The average area of land holding declined from 6,823,947 ha in 2005-06 to 6,488,370 ha in 2010-11. The shares of total land operated by marginal and small farmers have increased from 58.7 to 60. 6 per cent (Figure 3).

4.4 Irrigation Patterns

The net irrigated area in 2015-16 is around 2.83 million hectares and the net sown area in 2015-16 is 4.83 million ha (Statistical Hand Book of Tamil Nadu, 2017). The state's irrigation potential in terms of per-capita is only about 0.08 ha when compared to the all India average of 0.17 ha. The net irrigated area in Tamil Nadu was 2.5 million hectares in 1960-61, which has now increased to 2.83 in 2015-16. The net irrigated area during 2015-16 ha is 58.62 per cent of the net sown area and balance area of about 2 m hectares (41.38 per cent are rain fed). The cropping intensity of the state is around 125 per cent in 2015-16, an increase from 120 per cent in 2000-01. The average irrigation ratio of the state in 2015-16 is 73.9 per cent that increased from 65.9 per cent in 2001-02. Figure 4 shows the increasing irrigation intensity and presents the availability of increasing irrigation facility of the state.

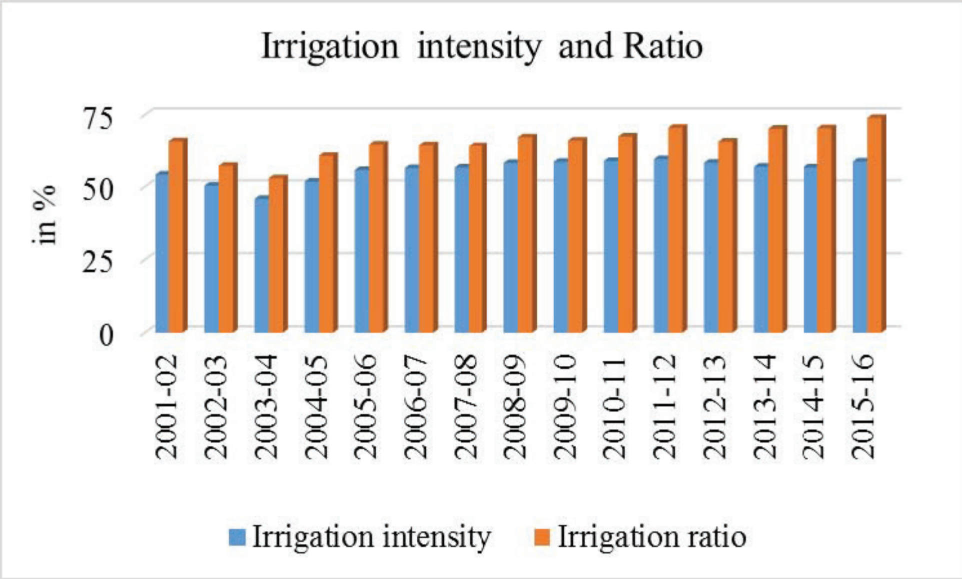


Figure 4 : Irrigation Intensity and Ratio during 2001-02 to 2015-2016

The various sources of irrigation in Tamil Nadu are canals, tanks, tube wells, open wells and bore wells. Table 3 represents the source of irrigation and its contribution to net irrigation. Among different sources of irrigation, well irrigation is a major contributor, with nearly 60 per cent of the irrigation through well irrigation. The total area irrigated through well irrigation including open, tube and other well in 2015-16 are 17.20 lakh hectares. After well irrigation, irrigation through canals contributes to nearly 23.72 per cent of the total irrigation and irrigated around 6.72 lakh hectares. Tank irrigation also have a significant role, that contributes 15.5 per cent (4.38 lakh hectare) the total irrigation.

Table 3 : Source-wise Irrigation Details

Source	Availability (Nos.)	Net Area Irrigated (lakh ha)	per cent with reference to Net Area Irrigated
Canals	2239	6.72	23.72
Tanks	41127	4.38	15.45
Wells (open well; tube well; other wells	18,72,088	17.2	60.73
Others		0.03	0.1
TOTAL	28.32	100	

(Source : Statistical Hand Book 2017, Department of Economics and Statistics, Government of Tamil Nadu)

While tank irrigation share has declined from 31.5 per cent in 1970s to 15.45 per cent in 2015-16, the irrigation from canal share has also shown a declining trend from 33.2 per cent in 1970s to 23.72 per cent in 2015-16. Table 4 lists the trends of usage of different sources such as canal tank and well for irrigation purposes. People in ancient days had created excellent water harvesting structures keeping in mind the state's rainfall patterns and its topography and constructed a series of tanks for irrigation drinking and other purposes. The irrigation through tanks have declined significantly in recent decades. The irrigation through canals has also reduced in the past 50 years. This ultimately leads to more pressure on groundwater to meet the increasing irrigation intensity. Thus, increasing the share of well irrigation share from 35.3 per cent in 1970s to 60.73 per cent in 2015-16.

Table 4 : Source-wise Irrigation Trends During Past 50 Years (in per cent)

	1970s	1980s	1990s	2000s	2010s
Canals	33.2	33	29.7	27.12	23.72
Tanks	31.5	24.6	22.4	18.95	15.45
Wells	35.3	42.4	47.9	53.45	60.73

4.5 Cropping Patterns

The cropping pattern, an important determinant of water availability, has oriented mainly towards crops. The principal major crops in Tamil Nadu are paddy, cereals, pulses, cotton, groundnut, cholam, ragi and sugarcane. Figure 5 shows the trends of cropping pattern of crops during 2000-01 to 2015-16 and depict the changes in the pattern. Cropping pattern during the past 15 years also shows that farmers are moving towards shifting the pattern of cropping.

The total pulses and cereals show an increasing trend. There is a decrease in groundnut's cultivation, which is a major rain fed crop. The area of ground nut cultivation in 2001-02 was 663 ha and it has come down to 347 ha in 2015-16. Nearly half of groundnut cultivators have shifted to other crops. Other principal crops such as cumbu, ragi and gingelly cultivation have also reduced significantly during this period.

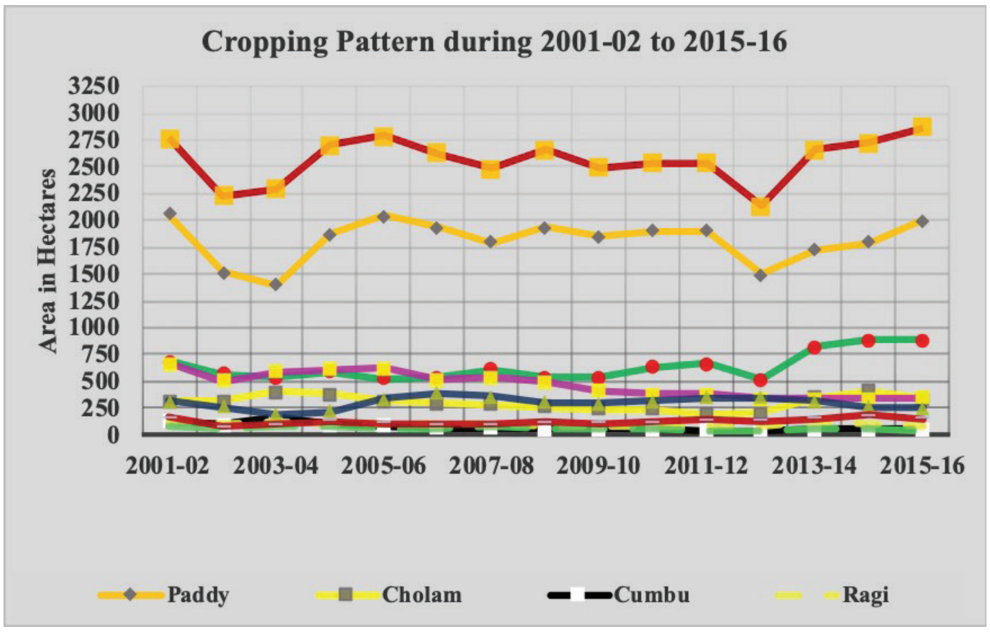


Figure 5 : Cropping patterns during 2001-02 to 2015-16

5 River Basin Analysis of the State

The river basins in Tamil Nadu are grouped into 17 major river basins (Figure 6), comprising 34 river basins, which is further divided in to 127 sub basins (Figure 7). The major river basin groups are Chennai basin, Palar basin, Varahanadhi basin, Pennaiyar basin, Vellar basin, Paravanar basin, Cauvery basin, Agniyar basin, Pambar and Kottakaraiyar basin, Vaigai basin, Gundar basin, Vaippar basin, Kallar basin, Thambaraparani basin, Nambiar basin, Kodaiyar basin and Parambikulam Azhiyar Project (PAP) basin. The entire 17 river basin group is based on the 34 river basin which is flowing in the state of Tamil Nadu and involves interstate operations. Cauvery is the only major basin. Of the others, 13 basins are medium and 3 are minor river basins. Some of the major rivers flowing in the state are Cauvery, Bhavani, Cheyyar, Chittar, Ponniyar, Thamirabarani, Vaigai, Gundar, Noyil and Vaipar. Table 5 shows the name of the major river basin groups and major basins in the group. The districts covered by each basin are tabulated in Table 6 and geospatially represented in Figure 8.

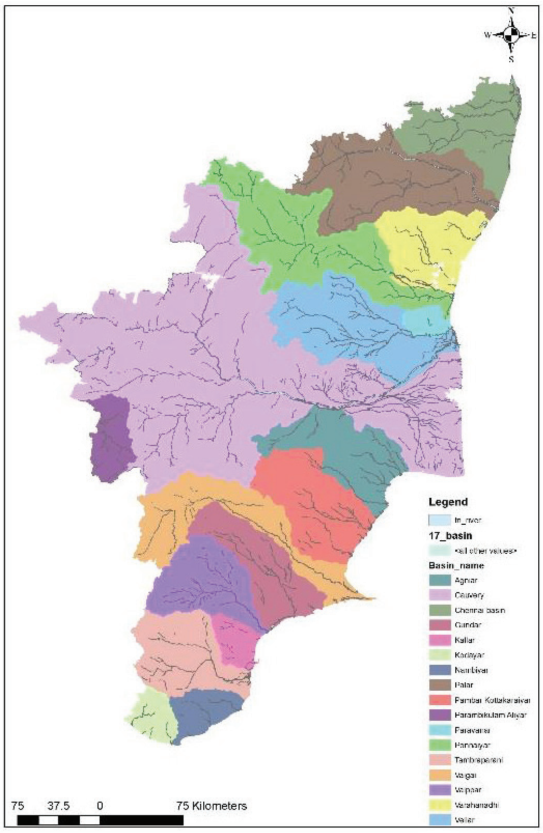


Figure 6: Major river basin group map of Tamil Nadu

Table 5 : Major River Basins of Tamil Nadu

S. No.	Name of the Major River Basin Group	S. No.	Major River basins in the group
1	Chennai Basin Group	1	Araniyar
		2	Kusaithalaiyar
		3	Cooum
		4	Adayar
2	Palar	5	Palar
3	Varahanadhi	6	Ongur
		7	Varahanadhi
4	Pennaiyar	8	Malattar
		9	Ponnaiyaar
		10	Gadilam
5	Vellar	11	Vellar
6	Paravanar		
7	Cauvery	12	Cauvery
8	Agniyar	13	Agniyar
		14	Ambuliyar
		15	Vellar
9	Pambar and Kottakaraiyar	16	Koluvanar
		17	Pambar
		18	Manimukthar
		19	Kottakaraiyar
10	Vaigai	20	Vaigai
11	Gundar	21	Uthirakosamangaiyar
		22	Gundar
		23	Vembar
12	Vaippar	24	Vaippar
13	Kallar	25	Kallar
		26	Korampallam Aru
14	Thambaraparani	27	Thambaraparani

S. No.	Name of the Major River Basin Group	S. No.	Major River basins in the group
15	Nambiyar	28	Karmaniar
		29	Nambiyar
		30	Hanumanadhi
16	Kodaiyar	31	Palayar
		32	Valliyar
		33	Kodaiyar
14	Parmbikulam Aliyar	34	West flowing river

(Source : River basins in Tamil Nadu report to State Planning Commission by TNAU 2011)

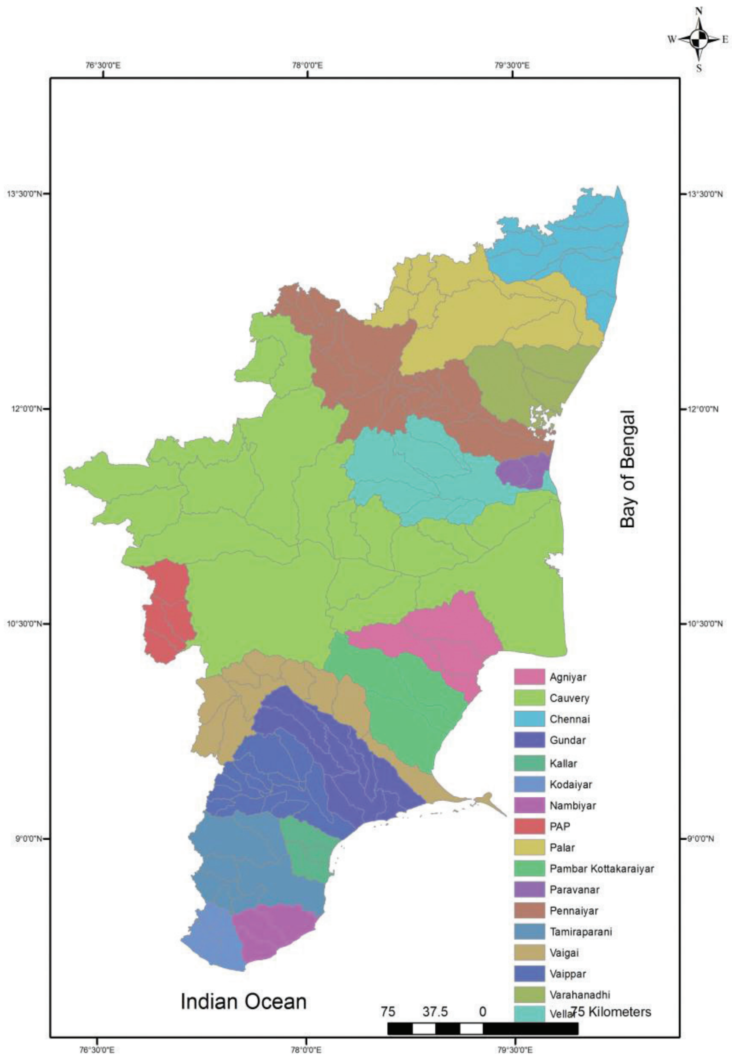


Figure 7 : Sub-basin map of Tamil Nadu

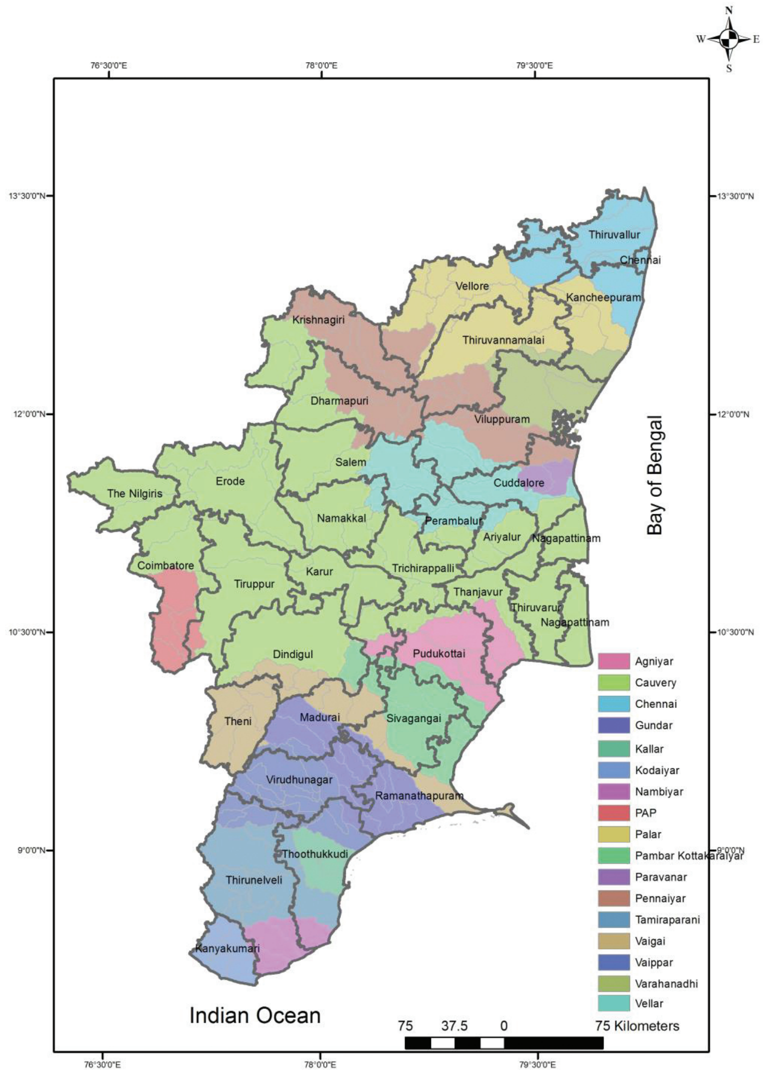


Figure 8 : Districts covered by basins and sub-basins

Table 6 : Major Basin Group and the Districts Covered

S. No.	Major	Area	Districts Covered
1	Agniyar	4663.04	Pudukottai, Thanjavur, Trichirappalli,- Sivagangai, Dindigul
2	Cauvery	43867	Namakkal, Dindigul, Salem, Thanjavur, Nagapattinam, Tiruppur, Thiruvarur, Coimbatore, Erode, The Nilgris, Karur, Trichirappalli, Perambalur, Ariyalur
3	Chennai Basin group	6118.34	Chennai, Kancheepuram, Thiruvallur, Vellore

S. No.	Major	Area	Districts Covered
4	Gundar	5684.32	Madurai, Sivagangai, Virudhunagar, Ramanathapuram and Thoothukudi
5	Kallar	1509	Thoothukudi
6	Kodaiyar	1646.964	Kanyakumari and a small portion in Thirunelveli district
7	Nambiar	2018.4	Thirunelveli, Thoothukudi and Kanyakumari districts
8	Palar	10217.18	Vellore, Thiruvannamalai, Kancheepuram, Thiruvallur, Vilupuram, Krishnagiri
9	Pambar Kottakaraiyar	5910.877	Sivagangai, Ramanathapuram, Pudukottai, Dindigul, Madurai,Trichy
10	Parambiku-lam-Aliyar basin	2388.7	Coimbatore
11	Paravanar	864.059	Cuddalore
12	Pennaiyar	11375	Krishnagiri, Dharmapuri, Salem, Vellore, Thiruvanamalai, Vilupuram, Cuddalore
13	Thamirabarani	5717.08	Thirunelveli, Thoothukudi
14	Vaigai	6823	Theni, Dindigul, Madurai, Sivagangai, Ramanathapuram
15	Vaippar	5,288	Thirunelveli, Virudhunagar, Thoothukudi
16	Varahanadhi	4499	Vilupuram, Thiruvannamalai, Kancheepur-am,Cuddalore
17	Vellar	7530.53	Dharmapuri, Salem, Namakkal, Trichirappalli, Perambalur,Ariyalur, Vilupuram, Cuddalore

5.1 Water Quantity

5.1.1 Surface water potential

The total surface water potential of the state is 853 TMC (24160 MCM) including 261 TMC (7319 MCM) from neighboring states. The surface water potential within the state resources is 592 TMC (16679 MCM). The surface flow accounts for about half of the states' total water potential. Table 7 shows the surface water potential of each of the river basin groups. The total water potential is higher in Cauvery river basin (5,358 MCM) followed by Palar river basin (1,393), Pennaiyar basin (1,319), and Chennai basin group (1,062). Most of the surface water has already been tapped primarily for irrigation, which is the largest user.

Table 7 : Basin-wise Surface Water Potential in 2018-19

S. No.	Name of the Major	Surface water
1	Agniyar	637
2	Cauvery	5358
3	Chennai Basin	1062
4	Gundar	549
5	Kallar	128
6	Kodaiyar	916
7	Nambiyar	203
8	Palar	1393
9	Pambar Kottakaraiyar	648
10	Parambikular Aliyar	675
11	Paravanar	176
12	Pennaiyar	1319
13	Thambaraparani	883
14	Vaigai	842
15	Vaippar	715
16	Varahanadhi	589
17	Vellar	981

(Source : Institute of Water Studies, Government Of Tamil Nadu)

5.1.2 Groundwater potential

The state's annual groundwater recharge is 20.22 BCM and annual extractable groundwater resources are 18.20 BCM (CGWB, 2017). the annual groundwater extraction is 14.73 BCM and the stage of groundwater extraction is 81 per cent. (Dynamic Groundwater Resources Assessment, 2017, Central Ground Water Board, Government of India). As compared to 2013 estimates, the annual groundwater recharge has declined from 20.65 to 20.22 BCM and the annual groundwater extraction has increased from 14.36 to 14.73 BCM. Consequently, there is an increase in groundwater extraction from 77-81 per cent. In the recent decades, the state's agriculture, industrial and domestic sectors majorly depend on groundwater.

5.1.3 Groundwater Extraction

The main source of groundwater is recharge from monsoon rainfall. In Tamil Nadu, more than 70 per cent of the geological formation is of hard rocks that limit the availability and extraction of groundwater unlike other formations. The dependency on groundwater has increased many folds during recent years and the groundwater extraction for irrigation, domestic and industries have resulted in lowering of water levels, long-term water level declining trend and even drying up of wells. The increasing number of over-exploited blocks indicates that there is a wide gap between groundwater draft and recharge. A recent groundwater resources assessment indicated that out of 1166 firkas, 462 firkas are over-exploited and 79 firkas are critical. Over-exploitation is occurring in more than a third of the firkas (39.6 per cent), 6.8 per cent firkas are critical, 14 per cent blocks are semi critical and 3 per cent firkas blocks are saline. Only 36 per cent of firkas are in safe. The percentage of over exploited firkas has gone up from 31-39.6 per cent and some of the critical firkas estimate have turned in to over-exploited block areas (Dynamic Ground Water Resource, 2013). Table 8 shows categorisation of firkas based on ground water assessments from 2013 and 2017.

Table 8 : Groundwater Resource Estimation 2013 & 2017

S.No.	Category of Revenue Firkas	2017		2013	
		No of Firkas	Percent of Firkas	No of Firkas	Percent of Firkas
1	Safe	427	36.6	429	38
2	Semi Critical	163	14.0	212	19
3	Critical	79	6.8	105	9
4	Over-exploited	462	39.6	358	31
5	Poor Quality/ Saline	35	3.0	35	3

District-wise groundwater categorisation shows all firkas (100 per cent) in Chennai district are overexploited followed by Salem (81.8 per cent firkas), Tiruppur (78 per cent firkas), Thiruvannamalai (71 per cent firkas), Namakkal (66 per cent firkas), Coimbatore and Dharmapuri districts (65 per cent firkas), Perambalur and Vellore districts (66 per cent firkas). The Nilgiris and Ramanathapuram districts have safer firkas as compared to other districts (Figure 10). More than 150 per cent groundwater extraction is in Chennai and Salem districts. Figure 9 shows the spatial map of ground water categorisation. The brown colour shows the over-exploited firkas and red colour denotes the critical firkas. Safe firkas are shown in green colour. This recent assessment by CGWB emphasises that an adoption of groundwater resource developmental activities are much needed at present and need to be enhanced for the future demand.

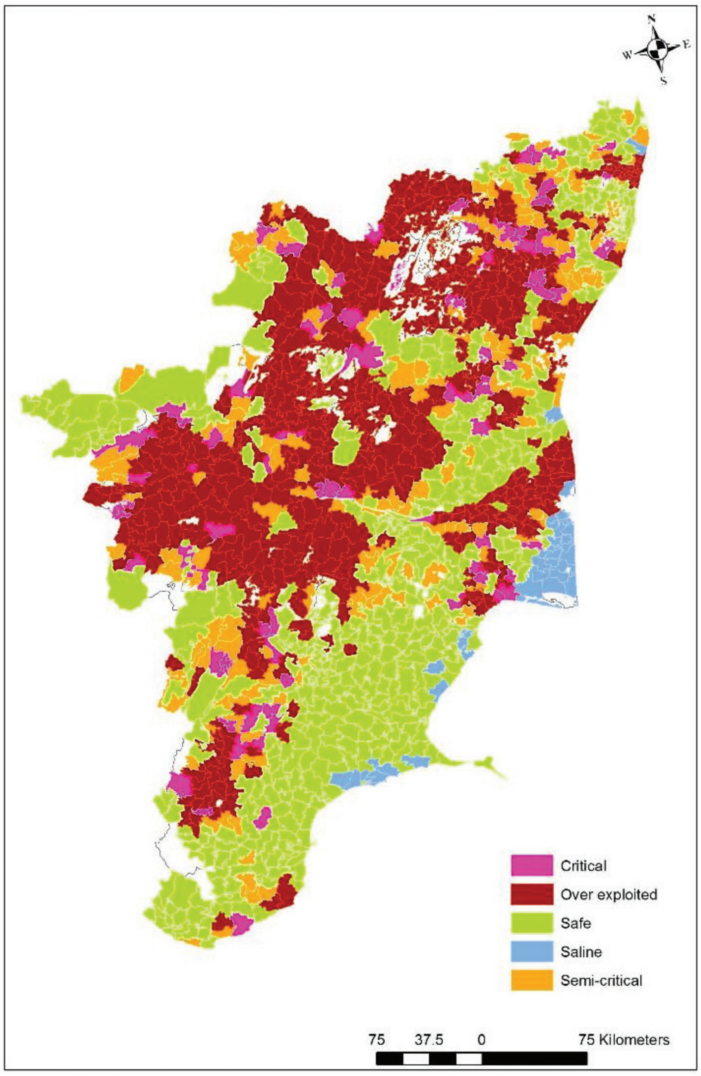


Figure 9 : Firka-wise groundwater extraction - 2017

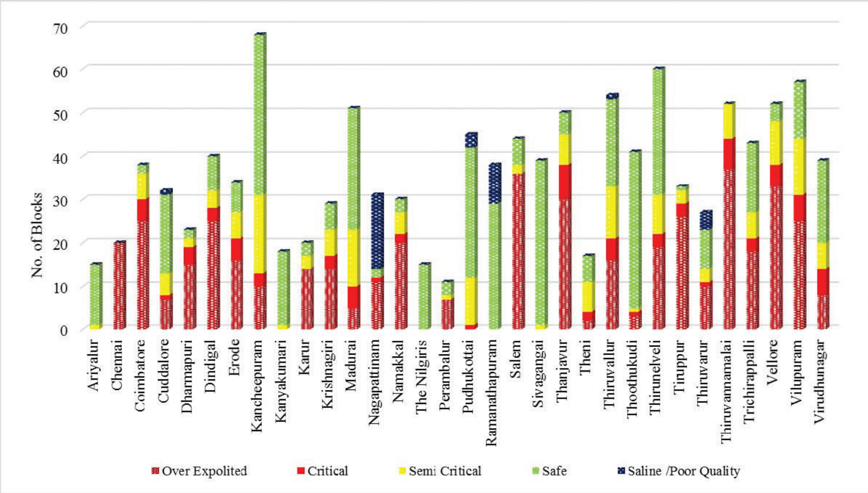


Figure 10 : District-wise groundwater resources assessment, 2017

5.1.4 Supply and Demand Gap

With rapid economic and demographic change, water demands in all the sectors are increasing, particularly in the agriculture, domestic and industrial sectors. The sectorial water for water in 2017 and 2040 and current water availability are taken from Central Water Commission's Tamil Nadu basin reports and are presented in Table 9. Cauvery basin and Vaippar basin reports are not available in the CWC report. The water demand for Vaippar basin from TNAU's report to State Planning Commission is presented in the table for visualisation purpose. The details on Cauvery basin is not presented and discussed here. So, the total water demand and its surplus/deficits are discussed for other 15 basins only.

Based on CWC's report, the total water demand in 2017 was 24,004.08 MCM. The demand for irrigation sector was 19,003.31 MCM in 2017 and the demand was more in Pennaiyar, Palar, Agniyar, Vaigai, Vellar, Paravanar, Varahanadhi and Tamirabarani basins. The water demand for domestic purpose was 1,147.56 MCM and the demand was more in the Chennai basin (335.51 MCM) followed by Palar, Vaigai and Pennaiyar basins. The water demand for industrial purposes was nearly 1,392.94 MCM in Chennai basin followed by Vaigai basin (302.31 MCM) and Palar basin (258.38 MCM). The total water potential is estimated at 25611 MCM (excluding Cauvery basin). Thus, the deficit was 238.185 MCM. This demand would increase to 16,727 MCM in 2040. The demand for non-agricultural purposes in the year 2040 would be about 20,745 MCM and demand for agriculture purposes will be about 19,878.973. This leaves a supply-demand gap of about 41 per cent in 2040 (Table 10). According to the projections by National Commission on Integrated Water Resources Development (NCIWRD), the irrigation sector alone is going to need additional 71 BCM by 2025 and 250 BCM of water by 2050 compared to the demands of 2010 (Press Information Bureau, 2013). While in Tamil Nadu, domestic and industrial and energy sectors are in need of additional water.

Table 9 : Basin Wise Water Potential, Demand and Deficit in 2017 & 2040

Major Basin Group	Year	Demand of water in various sectors (MCM)					Water availability (MCM)					Surplus / Deficit in MCM
		Irrigation	Domestic	Industries	Livestock	Total	Surface water potential	Ground water potential	Quantity of recy water from Sewage	Quantity of water from desilting	Total	
Agniyar	2017	1882.96	38.08	129.98	89.185	2140.21	1136	893.892	-	0	2029.89	-110.31
	2040	1882.96	0	763.25	108.335	2754.55						-724.65
Chennai	2017	1359	335.51	1392.94	85.66	3173.11	1062	743.632	-	49.32	1854.95	-1318.16
	2040	1359	519.28	8180.72	100.502	10159.5						-8304.6
Gundar	2017	731.38	40.69	153.8	55.49	981.36	549	578.89	-	-	1127.89	146.54
	2040	731.38	54.88	903.37	57.16	1746.79						-618.9

Major Basin Group	Year	Demand of water in various sectors (MCM)					Water availability (MCM)					Surplus / Deficit in MCM
		Irrigation	Domestic	Industries	Livestock	Total	Surface water potential	Ground water potential	Quantity of recy water from Sewage	Quantity of water from desilting	Total	
Kallar	2017	100.2	24.52	38.26	11.67	174.65	128	57	247.56	---	432.56	257.91
	2040	100.2	37.8	225.81	11.27	375.08						57.48
Kodaiyar	2017	728	50.12	70.28	14.57	862.98	916	239.59	---	---	1155.59	292.61
	2040	728	76.22	415.07	15.29	1234.58						-79
Nambiar	2017	356.88	14.47	40.61	7.49	419.45	203	780.98	117.57	0.89	984.87	565.42
	2040	356.88	20.47	235.92	7.44	620.71						364.16
Palar	2017	1950.59	142.68	258.39	120.794	2472.45	1392.3	891.669	-	181.21	2465.18	-7.28

Major Basin Group	Year	Demand of water in various sectors (MCM)					Water availability (MCM)					Surplus / Deficit in MCM
		Irrigation	Domestic	Industries	Livestock	Total	Surface water potential	Ground water potential	Quantity of recy water from Sewage	Quantity of water from desilting	Total	
Palar	2040	1950.59	209.17	1516.51	221.74	3898.01						-1432.8
Pambar & Kottakaraiyar	2017	1460	43.08	98.85	72.654	1674.58	648	811.966	-	-	1459.97	-214.62
	2040	1460	61.91	581.43	75.296	2178.64						-718.67
Parambikulam -Aliyar	2017	840	18.38	117.15	11.47	987.001	675	450.02	-	116.908	1241.9	-254.92
	2040	840	27.5	689.42	11.43	1568.35						326.43
Paravanar	2017	1738.65	13.97	64.037	18.26	1834.92	379	1284.95	-	3.686	1667.64	-167.29
	2040	1738.65	19.29	375.99	19.5	2153.44						-485.8

Major Basin Group	Year	Demand of water in various sectors (MCM)					Water availability (MCM)					Surplus / Deficit in MCM
		Irrigation	Domestic	Industries	Livestock	Total	Surface water potential	Ground water potential	Quantity of recy water from Sewage	Quantity of water from desilting	Total	
Pennaiyar	2017	2076.33	102.06	300.2	33.82	2478.59	1319.58	766.77	4.1	59.23	2149.68	-328.91
	2040	2076.33	145.34	1760.66	36.26	3982.33						-1891.9
Thamirabarani	2017	1054.57	79.56	63.24	59.57	1256.94	883	812.08	123.81	44.88	1739.96	483.02
	2040	1054.57	119.66	371.06	58.93	1604.22						135.74
Vaigai	2017	1802	133.32	302.31	35.57	2273.2	1371	548.99	0	32.01	1952	-321.2
	2040	1802	202.24	1772.82	37.66	3814.72						-1862.7
Varahanadhi	2017	1250.75	40.62	100.26	94.98	1391.634	428	1256	3.65	3.09	1690.74	299.11

Major Basin Group	Year	Demand of water in various sectors (MCM)					Water availability (MCM)					Surplus / Deficit in MCM
		Irrigation	Domestic	Industries	Livestock	Total	Surface water potential	Ground water potential	Quantity of recy water from Sewage	Quantity of water from desilting	Total	
Varahanadhi	2040	1250.75	58.12	589.8	95.35	1898.67						-211.02
Vellar	2017	1672	70.5	122.236	18.26	1883	981	864.85	-	29.532	1875.39	-7.62
	2040	1672	94.17	717.71	19.5	2503.38						-628
*Cauvery & Vaippar Basins reports are not available in Central Water Commission's Basin Report												
Vaippar	2044	1386.15	152.01	103.1	13.76	1654.92					1783	128

Table 10 : Sectoral Water Demand Situation in MCM

Sectors	2017	2040
Irrigation	19003.31	19003.31
Domestic	1147.56	1646.05
Industries	3252.54	19099.54
Livestock	729.44	875.66
Total	24004.08	40492.97
Availability	23765.89	
Demand	238.185	16727.08

5.2 Water Quality

Water quality is one of the major issues pertaining to water security due to climate change. Rapid urbanisation and industrial growth has affected the availability and quality of water due to its exploitation. The problems of water quality are more acute in areas that are densely populated and thickly industrialised. The common pollutants of water are discharge of agricultural, domestic, and industrial waste, pesticides, etc.

The chemical constituents found in the state's ground water beyond BIS Norms are listed in Table 11. The major common pollutants found in majority of the districts are fluoride and nitrate. Heavy metals such as lead, cadmium and chromium are also found in some districts. Salinity is more (EC > 3000 μS/cm at 25 °) in Dharmapuri, Pudukkottai, Thoothukkudi, Coimbatore, Dindugal, Ramanathanpuram, Salem, Karur, Namakkal, Perambalor, Thiruvannamalai, Vellore, Villupuram and Cuddalore districts.

Table 11 : Chemical Constituents Found in State's Ground Water beyond BIS Norms

	Fluoride (above 1.5 mg/l)	Nitrate (above 45 mg/l)	Iron (above 1.0mg/l)	Heavy metals: Lead (above 0.01 mg/l) Cadmium (above 0.003 mg/l) Chromium (above 0.05 mg/l)
Districts	Coimbatore, Dharmapuri, Dindigul, Erode, Karur, Krishnagiri, Namakkal, Perambalur, Pudukottai, Ramanathapuram, Salem, Sivagangai, Theni, Thiruvannamalai, Tiruchirapalli, Thirunelveli, Vellore, Virudhunagar	Chennai, Coimbatore, Cuddalore, Dharmapuri, Dindigul, Erode, Kancheepuram, Kanyakumari, Karur, Madurai, Namakkal, The Nilgiris, Perambalur, Pudukottai, Ramanathapuram, Salem, Sivagangai, Theni, Thiruvannamalai, Thanjavur, Thirunelveli, Thiruvallur, Trichirappalli, Tuticorin, Vellore, Vilupuram, Virudhunagar	Namakkal, Salem	Lead: Dindigul, Tiruvallur, Kancheepuram Cadmium: Thiruvallur Chromium: Cuddalore, Dindigul, Erode, Kanchipuram, Thiruvallur

6 Climate Profile of Tamil Nadu

Tamil Nadu has a tropical climate. Due to its proximity to the sea, summers are less hot and winters are less cold. The maximum daily temperature rarely exceeds 43^{0}C and the minimum daily temperature seldom falls below 18^{0}C. The Western Ghats acting as a barrier deprive the state of the full blast of south-west monsoon winds. However, south-west monsoon has a precipitation of about 1/3rd of the normal rainfall received in Tamil Nadu which helps in taking up the rainfed cultivation. The state depends on the north-east monsoon rains that are brought by the troughs of low pressure establishing in south Bay of Bengal between October and December.

6.1 Past Climate Hazards

6.1.1 Drought

Low rainfall coupled with the erratic monsoons in the state makes it the most vulnerable to drought. Drought is more recurrent during the months of June to September. Usually, the districts which are severely prone to drought hazard are Dharmapuri, Madurai, Coimbatore, Ramanathapuram, Salem, Tiruchirapalli, Thirunelveli and Kanyakumari. The list of drought-affected districts declared by the state during 2000-2014 is listed in Table 12.

Table 12 : Drought Affected Districts during 2000-2014

Year	Districts
2002	Coimbatore, Cuddalore, Dharmapuri, Dindigul, Erode, Kancheepuram, Kanya-kumari, Karur, Madurai, Nagapattinam, Namakkal, Perambalur, Pudukkottai, Ramanathapuram, Salem, Sivagangai, Thanjavur, The Nilgiris, Theni, Thiruvallur, Thiruvarur, Thoothukudi, Trichirappalli, Thirunelveli, Thiruvannamalai, Vellore, Vilupuram, Virudhunagar,
2003	Coimbatore, Cuddalore. Dharmapuri. Dindigul, Erode, Kancheepuram, Kanya kumari, Karur, Krishnagiri, Madurai, Nagapattinam, Namakkal, Pudukkottai, Ramanathapuram, Salem, Perambalur, Sivagangai, Thanjavur, The Nilgiris, Theni, Thiruvallur, Thiruvarur, Thoothukudi, Trichirappalli, Thirunelveli, Thiruvannamalai, Vellore, Vilupuram, Virudhunagar,

Year	Districts
2012	Ariyalur, Coimbatore, Cuddalore, Dharmapuri, Dindigul, Erode, Kancheepuram, Kanyakumari, Karur, Krishnagiri, Madurai, Nagapattinam, Namakkal, Perambalur,Pudukkottai, Ramanathapuram, Salem, Sivagangai, Thanjavur, The Nilgiris, Theni, Thiruvallur, Thiruvarur, Thoothukudi, Trichirappalli, Thirunelveli, Tirupur, Thiruvannamalai, Vellore, Vilupuram, Virudhunagar

(Source: Http://Farmer.Gov.In/Drought/Droughtexport.Aspx?5+Z96qeraji=)

During 2017, Tamil Nadu experienced the most severe drought in its history that adversely affected the agricultural and drinking water sectors. Drought has a direct and significant impact on food production, livelihoods and the overall economy.

6.1.2 Floods

Tamil Nadu is also subjected to annual flooding, including flash floods due to cloud bursts, monsoon floods of single and multiple events and cyclonic floods. Every year, number of people are affected - some succumbing to the floods, thousands are rendered temporarily homeless and several hectares of crops get damaged. Floods in the state are mainly caused during cyclones and heavy rains. At the time of depressions, the coastline of Tamil Nadu experience heavy flooding.

For instance, in the years 1997 to 2005, even though there were no cyclonic storms, extremely heavy rainfall caused severe floods in most of the coastal areas and affected the districts of Chennai, Kancheepuram, Thiruvallur, Cuddalore, Thanjavur, Nagapattinam, Thiruvarur, Pudukottai and Thoothukudi (State Disaster Management Perspective Plan, 2018-2030). On an average, over the past several years, over 5000 houses have been damaged annually due to rains, storm surge and local flooding. The average estimate is that in Tamil Nadu 0.45 million hectares of land is prone to floods. In total, 4,399 areas based on legacy data have been identified as vulnerable to monsoon-related disasters and are classified as below. ***(https://tnsdma.tn.gov.in/pages/view/Risk-Mapping)***

6.1.3 Heat Waves

A heat wave is a period of abnormally high temperatures, more than the normal maximum temperature that occurs during the (hot weather) summer season. Heat Waves typically occur between March and June. The extreme temperatures and resultant atmospheric conditions adversely affect people living in these regions as they cause physiological stress, sometimes resulting in death. Some of the districts in Tamil Nadu that have witnessed heat wave impacts are Vellore, Thiruvannamalai, Krishnagiri, Dharmapuri, Salem, Namakkal, Tiruppur, Coimbatore, Erode, Karur, Trichirapalli, Ariyalur, Perambalur, Sivagangai, Virudhunagar, Theni, Dindigul and Madurai. (https://tnsdma.tn.gov.in)

6.2 Observed Climate Variability

India Meteorological Department (IMD) high resolution gridded temperature (1°× 1°) and rainfall data (0.25°× 0.25°) were used to calculate the observed climate change over the period 1951- 2015 (65 years) (Rajeevan et al., 2006). District wise maximum, minimum temperature and rainfall average and its changes over the period were calculated. In total, 224 rainfall and 24 temperature grids covering entire state were extracted from IMD gridded data set and analysed. District wise annual rainfall and temperature mean values were calculated for the period 1951-2015 and its trends were also projected.

6.2.1 Mean Maximum temperature and its changes during 1951-2015

The annual maximum temperature for Tamil Nadu is 32.2°C with a range varying from 28.9°C to 33.4°C (Figure 11a). Among the districts, the highest value of annual maximum temperature (33.3°C) were observed in Chennai and Kancheepuram districts followed by Thiruvallur (33.2°C) and Vilupuram, Trichirappalli, Cuddalore, Perambalur, Nagapattinam, Pudukottai, Thiruvarur, Ariyalur districts (32.1°C). While the lowest value (29.8°C) were observed in The Nilgiris and the average maximum temperature in Coimbatore district is 29.7°C.

Increasing trend of maximum temperature has also been observed in all districts. Even though the maximum temperature in north-east coastal districts is high, change in temperature is more in the middle and southern coastal districts such as Thiruvarur, Thanjavur, Nagapattinam, Ramanathapuram, Pudukkottai, Thirunelveli, Thoothukkudi, Sivagangai, Virudhunagar, Kanyakumari and Madurai (Figure 11 b).

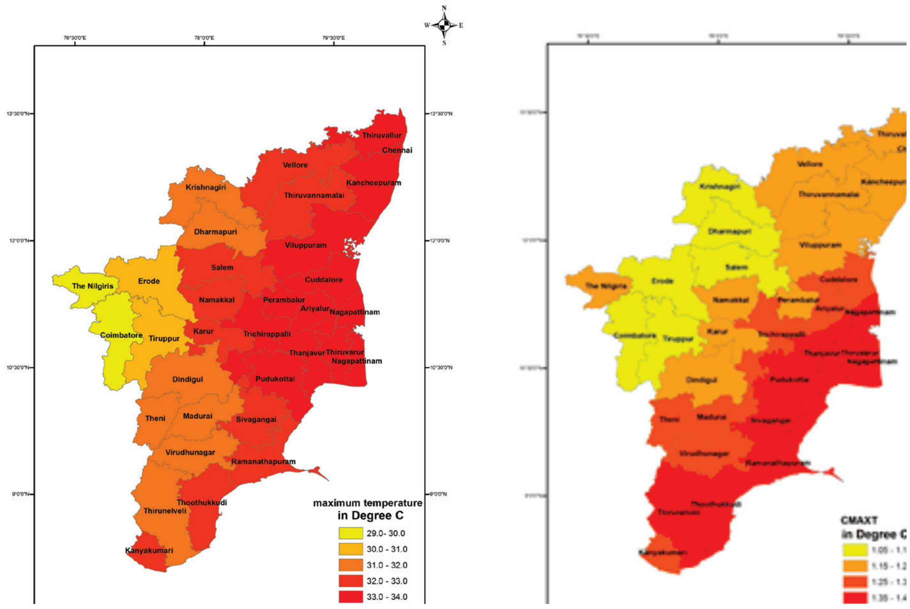


Figure 11 : District wise a) Annual mean maximum temperature and b) changes during 1951-2015

6.2.2 Mean Minimum temperature and its changes during 1951-2015

The average annual minimum temperature for Tamil Nadu is 22.6°C with a range varying from 19.0°C to 24.3°C (Figure 12 a). The night time temperature is highest in Thiruvarur (24.3°C) district, followed by Nagapattinam, Cuddalore (24.1°C), Thanjavur (24°C) districts, while the lowest values were observed in the Nilgiris district. Ariyalur, Pudukkottai, Kanyakumari, Chennai, Thoothukkudi, Kancheepuram, Ramanathapuram, Sivagangai, Vilupuram, Trichirappalli, Perambalur, Thirunelveli, Thiruvallur, Thiruvannamalai, Virudhunagar, Madurai, Karur, Vellore and Namakkal were in the range of 23.9°C to 22.1°C. The moderate temperature ranges (21°C to 22°C) were observed at Theni, Dindigul, Salem, Namakkal and Dharmapuri districts. Krishnagiri, Tiruppur, Coimbatore and Erode districts showed the lowest range from 20.6°C to 19.8°C. The Nilgiris district have an average night temperature of 19°C. Though interior districts average night time temperature is lower as compared to other districts, the change in minimum temperature is high in central-west districts such as Erode, Namakkal, Tiruppur, Salem, Dindigul, Thiruvannamalai and Krishnagiri (Figure 12 b).

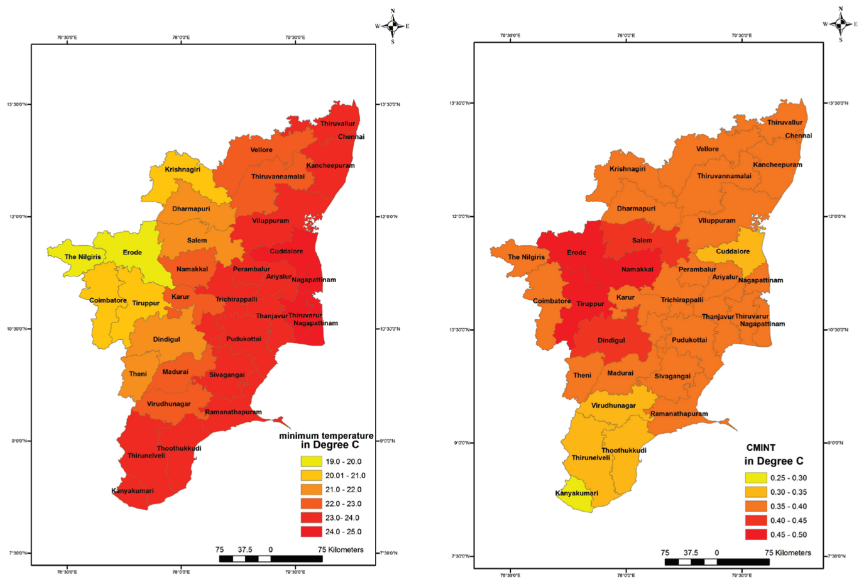


Figure 12 : District wise a) Annual mean minimum temperature and b) changes during 1951- 2015

6.2.3 Annual Average rainfall during 1951-2015

The average annual rainfall in Tamil Nadu during the period 1901-2015 has been 1,003 mm that ranged between 1425mm to 712 mm (Figure 13 a). The Nilgiris, Nagapattinam, Chennai, Thiruvarur, Cuddalore, Kancheepuram, Thiruvallur, Coimbatore, Thanjavur Kanyakumari districts received an average of above 1,000 mm rainfall during the past 115 years. Perambalur, Vellore, Pudukkottai, Theni, Salem and Dharmapuri districts received rainfall between 900 to 1000 mm.

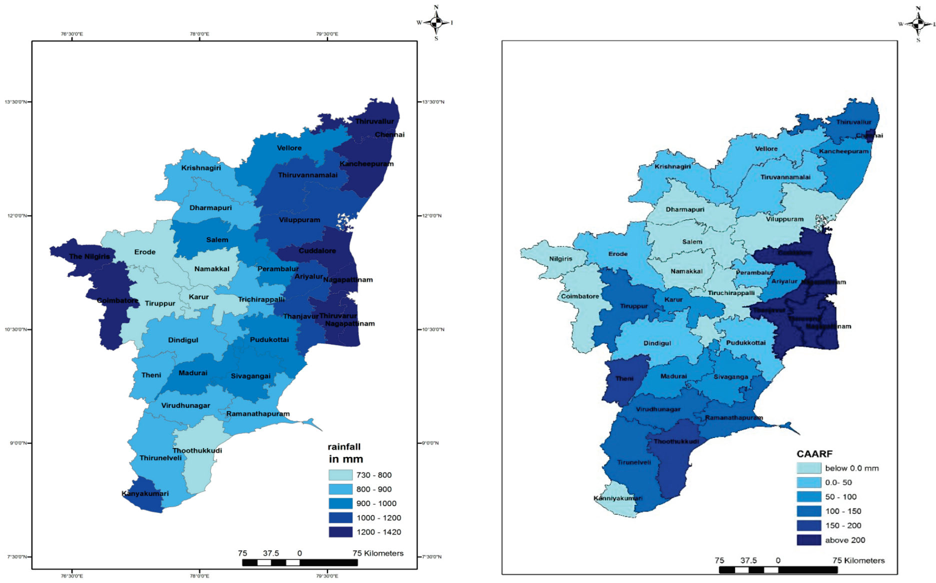


Figure 13 : District wise a) annual average rainfall b) rainfall changes during 1951-2015

Madurai, Sivagangai, Trichirappalli, Dindigul, Ramanathapuram, Krishnagiri, Thirunelveli, Virudhunagar, Erode, Namakkal, and Tiruppur districts received 800-900 mm rainfall. Karur and Thoothukkudi districts received rainfall below 800mm. Rainfall in Vilupuram, Trichirappalli, Dharmapuri, Namakkal, Salem, Kanyakumari, The Nilgiris and Coimbatore districts is on a decreasing trend (-4 to -185mm). Increased rainfall is observed in Nagapattinam, Thanjavur, Chennai, Thiruvarur, Cuddalore, Thoothukkudi and Theni Districts, in the range of 150-260mm (Figure 13 b).

6.3 Future climate change scenarios

District-wise future climate change scenario data were downloaded from GIZ's climate vulnerability portal 'http://climatevulnerability.in/'. 10 GCMs from CORDEX domain under RCP 4.5 (moderate emission scenario) and 8.5 (high emission scenario) scenario for mid-century (MC) (2040-70) and end century periods (EC) (2070-2100) were considered. The GCMs in CORDEX domain are attached in Annexure 1. The mutli model ensemble mean for 10 GCMs are used in future climate projection for the state of Tamil Nadu. The downloaded data are analysed and spatially mapped using Arc GIS.

6.3.1 Temperature projections

Ensemble mean of the CORDEX South Asia climate data for IPCC AR5 RCP 4.5 and RCP 8.5 scenarios for districts of Tamil Nadu area were analysed to understand the changes in the annual maximum and minimum temperature. The average annual maximum temperature for IPCC AR5 RCP 4.5 scenario is projected to increase by about 0.9°C towards mid-century and by 1.3°C towards end-century. While for IPCC AR5 RCP 8.5 scenario, it is projected to increase by about 1.4°C towards mid-century and 3.4°C towards EC for Tamil Nadu. The projected temperature increase is higher in end-century than mid-century. Figure 14 shows change in annual maximum temperature towards mid-century (MC) and end-century (EC) with respect to baseline (BL) under IPCC AR5 RCP4.5 scenarios.

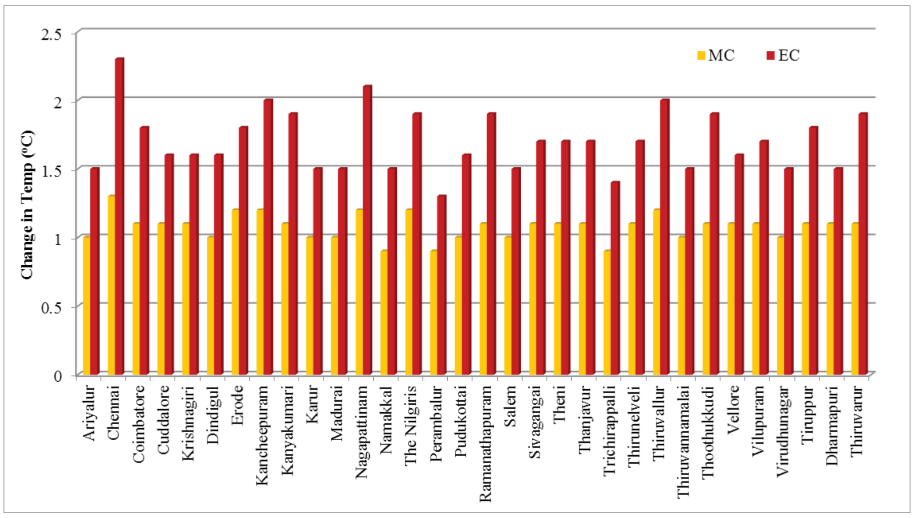


Figure 14 : Projected changes in Maximum Temperature for MC & EC periods from BL under IPCC AR5 RCP 4.5 scenario

The projected increase in maximum temperature towards MC varies from 1°C to 1.6°C and 1.2°C to 1.8°C for EC period under IPCC AR5 RCP 4.5 scenario. The projected increase in maximum temperature varies from 1.3°C to 2.3°C for MC period while the same varies from 3.0°C to 4.6°C towards EC period for IPCC AR5 RCP 8.5 (Figure 15). For both IPCC AR5 RCP 4.5 and RCP 8.5 scenarios, increase in annual maximum temperature is projected for Rajasthan and its districts towards MC and EC. However, IPCC AR5 RCP 8.5 scenario shows higher increase than that of IPCC AR5 RCP 4.5 scenario.

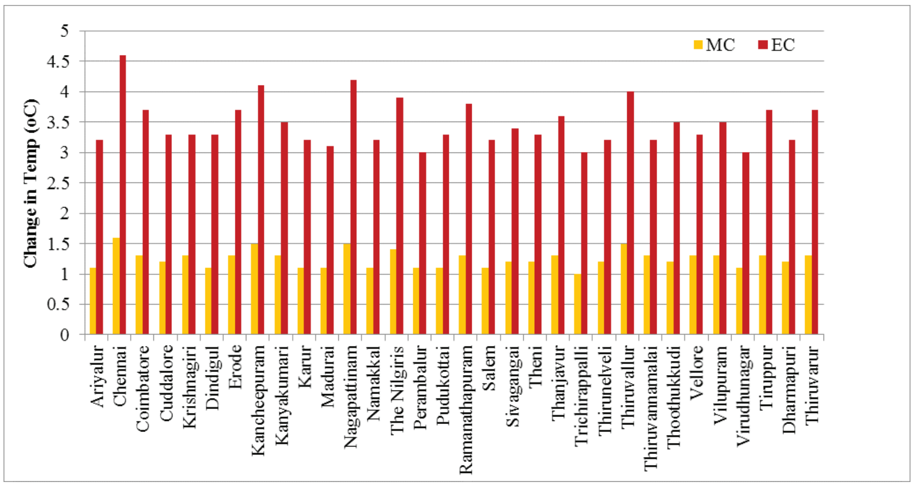


Figure 15 : Projected changes in maximum temperature for MC & EC period from BL under IPCC AR5 RCP 8.5 scenario

The average annual minimum temperature for IPCC AR5 RCP 4.5 scenario is projected to increase by about 1.2°C towards mid-century and by 2.8°C towards end-century. While for IPCC AR5 RCP 8.5 scenario, it is projected to increase by about 1.2°C towards mid-century and 3.4°C towards EC for Tamil Nadu. The projected temperature increase is higher in end-century than mid-century. Figure 16 shows change in annual minimum temperature towards MC and EC with respect to BL under IPCC AR5 RCP4.5 scenarios. The projected increase in maximum temperature towards MC varies from 1°C to 1.4°C and 1.8°C to 2.5°C for EC period under IPCC AR5 RCP4.5 scenario.

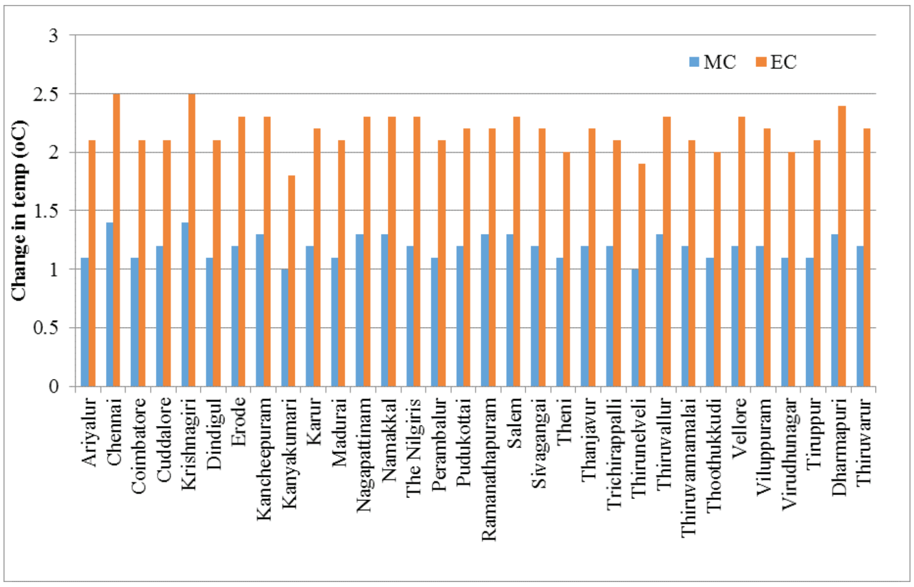


Figure 16 : Projected changes in minimum temperature for MC & EC periods from BL under IPCC AR5 RCP4.5 scenario

The projected increase in minimum temperature varies from 1.2°C to 1.7°C for MC period while the same varies from 3.2°C to 4.8°C towards EC period for IPCC AR5 RCP 8.5 (Figure 17). For both IPCC AR5 RCP 4.5 and RCP 8.5 scenarios, increase in annual maximum temperature is projected for Rajasthan and its districts towards MC and EC. However, IPCC AR5 RCP8.5 scenario shows higher increase than that of IPCC AR5 RCP 4.5 scenario. The Chennai, Krishnagiri and Dharmapuri districts show high increase in minimum temperature. Figure 18 represents spatial representation of changes in maximum, minimum temperature and rainfall for MC period under RCP 4.5 scenario.

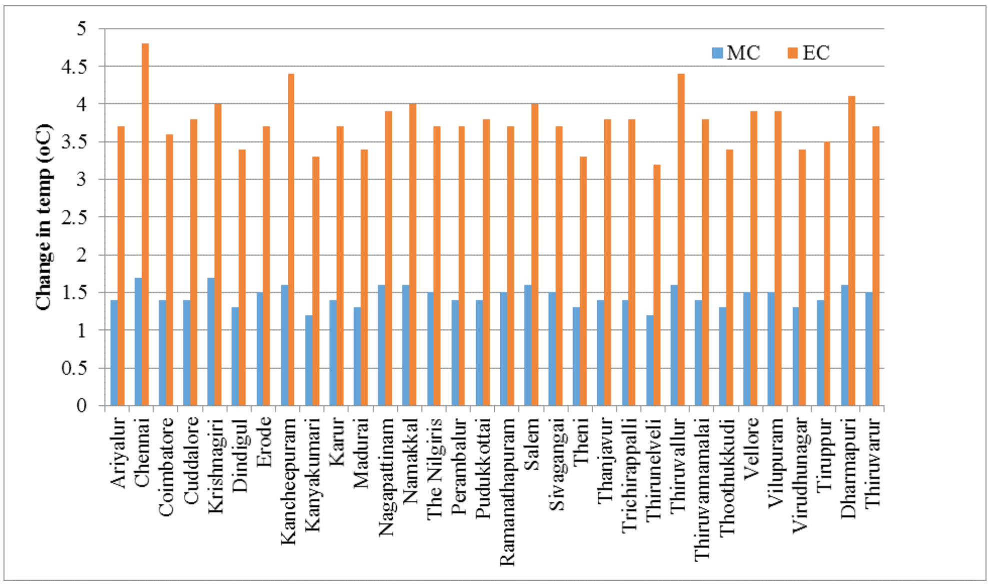
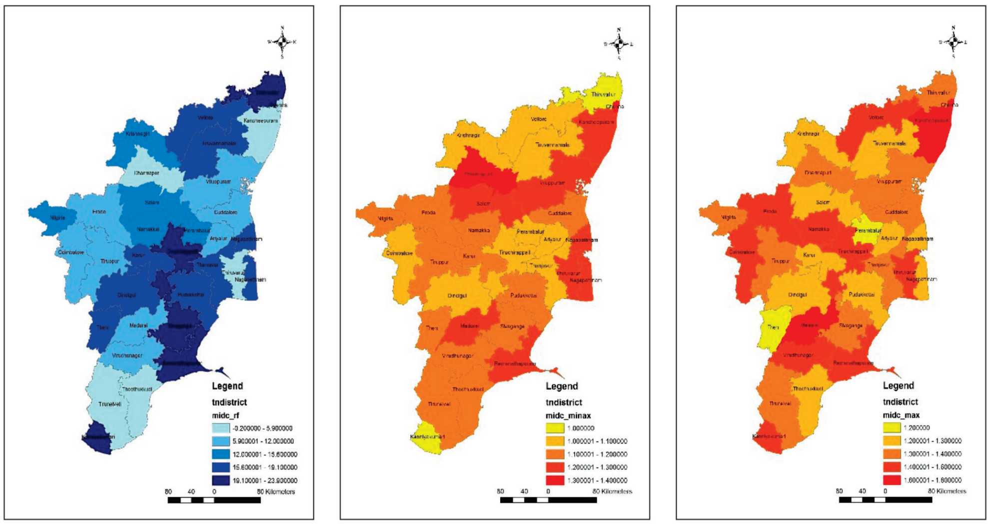


Figure 17 : Projected changes in minimum temperature for MC & EC periods from BL under IPCC AR5 RCP 8.5 scenario

6.3.2 Rainfall Projections

Figure 19 shows percentage change in annual rainfall towards MC and EC with respect to BL under IPCC AR5 RCP4.5 scenarios. Average annual rainfall for IPCC AR5 RCP4.5 scenario is projected to increase about 13 per cent towards mid-century and increase by about 21 per cent towards end-century period. While spatial variability of rainfall is observed between districts, for IPCC AR5 RCP8.5 scenario, it is projected to increase marginally by about 10 per cent towards mid-century and 26 per cent towards end-century for the state (Figure 20). The percentage of the projected rainfall increase is high in EC and MC, and EC under both RCP climate scenarios.



a b c

Figure 18 : Future climate projections under IPCC AR5 RCP 4.5 scenario a) maximum temperature b) minimum temperature c) annual rainfall

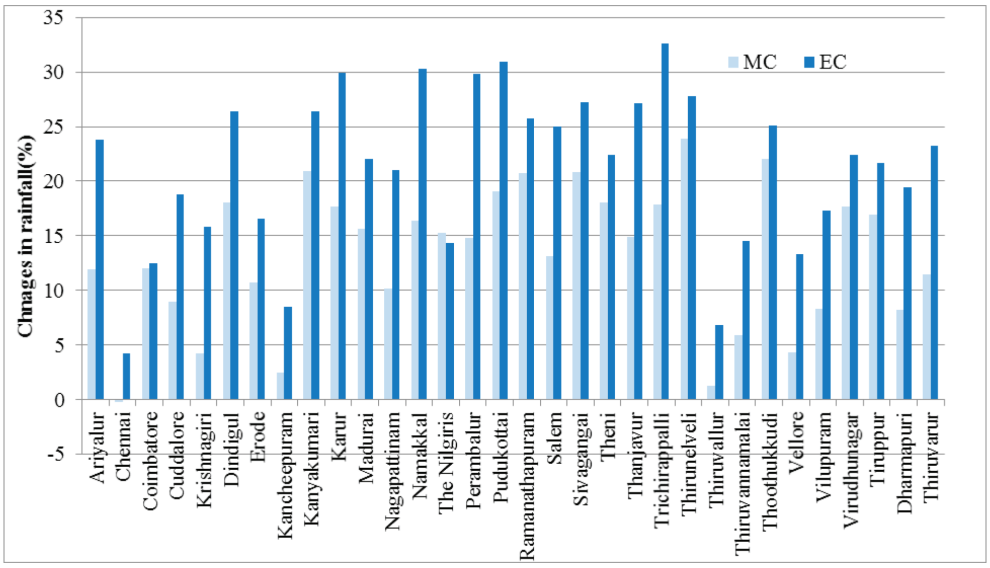


Figure 19 : Projected changes in Rainfall for MC & EC periods from BL under IPCC AR5 RCP 4.5 scenario

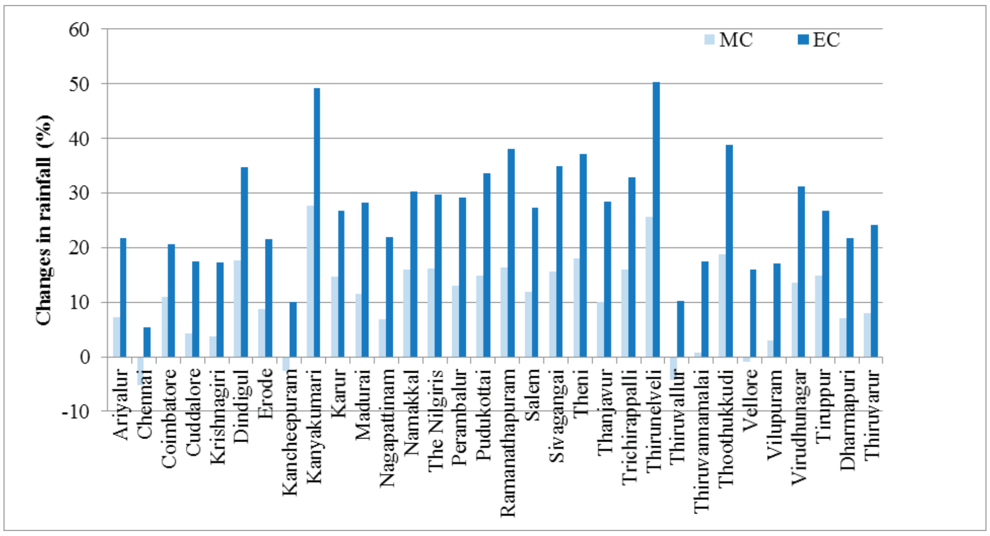


Figure 20 : Projected changes in Rainfall for MC & EC periods from BL under IPCC AR5 RCP 8.5 scenario

The districts in the central part of Tamil Nadu namely, Perambalur, Karur, Namakkal, Pudukkottai and Tiruchirappalli show highest projected increase in rainfall as compared to the other districts towards EC period with respect to BL period. Chennai district shows decrease in annual rainfall towards MC with respect to BL for IPCC AR5 RCP4.5 scenario. Chennai, Kancheepuram and Thiruvallur districts show decrease in rainfall under RCP 8.5 scenario. The observed and projected changes in climate will have serious impacts on the state's

- Soil moisture
- Evapotranspiration
- River flow
- Water availability
- Water quality

The changes in climate and alteration in monsoon patterns as captured by the analysis will lead to threats such as increasing water demand for irrigation domestic and industrial purposes and lowering water table. The salinity would increase due to seawater intrusion. Hydro-electric power generation would also be affected, Delta Levees will be affected due to sea level rise. On the whole, climate change induced water-related issues will affect habitats and its sustainability.

7 Selection of Vulnerability Areas for the Pilot Study

The pilot areas are selected based on vulnerability assessment of the area undertaken as part of the study. IPCC defined Vulnerability as 'the propensity or predisposition to be adversely affected' (IPCC 2014). Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and the lack of capacity to cope and adapt. Vulnerability is determined by sensitivity and adaptive capacity of the system (Figure 21). Generally, vulnerability assessments are made to identify.

- current and potential hotspots
- drivers of vulnerability
- entry points for intervention
- prioritise adaptation interventions

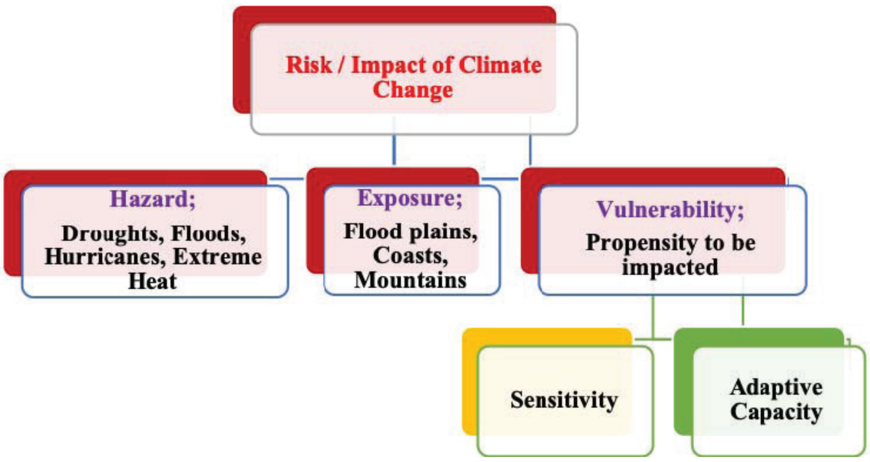


Figure 21 : Vulnerability as defined in IPCC

7.1 Steps in Vulnerability Assessment

In this study, district-wise vulnerability assessment (VA) has been carried out using IPCC methodology on vulnerability assessment. The vulnerability analysis conducted in 32 districts of Tamil Nadu which were listed. With focus on rural water security, 31 districts among 32 districts were considered for vulnerability assessment except Chennai district. Some indicators of VA for rural areasdoes not cover Chennai district as it is 100 per cent urbanised (Census 2011). The following steps are used to derive Composite Vulnerability Index (CVI) via multivariate analysis for current climate change scenario.

7.1.1 Selection of Indicators

Biophysical and socio-economic indicators which have influence on the state's rural water security were identified and selected through expert opinion. The related data were collected from various authorised sources. About 18 indicators under 4 dimensions via climate (5), water (5), agriculture (4) and socio□demographic (4) have been composed and categorised into adaptive capacity, sensitivity and exposure indicators for the analysis (Table 13). The spatial maps of selected indicators are shown in Annexure II. These cautiously selected indicators warrant identification of districts that are vulnerable to climate change and need special attention for adaptation.

Table 13 : Indicators Selected for State's Rural Water Security

	Indicators	Sensitivity/ Adaptive Capacity	Source	Functional Relationship with Vulnerability	Year
Climate	Changes in mean maximum temperature	Exposure	IMD Gridded data, IMD Pune	Positive	1951-2015
	Changes in mean minimum temperature	Exposure	IMD Gridded data, IMD Pune	Positive	1951-2015
	Changes in annual average rainfall	Exposure	IMD Gridded data, IMD Pune	Positive	1951-2015
	Number of excess rainfall years (>19 per cent to +59 per cent)*IMD norms	Exposure	IMD Gridded data, IMD Pune	Positive	1951-2015
	Number of deficient rainfall years (<-19 per cent to -59 per cent)* IMD norms	Exposure	IMD Gridded data, IMD Pune	Positive	1951-2015

	Indicators	Sensitivity/ Adaptive Capacity	Source	Functional Relationship with Vulnerability	Year
Water	Ground water extraction (Existing Gross GW Draft for All uses/ Annual Extractable GW resources)	Sensitivity	Central ground Water Board	Positive	2017
	Ground water recharge	Adaptive Capacity	Central ground Water Board	Negative	2017
	Surface water availability	Adaptive Capacity	GIZ-INRM SWAT hydrological model	Negative	1981-2010
	Water gap (Supply -Demand)	Sensitivity	State Irrigation Plan -PMKSY 2016	Positive	2016
	Water contamination	Sensitivity	Pollution database of Tamil Nadu-Water Pollution	Positive	2014
Agriculture	Rain fed area	Sensitivity	Statistical Hand Book 2017 Department of Economics and Statistics, GoTN	Positive	2015-2016
	Cropping intensity	Adaptive capacity	Statistical Hand Book 2017 Department of Economics and Statistics, GoTN	Positive	2015-16
	Evapotranspiration	Sensitivity	CCDM-PRECIS Model	Negative	1987-2017

	Indicators	Sensitivity/ Adaptive Capacity	Source	Functional Relationship with Vulnerability	Year
Agriculture	Soil moisture	Sensitivity	CCDM-PRECIS Model	Positive	1987-2018
Socio economic	Rural proportion (per cent of rural proportion to the total population)	Sensitivity	Census 2011, Govt. of India	Positive	2011
	Multidimensional Poverty Index (Health-IMR, birthrate; Education-Dropout in primary and secondary education;-Standard of living-Cooking fuel, toilet facilities, safe water facilities)	Sensitivity	Tamil Nadu State Human Development Report 2017,	Positive	2017
	Rural Water Access (per cent of households having water with in in rural)	Adaptive Capacity	Census 2011, Govt. of India	Negative	2011
	Marginal farmers	Sensitivity	Statistical Hand Book 2017, Department of Economics and Statistics, GoTN	Positive	2017

7.1.2 Normalisation of Indicators

The identified indicators are from different sources and measured in different units. As the vulnerability assessment is about ranking, the indicators have to be in common units. This is done through normalisation. The normalisation process varies, depending on the nature of relationship of that particular indicator with the vulnerability. The following formula used in this study are:

- for indicators with positive relationship with vulnerability

$$x_{ij}^{P} = \frac{Xij - Min\, i\,\{Xij\}}{(Max\, i\,\{Xij\} - Min\, i\,\{Xij\}} \quad (1)$$

- for indicators with negative relationship with vulnerability

$$x_{ij}^{n} = \frac{Max\, i\,\{Xij\} - Xij}{Max\, i\,\{Xij\} - Min\,\{Xij\}} \quad (2)$$

The district-wise normalised values are attached in Table 14. Figure 22 depicts the magnitude and dimensions of indicators for all districts.

7.1.3 Aggregation and Categorisation of Indicators

The normalised values of indicator sets are aggregated to obtain the vulnerability index and categorized in high, medium and low vulnerability classes.

$$VI = \frac{\sum_{i}^{N} K_i S_i}{K_i} \quad (3)$$

Table 14 : Normalised Indicator Values

District Name	changes in maxT	changes in minT	changes in RF	Excess RF years	Deficient years	GW extraction	GW Recharge	surface water	water gap	water contamination	Rain fed area	Cropping intensity	Soil moisture	ET	Rural proportion	MPI	source drinking water	landhol -dings
Ariyalur	0.584	0.438	0.635	0.583	0.615	0.221	0.803	0.434	0.394	0.228	0.638	0.904	0.398	0.286	1.000	0.765	0.685	0.869
Coimbatore	0.215	0.565	0.000	0.417	0.231	0.787	0.813	0.000	0.926	0.199	0.324	0.981	0.269	0.429	0.135	0.147	0.000	0.227
Cuddalore	0.578	0.283	0.940	0.667	0.538	0.360	0.086	0.774	0.657	0.037	0.343	0.551	0.442	0.286	0.678	0.059	0.426	0.809
Dharmapuri	0.170	0.565	0.382	0.417	0.154	0.831	0.808	0.961	0.271	1.000	0.669	0.557	0.933	0.143	0.913	1.000	1.000	0.801
Dindigul	0.469	0.631	0.429	0.250	0.308	0.721	0.672	0.940	0.358	0.451	0.562	0.973	0.347	0.286	0.631	0.676	0.685	0.618
Erode	0.000	1.026	0.493	0.250	0.462	0.632	0.638	0.947	0.075	0.323	0.287	0.910	0.489	0.143	0.434	0.471	0.557	0.432
Kancheepuram	0.445	0.565	0.582	0.583	0.615	0.397	0.441	0.833	0.270	0.023	0.070	0.799	0.688	0.429	0.264	0.000	0.354	0.836
Kanyakumari	0.685	0.000	0.218	0.583	0.385	0.088	0.900	0.652	0.167	0.240	0.624	0.915	0.000	1.000	0.000	0.412	0.033	0.999
Karur	0.458	0.565	0.578	0.417	0.615	0.654	0.871	0.978	0.296	0.400	0.419	0.939	0.469	0.143	0.583	0.735	0.613	0.434
Krishnagiri	0.067	0.574	0.502	0.500	0.308	0.772	0.806	0.948	0.303	0.386	0.677	0.790	1.000	0.000	0.836	0.706	0.849	0.772

District Name	changes in maxT	changes in minT	changes in RF	Excess RF years	Deficient years	GW extraction	GW Recharge	surface water	water gap	water contamination	Rain fed area	Cropping intensity	Soil moisture	ET	Rural proportion	MPI	source drinking water	landhol -dings
Madurai	0.625	0.467	0.568	0.333	0.538	0.419	0.658	0.996	0.000	0.422	0.377	0.892	0.406	0.429	0.302	0.265	0.692	0.878
Nagapattinam	0.837	0.399	1.000	0.917	0.769	0.662	0.962	0.220	0.306	0.201	0.168	0.265	0.269	0.286	0.838	0.147	0.489	0.754
Namakkal	0.316	0.848	0.322	0.417	0.231	0.897	0.820	0.896	0.193	0.306	0.540	0.705	0.667	0.143	0.590	0.706	0.538	0.672
The Nilgiris	0.270	0.565	0.044	0.333	0.000	0.000	1.000	0.450	0.760	0.000	1.000	0.998	0.199	0.857	0.324	0.471	0.872	0.815
Perambalur	0.469	0.545	0.445	0.750	0.385	0.787	0.914	0.875	0.125	0.176	0.749	0.865	0.567	0.286	0.914	0.794	0.725	0.807
Pudukottai	0.806	0.498	0.527	0.500	0.538	0.250	0.441	0.926	0.341	0.007	0.192	0.964	0.355	0.286	0.882	0.441	0.934	0.868
Ramanathapuram	0.817	0.437	0.731	0.500	1.000	0.000	0.687	0.992	0.379	0.565	0.656	1.000	0.808	0.714	0.730	0.794	0.980	0.822
Salem	0.175	0.797	0.245	0.000	0.154	1.000	0.728	0.923	0.366	0.268	0.551	0.658	0.805	0.143	0.440	0.500	0.869	0.769
Sivagangai	0.741	0.492	0.587	0.333	0.615	0.037	0.459	0.972	0.277	0.273	0.216	0.999	0.616	0.429	0.723	0.559	0.748	0.88
Thanjavur	0.864	0.465	0.969	0.667	0.846	0.713	0.563	0.678	0.638	0.253	0.015	0.592	0.334	0.286	0.659	0.676	0.393	0.805
Theni	0.517	0.417	0.826	0.083	0.769	0.456	0.797	0.871	0.363	0.650	0.452	0.897	0.280	0.571	0.400	0.706	0.374	0.718

District Name	changes in maxT	changes in minT	changes in RF	Excess RF years	Deficient years	GW extraction	GW Recharge	surface water	water gap	water contamination	Rain fed area	Cropping intensity	Soil moisture	ET	Rural proportion	MPI	source drinking water	landhol -dings
Thiruvallur	0.380	0.524	0.723	0.667	0.462	0.419	0.510	0.872	0.506	0.158	0.068	0.595	0.343	0.286	0.242	0.294	0.423	0.852
Thiruvarur	1.000	0.436	0.941	0.833	0.538	0.382	0.432	0.401	0.325	0.090	0.000	0.000	0.293	0.286	0.869	0.500	0.525	0.692
Thoothukudi	0.771	0.357	0.861	0.583	0.692	0.721	0.379	0.981	0.295	0.092	0.811	0.979	0.443	0.429	0.452	0.382	0.820	0.533
Trichirappalli	0.583	0.553	0.383	0.417	0.538	0.551	0.888	0.884	0.213	0.087	0.518	0.902	0.542	0.286	0.465	0.324	0.423	0.807
Thirunelveli	0.771	0.198	0.707	0.667	0.462	0.794	0.773	0.863	0.671	0.024	0.274	0.839	0.212	0.429	0.462	0.294	0.541	0.812
Tiruppur	0.183	0.836	0.700	0.500	0.615	0.566	0.644	0.914	0.825	0.455	0.357	0.983	0.357	0.143	0.294	0.176	0.443	0
Thiruvannamalai	0.267	0.591	0.439	1.000	0.769	0.221	0.726	0.915	0.737	0.392	0.289	0.683	0.842	0.286	0.874	0.500	0.548	0.857
Vellore	0.254	0.519	0.479	0.333	0.385	0.772	0.680	0.946	0.385	0.445	0.509	0.793	0.836	0.286	0.549	0.206	0.439	0.859
Vilupuram	0.387	0.496	0.407	0.500	0.615	0.574	0.000	0.895	1.000	0.007	0.254	0.628	0.707	0.429	0.945	0.647	0.780	0.842
Virudhunagar	0.694	0.313	0.699	0.333	0.846	0.382	0.707	1.000	0.238	0.146	0.601	0.950	0.549	0.286	0.447	0.765	0.849	0.726

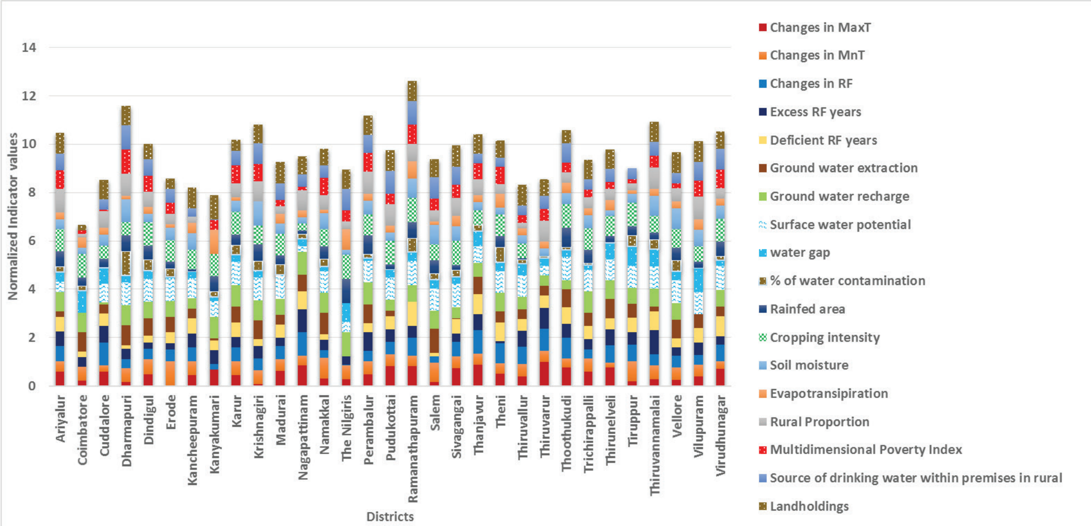


Figure 22 : Indicators dimensions

7.1.4 Composite Vulnerability index (CVI)

The CVI values were calculated and districts were ranked as high, medium and low vulnerable based on the CVI values. The district-wise CVI valves are listed in Table 15 and ranking is shown in figure 23.

Table 15 : Vulnerability Ranking of Districts

District name	CVI
Ramanathapuram	0.70
Dharmapuri	0.64
Perambalur	0.62
Thiruvannamalai	0.61
Krishnagiri	0.60
Thoothukkudi	0.59
Virudhunagar	0.58
Ariyalur	0.58
Thanjavur	0.58
Karur	0.56
Theni	0.56

District name	CVI
Viluppuram	0.56
Dindigul	0.56
Sivagangai	0.55
Namakkal	0.54
Thirunelveli	0.54
Pudukottai	0.54
Vellore	0.54
Nagapattinam	0.53
Salem	0.52
Trichirapalli	0.52
Madurai	0.51
Tiruppur	0.50
The Nilgiris	0.50
Erode	0.48
Thiruvarur	0.47
Cuddalore	0.47
Thiruvallur	0.46
Kancheepuram	0.46
Kanyakumari	0.44
Coimbatore	0.37

Ramanathapuram district, Dharmapuri, Perambalur, and Tiruvannamalai districts are ranked high in cumulative vulnerability index and the CVI values are 0.7, 0.64, 0.62 and 0.61, respectively, followed by Krishnagiri district (0.6). Thoothukkudi, Virudhunagar, Ariyalur, Thanjavur, Karur, Theni, Viluppuram, Dindigul, Sivagangai, Namakkal, Thirunelveli, Pudukottai, Vellore, and Nagapattinam with the CVI values in the range of 0.59 to 0.53. Kancheepuram, Kanyakumari and Coimbatore districts show low vulnerability index values.

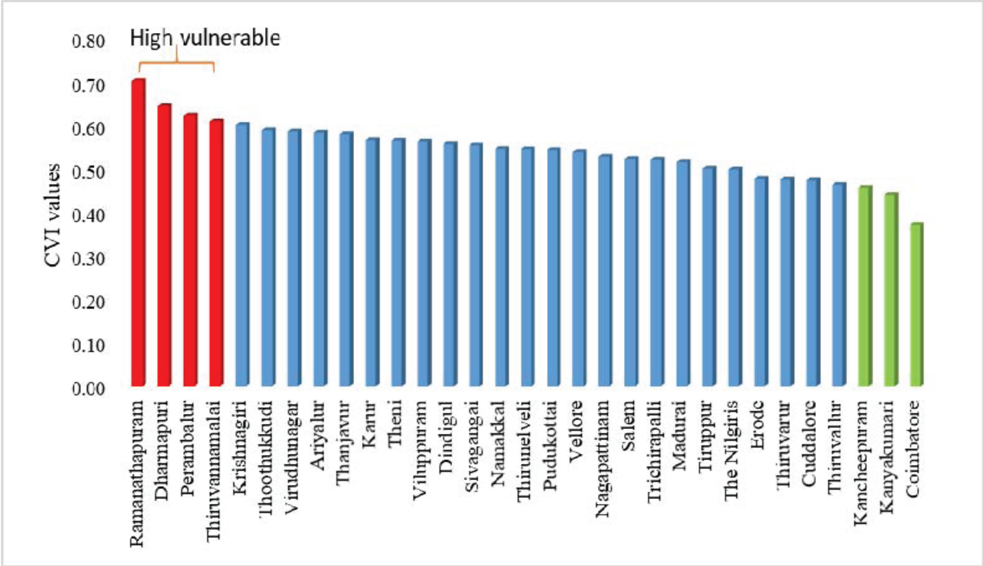


Figure 23 : Vulnerability ranking of districts

7.2 Identified Hotspot Districts

The districts ranked as highly vulnerable viz., Ramanatahpuram, Dharmapuri, Perambalur and Thiruvannamalai are priority areas for pilot project demonstration of water security and climate adaptation in rural Tamil Nadu (Figure 24).

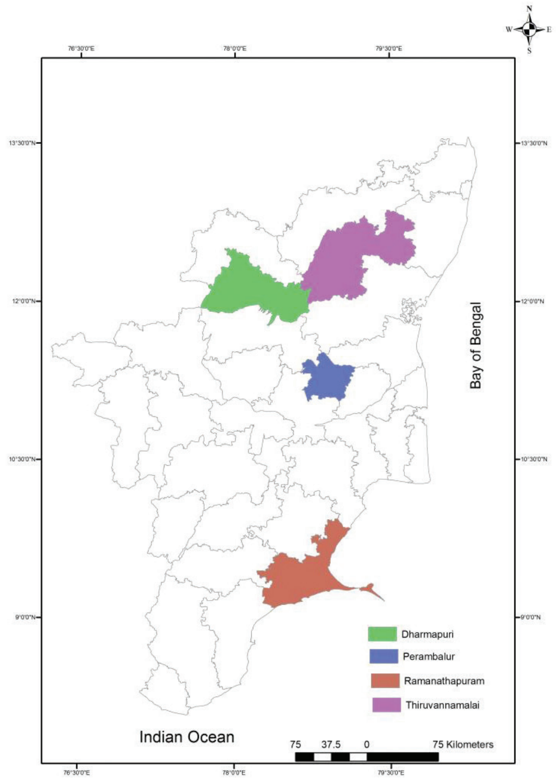


Figure 24 : Priority Districts for pilot project demonstration

The basins that cover Ramanatahpuram district are Vaigai, Gundar and Pambar Kottakaraiyar and that cover Dharmapuri district are Ponnaiyar and Cauvery basin. The basins covering Thiruvanamalai district form major part of Palar, Ponnaiyar and small part of the Varahanadhi basin and those covering Perambalur district are Cauvery and Vellar basin. The basins which cover vulnerable hotspot districts are shown in Figure 25 and details of hot spot districts covering basins and subbasins are listed in Table 16.

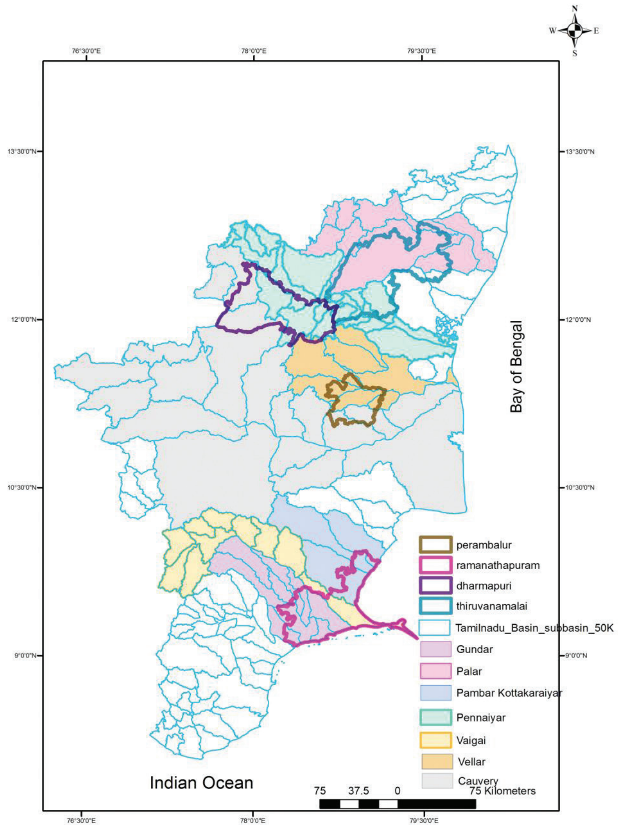


Figure 25 : Basins and sub-basins within vulnerable hot spot districts

Table 16 : Hotspot Districts & Basin and Sub-Basin within the District

Hot spot Districts	Covering Basins	Sub basins in the districts
Ramanathapuram	Vaigai, Gundar, Pambar Kottakaraiyar	Kottakkaraiyar, Manimuthar, Pambar, Lower Vaigai Gridhamal, Lower Gundar, Palar, Kanal Odai, Paralaiyar, Upper Gundar, Uthirakosa-mangaiyar Vembar, Lower Vaigai
Dharmapuri	Pennaiyar, Cauvery and a small portion Vellar	Manimukdhanadhi, Upper Vellar, Kambainallur, Kottapattikallar, Krishnagiri to Pambar, Matturar Pambar, Pambanar and Varattar, Pambar to ThirukovilurKrishnagiri Reservoir, Vaniyar, Chinnar Mettur Reservoir to Noyel Confluence, Tirumanimuttar

Hot spot Districts	Covering Basins	Sub basins in the districts
Perambalur	Cauvery Vellar	Anaivari Odai, Chinnar, Lower Vellar, Swethanadhi Upper Vellar, Ayiaar, Marudaiyar, Nandiyar -Kulaiyar
Thiruvannamalai	Pennaiyar, Palar and a small portion of Varahanadhi	Aliyar, Kottapattikallar, Matturar, Musukundanadhi Pambanar and Varattar, Pambar to Thirukovilur, Ramakal Odai, Thurinjalar, Valayar Odai, Agaramar, Cheyyar, Kiliyar, Vegavati, Varahanadhi, Ongur

7.3 Factors determining the vulnerability of the selected hot spots

The vulnerability ranks were calculated on the basis of climate extremities, water resource, agriculture and socio-economic dimensions, the results of which are tabulated for identified hotspot districts (Table 17).

Table 17 : Sectoral Vulnerability Ranks of Identified Hotspot Districts

Districts	Climate vulnerability rank	Water Resource vulnerability rank	Agriculture vulnerability rank	Socio-economic vulnerability rank
Ramanathapuram	4	16	1	13
Dharmapuri	28	1	9	11
Perambalur	18	12	6	7
Thiruvannamalai	6	11	17	5

The detailed discussion on the factors determining the vulnerability of the selected hotspots and indicator interferences are given below:

7.3.1 Hot Spot 1 - Ramanathapuram District

The geographical extent of Ramanathapuram District is 4,089.57 sq.km and accounts 3.14 per cent of the geographical area of the state. It is a plain coastal district located in southern agro climatatic zone. The number of village panchayats is 429 and is further bifurcated into 38 firkas. Principal crops are Cotton (9.1 per cent), Cumbu (5.1 per cent), Cholam (3.8 per cent), Groundnut (1.8 per cent), Paddy (1.4 per cent), Gingelly (1.1 per cent), to the total area sown in 2015-16. The net irrigated area is 53599 ha in 2015-2016. Source-wise, net area irrigation and open wells contribute more. There are 24,633 tanks, 28,688 open wells and 278 tube wells. Generally, the climate is hot, the mean annual maximum temperature is 32.6°C and minimum temperature is 23.8°C during the long-term period 1951-2015. The annual average rainfall is 847.3 mm. North-east rainfall is the major contributor and accounts nearly 61 per cent of the total annual rainfall, and south-west monsoon contributes 18 per cent of the total rainfall. Climate projection based on global climate models indicate there would be 1.1°C increase in maximum temperature in mid-century period (2041-2070) and 1.9°C increase in end-century period (2071-2100) from the baseline scenario under RCP 4.5 climate scenario. The minimum temperature would increase nearly 1.3oC and 2.2°C during MC and EC periods. The dimensions of vulnerability indicators are shown in Figure 26 and its inference are discussed below:

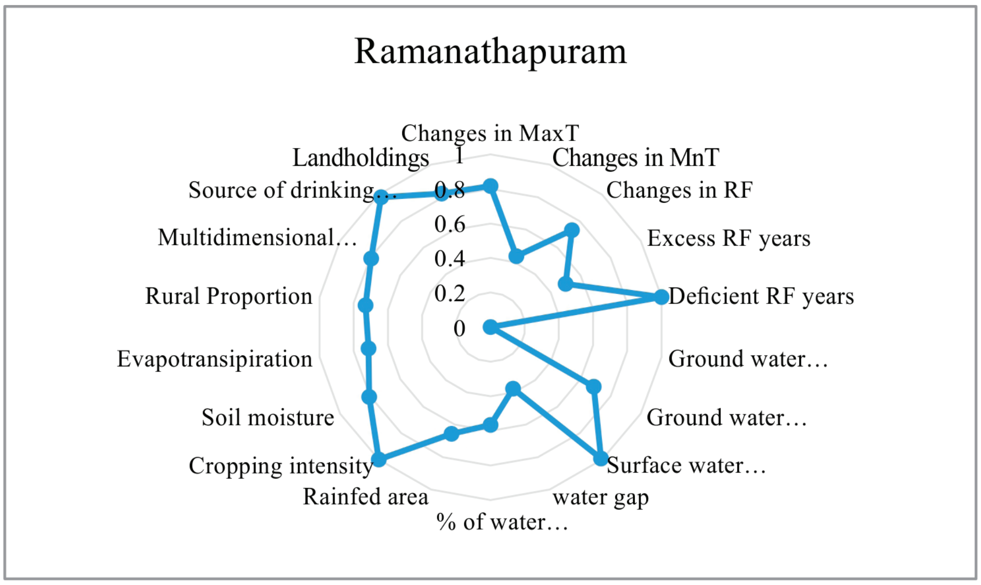


Figure 26 : Indicators dimensions – Ramanathapuram District

Indicators interference :

Exposure in climate extremities is very high during 1951-2015

- Increase in day time temperature is very high (1.4oC)
- Rainfall variability is very high
- Deficient rainfall years (below 59 per cent)are highest among all districts (18 years)

Water resource vulnerability

- Low surface water availability

- Supply and Demand gap
- Saline/poor quality of water – firkas are more

Agriculture vulnerability is very high among all districts

- Rain fed area (66.28 per cent)
- Cropping intensity is very low
- Evapotranspiration is more
- Soil moisture is very less

Socio-economic vulnerability

- Poverty index is more (0.63)
- Source of drinking water within premises in rural area is very low (5.6 percent)
- Marginal farmers are more (93 percent)
- High rural proportion (69.7 percent)

7.3.2 Hot Spot 2 - Dharmapuri District

Dharmapuri District with a geographical area of 9641.03 Sq.Kms. is located on the North Western corner of the Tamil Nadu and falls under North Western agro-climate zone. The number of village panchayats are 251 and number of Firkas are 23. The principal crops are Ragi (23.2 per cent) Cotton (7.3 per cent), Cholam (5.8 per cent), Gingelly (3.9 per cent), Sugarcane (3.1 per cent) Cumbu (3 per cent), Groundnut (3 per cent), Paddy (1.7 per cent), to the total area sown in 2015-16. The net area irrigated area is 60,261 ha and source wise, net area irrigation open well contributes more (58151) along with Canals (548), Tank (749), and Tube well (813). Generally, the climate is hot the mean annual maximum temperature is 31.9°C and minimum temperature is 21.3°C during the long-term period 1951-2015. The annual average rainfall is 905.7mm. South-west monsoon contributes more to the annual rainfall, about 44 per cent, and north-east rainfall accounts about 37 per cent of the total annual rainfall due to its orography. Climate projection based on global climate models indicate that there would be 1.1°C increase in maximum temperature in mid-century period (2041-2070) and 1.5°C increase in end-century period (2071-2100) from the baseline scenario under RCP 4.5 climate scenario. The minimum temperature would increase nearly 1.3°C and 2.4°C during MC and EC periods. The dimensions of vulnerability indicators are shown in Figure 27 and its inference are discussed below:

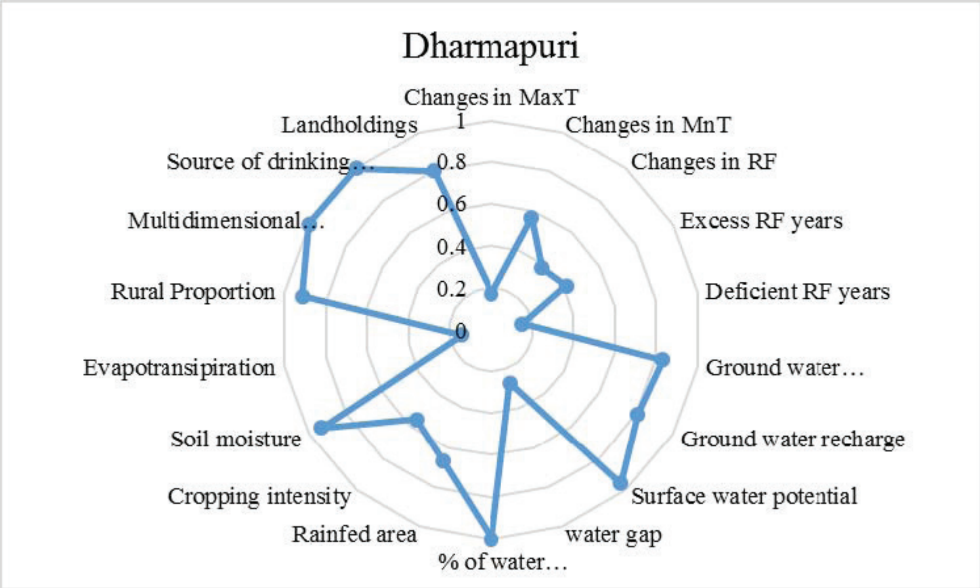


Figure 27 : Indicators dimensions –Dharmapuri District

Indicators interference:

Exposure in climate extremities are high during 1951-2015

- Increase in day time temperature is high (1.10C)
- Decreasing rainfall trend
- Erratic rainfall

Water resource vulnerability is very high among all districts

- High ground water extraction (126 per cent)
- Out of 23 firkas, 15 are over exploited; 4 are in critical and only 2 firkas are safe
- Low surface water availability
- Very high water contamination (88.1 per cent)
- Fluoride, Nitrate contamination in water

Agriculture vulnerability

- Soil moisture is very less
- Evapotranspiration is more
- Raid fed area (67.54 per cent)

Socio-economic vulnerability

- Poverty index is very high among all districts (0.7)

- Source of drinking water within premises in rural are a is very low (5 per cent)
- Marginal farmers are more (92.8 per cent)
- Very High rural proportion (82.7 per cent)

7.3.3 Hot Spot 3 - Perambalur District

The geographical extent of Perambalur district is 369,298 sq.km and accounts for 2.83 per cent of geographical area of Tamil Nadu state. It is located in Cauvery delta- agro climate zone. The total number of village panchayats are 430. The principal crops cultivated in the district in the total sown area in 2015-16 are Cotton (6.2 per cent), Groundnut (2.5 per cent), Sugarcane (2.4 per cent), Gingelly (1.3 per cent), Cumbu (1.4 per cent), Paddy (1.2 per cent). Total net irrigated area is 36447 ha in 2015-2016. In the source wise net area irrigation of the district, canals (7348) and tube wells (21504) contribute more, and tanks (2629) and open well (4966) have a significant contribution to the net irrigation. Generally, the annual maximum temperature is 33.2°C and minimum temperature is 23.4°C during the long-term period 1951-2015. The annual average rainfall is 991.5mm. North-east rainfall accounts about 49 per cent of the total annual rainfall and south west monsoon contributes nearly 36 per cent of the total rainfall. Climate projection based on global climate models indicate that there would be 0.9°C increase in maximum temperature in mid-century period (2041-2070) and 1.3°C increase in end-century period (2071-2100) from the baseline scenario under RCP 4.5 climate scenario. The minimum temperature would increase nearly 1.1°C and 2.1°C during MC and EC periods. The dimensions of vulnerability indicators are shown in Figure 28 and its inference are discussed below:

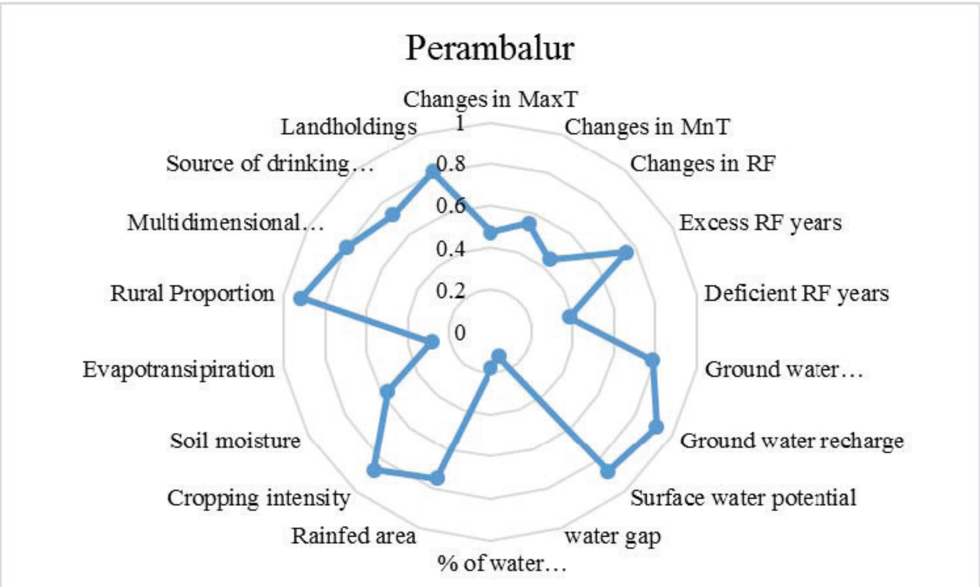


Figure 28 : Indicators dimensions – Perambalur District

Indicators interference:

Exposure in climate extremities are high during 1951-2015

- Increase in day time temperature is high (1.20C)
- Excess rainfall are more (15 years)

Water resource vulnerability

- High ground water extraction is high (120 per cent)
- Out of 11 firkas, 7 are over-exploited
- Ground water recharge is low
- Low surface water availability

Agriculture vulnerability

- Rain fed area (75.19 per cent)
- Low cropping intensity

Socio economic vulnerability

- Poverty index is very high among all districts (0.63)
- Source of drinking water within premises in rural are a is low (13.4 per cent)
- Marginal farmers are more (93 per cent)
- Very High rural proportion (82.8 per cent)

7.3.4 Hot Spot 4 - Thiruvanamali District

Located in north eastern agro climate zone, the geographical extent of the district is 6312.05 sq.km and accounts 4.85 per cent of the geographical area of Tamil Nadu. For administrative purpose, it has been further sub-divided into 52 forks, with 860 village panchayats. The principal crops cultivated are Groundnut (19.3 per cent), Cumby (9.4 per cent), Paddy (6.9 per cent), Sugarcane (2.4 per cent), and Raga (2.2 per cent) Gingelly (2.1 per cent), Cotton (0.2 per cent), Cholas (0.1 per cent), to the total area sown in 2015-16. Total net area irrigated area is 153,960 ha. Source wise net irrigated area are as follows: Canals (151), Tanks (22441), Open wells (128049), and Tube wells (3319). The annual maximum temperature of the district is 33°C and minimum temperature is 22.8°C during the long-term period 1951-2015. The annual average rainfall is 1,054.5 mm. North east rainfall accounts 45.8 per cent of the total annual rainfall and south west monsoon contribute nearly 43 per cent. Climate projection based on global climate models indicate that there would be 1°C increase in maximum temperature in mid-century period (2041-2070) and 1.5°C increase in end-century period (2071-2100) from the baseline scenario under RCP 4.5 climate scenario. The minimum temperature would increase nearly 1.2°C and 2.1°C during MC and EC periods. The dimensions of vulnerability indicators are shown in Figure 29 and its inference are discussed below:

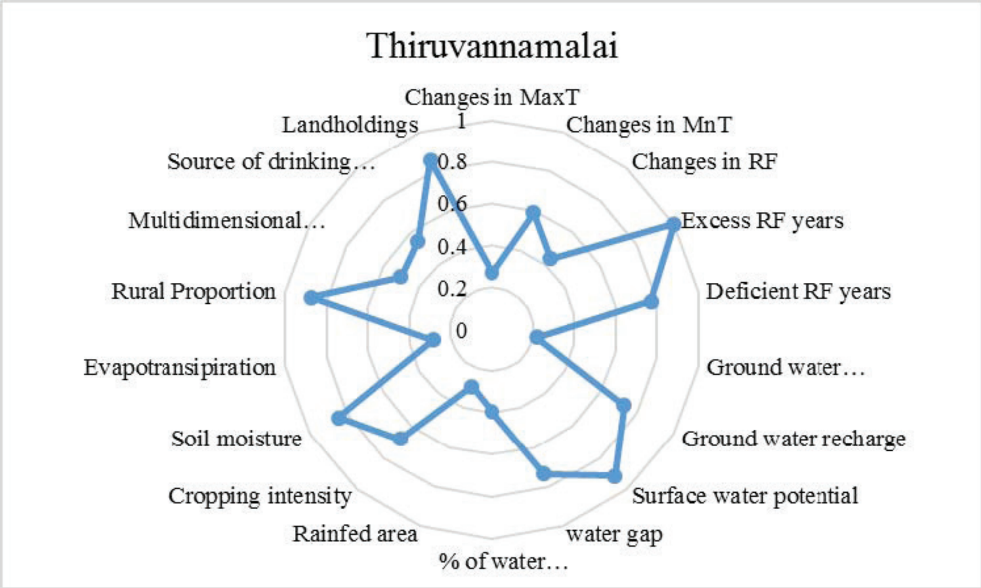


Figure 29 : Indicators dimensions –Thiruvannamalai District

Indicators interference

Exposure in climate extremities are high during 1951-2015

- Increase in day time temperature is high (1.2°C)
- Minimum temperature increase is high (0.5°C)
- Excess rainfall are more (15 years)
- Deficient rainfall years (15)

Water resource vulnerability

- Nearly 71 per cent of the blocks are overexploited
- Out of 52 firkas, 37 are over-exploited, 7 are critical, 8 are semi-critical and there is no safe firka
- Ground water recharge is low
- Low surface water availability
- Demand supply gap is more
- Fluoride, Nitrate contamination in water

Agriculture vulnerability

- Soil moisture is low
- Evapotranspiration is high

Socio economic vulnerability

- Poverty index is high (0.53)
- Source of drinking water within premises in rural is 18.8 per cent
- Marginal farmers are very high (94.7 per cent)
- Rural proportion is 79.9 per cent

8 Mapping of Existing Schemes, Projects and Policies related to Water Security and Climate Adaptation in Tamil Nadu

There are number of works related to water security and climate proofing in the state. The water security and climate related works carried out in the state are listed below under comprehensive management of river basin and natural resources conservation.

Comprehensive Management of River Basins

- Desilting of tanks
- Clearing & widening drainage carriers to original standards
- Check dams across river courses with necessary scour vents for recharging the downstream stretches
- Construction of regulators and barrages in riverine reservoirs, in stream reservoirs
- Interlinking of rivers
- Tail end regulators

Natural Resources Conservation

- Improving Inflow Channels
- Watershed development
- Special Area development programmes
- Integrated tribal development
- Micro irrigation
- Rainwater harvesting
- Artificial recharging of ground water
- New Irrigation Projects
- Prevention of sea water intrusion

- Rejuvenation of failed Wells
- Eco restoration of marsh lands, estuaries & creeks
- Conservation and restoration of creeks, marshlands and wetlands

These works are implemented through various schemes and projects by Central and State Government Departments such as PWD, RDPR etc.

8.1 National- and State-level Policies for Water Security and Climate Adaptation

- **National Action Plan on Climate Change**

o **National Water Mission**

The main objective of the National Water Mission (NWM) is to conserve water, minimise its wastage and ensuring it equitable distribution. The overall goal of this mission is to improve water use efficiency by 20 per cent. This mission possesses strong adaptation capacity with mitigation co-benefits through efficient energy use as well as carbon sequestration.

o **National Mission on Strategic Knowledge Management**

Strategic Knowledge Management allows for sustainable adaptation to climate change and mitigate the impact of drivers of climate change.

- **State Action Plan on Climate Change**

The State has developed a Tamil Nadu State Action Plan on Climate Change (TN SAPCC) for assessment, adaptation and mitigation measures with an aim to examine the targets, objectives and achievements of the national missions specified by the National Action Plan on Climate Change (NAPCC).

- **National Action Plan on Climate Change for Cauvery Delta**

Under Asian Development Bank assistance, the National Action Plan on Climate Change Programme, an eight-year Programme (2012-2020) is implemented. The major components of this Programme are (i) Integrated flood and salinity management, (ii) Sustainable Agriculture system, (iii) Shore line protection and management and (iv) Institutional development, training and awareness. This plan is designed to meet the key objectives of development needs, sustainability and adaptation to climate change. The program under the National Action Plan for Climate Change will modernise the surface water, groundwater and coastal drainage system in the Cauvery delta.\

8.2 National and State Schemes related to water security and climate adaptation

- **Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS)**

  The Mahatma Gandhi National Rural Employment Guarantee Scheme was launched on 2nd February 2006. The core objective of this scheme includes providing not less than one hundred days of unskilled manual work as a guaranteed employment in a financial year to every household in rural areas as per demand, resulting in creation of productive assets of prescribed quality and durability; strengthening the livelihood resource base of the poor; proactively ensuring social inclusion and strengthening of Panchayat Raj institutions. The district-wise works related to water security during 2018-19 are attached in Annexure III.

- **Pradhan Mantri Gram Sadak Yojana (PMGSY)**

  Pradhan Mantri Gram Sadak Yojana was launched in 2000 to provide all weather road access to unconnected habitations. PMGSY is a 100 per cent centrally sponsored scheme. From 2015-16 onwards, the funding pattern has been revised to 60 per cent central share and 40 per cent state share. The programme objective is to provide round-the–year connectivity by all-weather roads with necessary culverts and cross drainage structures. In Tamil Nadu, all habitations with more than 1,000 population and 99 per cent of unconnected habitations with population range 500-999 have been provided connectivity. The remaining habitations could not be provided connectivity due to various reasons such as habitations falling in reserve forest area, non-availability of land, etc.

- **Swachh Bharat Mission (Gramin)**

  Total Sanitation Campaign' (TSC) launched by Government of India to cover all households with sanitation facilities and promote hygiene behaviour was introduced in Cuddalore and Coimbatore districts, initially in 1999 and extended in phases to all other districts in Tamil Nadu by 2004. The scheme was renamed 'Nirmal Bharat Abhiyan' (NBA) to accelerate sanitation coverage in rural areas and achieve the vision of Nirmal Bharat by 2022 with all Village Panchayats in the country attaining open defecation free status. The unit cost was enhanced through convergence with Mahatma Gandhi National Rural Employment Guarantee Scheme.

- **Kudimaramathu Scheme**

  Kudimaramathu scheme ensures restoring water bodies through user communities. Kudimaramathu works include maintenance works in supply channels, canals, tanks, shutters, strengthening and reconstruction of surplus weirs, sluices, etc. Works are entrusted to Farmers' Organizations/ Council/ Ayacutdars/Users' Association on nomination basis. The district wise works during 2019-2010 ate listed in Annexure IV

- **Hogenakkal Water Supply & FMP: PWD**

  The Hogenakkal Water Supply & Fluorosis Mitigation Project have been implemented with the objective of providing portable water supply to Dharmapuri and Krishnagiri Districts in Tamil Nadu that comprise 3 municipalities, 17 town panchayats and 7639 rural habitations. The project is being implemented under three components, namely (i) Water Supply component; (ii) Fluorosis Mitigation Component and (iii) Capacity Building of Local Bodies for efficient O&M and financial sustainability.

- Water supply schemes under TNUDP-III, JNNURM, KfW, JICA, IUDM, IGFF and Capital Grant Fund
- Mahalir Thittam - Tamil Nadu Corporation for development of women Ltd. (TNCDW)

ACTS

- The Tamil Nadu Additional Assessment and Additional Water Cess Act, 1963
- The TWAD Board Act (Investigation, Execution and Maintenance of Water Supply Scheme and Drainage Scheme) Rules, 1973
- The Water (Prevention and Control of Pollution) Act, 1974
- Chennai Metropolitan Area Ground Water (Regulation) Act, 1987
- State Water Policy, 1994
- The Tamil Nadu Panchayat Act, 1994
- The Tamil Nadu Farmers Management of Irrigation Systems Act, 2000
- Tamil Nadu State Groundwater Development and Management Act, 2003
- The National Environment Policy, 2006
- The Tamil Nadu Protection of Tanks and Eviction of Encroachment Act, 2007
- National Water Policy, 2012

8.3 Existing projects related to Water Security and Climate Adaptation

- **National Hydrology Project**

  The National Water Informatics Centre (NWIC) will be established as a repository of nation-wide water resources data in order to improve the extent, quality, and accessibility of water resources information, decision support system for floods and basin-level resource assessment/planning and to strengthen the capacity of targeted water resources professionals and management institutions in India.

NWIC is envisaged as an independent organisation with adequate administrative and financial powers under the overall control of Secretary, Ministry of Jal Shakti.

- **Tamil Nadu Irrigated Agriculture Modernisation and Water Bodies Restoration and Management Project (TN IAMWARM)**

  The TN IAMWARM project is being implemented with World Bank assistance at an outlay of 2,547 crores since 2007 to benefit 6.69 lakh ha for a period of six years. The Water Resources Department and seven other line departments of the Government are the implementing departments. 4,922 tanks, 669 anicuts and 8,071 km length of supply channels have been constructed under the TN IAMWARM Project. This also includes tank system modernisation by restoring & repairing water bodies, improving canal irrigation system through repair and rehabilitation, besides crop diversification and improving application efficiency at farm level for increased productivity of water supplemented by livelihood improvement through livestock productivity

- **Irrigated Agriculture Modernization Project (IAMP)**

  This is the second phase of IAMWARM. Rehabilitation of 4,778 Tanks and 477 Anicuts, construction of check dams, artificial recharge wells in water-spread area of tanks and improving drainage cum irrigation channels in Cauvery Delta and other sub-basins

- **Master plan for artificial recharge**

  A Master plan for artificial recharge scheme at an estimated cost of Rs. 550 crores is being implemented by the Water Resources Department, TWAD Board, Agricultural Engineering Department and Forest Department. Under this scheme, construction of check dam, percolation pond and recharge shaft are being implemented.

- **Coastal Protection Works**

  The 13th Finance Commission constituted by the Government of India has recommended a grant of Rs. 200 crore for Coastal Protection Works over a period of 4 years from 2011-12 under the state specific needs grant to protect the coastline from sea erosion. On priority basis, vulnerable reaches have been identified and the state government have accorded administrative sanction for 50 coastal protection works in 7 coastal districts, at an estimate of Rs. 199.93 crore and the works are in progress.

- **Restoration**

  Restoration of 674 traditional water bodies over a period of 4 years from 2011 -2012 have been taken and the works are under progress.

- **Flood Management Programme in Tamil Nadu**

  The Government of Tamil Nadu has taken measures to tackle the recurrent heavy floods experienced during the north-east monsoons. Under the National Perspective plan, the Flood Management Programme with a Centre - State share of 75:25, is under implementation in Tamil Nadu. The schemes involved flood protection works to the Araniar, Kosasthalaiyar, Vellar, Pennaiyar, Gadilam, Malattar, Uppanar, Paravanar and Kollidam rivers to safeguard Thiruvallur, Villupuram, Cuddalore, Thanjavur and Nagapattinam districts for a total value on Rs.635.54 crores. The above work is being executed by State Water Resources Department since 2010 and is currently under progress.

- **Dam Rehabilitation and Improvement Project (DRIP)**

  This project strengthens and improves the safety and operational performance of the existing dams in a sustainable manner. The dam rehabilitation and improvement project with the World Bank assistance is proposed to be taken up over a period of 6 years from 2012-2013 in 4 phases. The project aims to restore the capacity of the dams, achieve effective utilisation of stored water and manage long-term performance of the dams. Three organizations, viz Water Resources Department, Tamil Nadu Generation and Distribution Corporation Limited/Tamil Nadu Electricity Board and Agricultural Engineering Department are participating in this project. The project covers 66 WRD dams and 38 TANGEDCO dams at a cost of Rs. 745.49 Crore (Annexure IV).

- **Linking of Rivers within the State**

  Two interlinking works in the state are under implementation to primarily serve as flood carriers and to divert the flood flows to reach the drought prone areas. These are interlinking of Cauvery, Manimuthar, Vaigai and Gundar Rivers, and formation of a flood carrier canal from the Kannadian Channel to drought prone areas of Sathankulam and Thisaiyanvilai.

- **Rainwater harvesting**

  The Tamil Nadu Government has been enforcing the construction of rainwater harvesting structures in all households, government buildings constructed under various schemes and private commercial buildings.

- **Recharge Structures**

  The recharge structures implemented by TWAD Board 2001 to 2015 are attached in Annexure V

9 Gap Areas related to Water Security and Climate Adaptation in the select areas identified

The study strongly recommends that the prioritised four sensitive blocks must receive immediate intervention to augment water resources. It requires detailed Participatory Rural Appraisal at the village level to bring climate proof sustainable water resource management. The general gaps observed through the study are

- Great void between supply and demand that require urgent alternative to develop synergetic adaptation towards water security
- Evidence-based water use with scientific data
- Efficient irrigation practices
- Mapping water availability in major and minor water bodies in time and space
- Periodical monitoring the state of system and non-system tanks
- Ensuring the free flow in water ways that carry excess water
- Proper water quality monitoring
- Agricultural best practices at the local level
- Prioritisation of work implementation should be based on scientific base data
- Identifying cadastral level (village level) vulnerable areas for water security

9.1 List of possible interventions

Specific areas of works including key action areas

- Increasing surface water storage with site specific water harvesting techniques
- Best irrigation practices coupled with improvised techniques for water use efficiency
- Agricultural research on crops that are drought/flood resistant.Inclusive rural development with people participatio
- Along with water conservation, soil conservation measures must be undertaken to facilitate water infiltration and percolation at the micro watershed level

- Proper monitoring and evaluation of schemes soon after implementation of the work
- Research on erratic rainfall intensity and its impacts on water quality and management
- Awareness programs on water security for rural community

10 Private Sector Partnerships

10.1 Non-Government Organizations

A list of organizations working in the sector and in the select hotspots in Tamil Nadu are listed below:

- MS Swaminathan Research Foundation
- Development of Humane Action (DHAN) Foundation
- Care Earth
- ASSEFA
- Siruthuli
- Non-conventional Energy and Rural Development
- Arghyam
- National Agro Foundation
- Centre for Environment and Development (CED)
- Gramalaya
- SCOPE
- EcoPro
- SEVA - Sustainable Agriculture and Environmental Voluntary Action
- Leadership through Education and Action Foundation (LEAF Society)
- Gandhigram Trust
- Scientific Educational Development for Community Organisation (SEDCO)
- Integrated Rural Development Trust
- Social Welfare Organization for Rural Development

10.2 Potential Cooperation and partnerships

There are a large number of private players contributing to water security and conservation under the Corporate Social Responsibility CSR (Corporate Social Responsibility) initiatives in Tamil Nadu. Some private partners have also joined hands with the WASH (Water, Sanitation and Hygiene) program.

- UNICEF India – Krinagiri District (ECOSAN)
- Oil and Natural Gas Corporation Ltd (ONGC)- Ariyalur District
- Bharat Petroleum Corporation
- ITC Limited- Integrated water shed program
- NLC India Limited.
- TVS groups of Companies
- Dalmiabharat
- ICICI Bank
- AXIS Bank
- Larsen & Toubro Ltd (L&T)
- Hindustan Petroleum Corp Ltd

11 Conclusions

Tamil Nadu State is one of the water-starved states. It has interstate rivers and more number of closed water basins as compared to other states. The state is entirely dependent on rains for recharging its water resources, and monsoon failures lead to acute water scarcity and severe droughts. In the recent decades, the water demand is increasing at a fast rate due to rapid increase in population, industrial and economic growth. The per capita availability of water in Tamil Nadu is declining fast; current per capita water availability is well below national average of 1,544 cubic meters. The land use pattern and cropping pattern in Tamil Nadu witnessed significant structural changes in the past 15 years. The land put to non-agricultural purposes had significantly gone up from 15.3 per cent in 2000-01 to 16.8 per cent in 2015-16. The net area sown has come down from 40.8 per cent in 2000-01 to 37 per cent in 2015-16. There is a decrease in the area of ground nut cultivation, a major rain fed crop during 2001-02 to 2015-16. Other principal crops such as combo, rage and gingelly cultivation have also significantly reduced. At the same time, the total pulses and cereals cultivated are at an increasing trend. However, irrigation intensity and irrigation ratio of the state has increased to is 73.9 per cent in 2015-16, from 65.9 per cent in 2001-02. The sources of irrigation in Tamil Nadu are canals, tanks, tube wells, open wells and bore wells. Well irrigation is a major source in the state with nearly 60 per cent of the irrigation through this source. People in ancient days had created excellent water harvesting structures keeping in mind the state's rainfall patterns and its topography and constructed a series of tanks for irrigation drinking and other purposes. However, irrigation through tanks and canal has significantly reduced in the recent decades. This has ultimately lead to more pressure on groundwater to meet the increasing irrigation intensity. Irrigation through wells has increased from 35.3 per cent in 1970s to 60.73 per cent in 2015-16. In this scenario, marginal and small farmers are holding nearly 91 per cent of the total holdings in the state and the area operated by them are 60.6 per cent of the total area. Monsoon failure or pressure on water resources ultimately affects these marginal and small farmers.

Increasing water demand, particularly from agriculture allied activities, domestic and industrial sectors, is placing additional pressure on the state's dwindling water resources. The dependency on ground water has increased many folds during the recent years and ground water extraction for irrigation, domestic and industries have resulted in lowering of water levels, which is at a long-term declining trend, as well as drying up of wells. The increasing number of over exploited blocks indicates that there is a wide gap between groundwater draft and recharge. According to recent Ground water resources assessment in 2017 indicated that the percentage of over exploited frikas has gone up by from 31 per cent to 39.6 per cent as 2013 estimate. While, the annual ground water recharge has been decreased from 20.65 to 20.22 BCM as compared to 2013 estimate. The ground water extraction has increased from 77 per cent to 81 per cent. In the recent decades, the state's agriculture, industrial and domestic sectors have become be more dependent on groundwater. Rapid urbanisation, and industrial growth also affects the quality of water. The pollutants beyond BIS norms found in many districts are fluoride, nitrate, heavy metals, etc.,

While the changes in the state's climate in the near past and future scenarios are evident, it has been severely impacted by annual flooding, including flash floods due to cloud bursts, monsoon floods of single and multiple events and cyclonic floods. Low rainfall coupled with the erratic monsoons in the state has made it among the most vulnerable state to droughts. In 2017, most of the districts in Tamil Nadu were severely affected by drought. The significant increase in day and night time temperature has been observed over 1951-2015. Even though there are no significant trends in rainfall, extreme rainfall has only increased in the recent decades. Due to high spatial variability, collecting water where it falls and transferring to water starved areas and collecting the sparse rainfall will be a challenge. Future climate change scenarios also indicated that the average annual maximum temperature for IPCC AR5 RCP4.5 scenario is projected to increase by about 0.9°C towards mid-century and by 1.3°C towards end-century. While for IPCC AR5 RCP 8.5 scenario, it is projected to increase by about 1.4°C towards mid-century and 3.4°C towards end-century. The changes in climate and alteration in monsoon pattern as captured by the analysis will lead to threats such as increasing water demand for irrigation domestic and industrial purposes and lowering water table.

Under these circumstances, as a first step towards enhancing the water security of the state under the changing climate scenario, an inclusive vulnerability assessment has been undertaken to identify the vulnerable districts. The bio-physical and socio-economic indicators are used to represent sensitivity and adaptive capacity of the state that helps determine rural water security. The key problems of prioritised districts are identified through indicators. The study also analyses the existing policies, schemes and projects. The best possible adaptation options for implementation towards improvements in water security of the district are listed.

There is a need to focus on efficient groundwater augmentation on a priority basis. Holistic and integrated management of water resources is the need of hour in the state. Collective water security actions including public, private sector, civil society and other stakeholders are indispensable towards integrated and sustainable water resources management of Tamil Nadu.

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Annexures

Annexure I

ASIA CORDEX RCMs used in this study and its driving GCMs

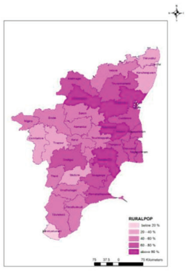
Asia CORDEX RCMs	RCM Condition	GCM Boundary	Institute	Scenario	Resolution period	Daily Time
ACCESS1-0_CSIRO-CCAM-1391M	CCAM	CSIRO-ACCESS 1-0	CSIRO	RCP4.5, RCP 8.5	0.5X0.5	1970-2099

Asia CORDEX RCMs	RCM Condition	GCM Boundary	Institute	Scenario	Resolution period	Daily Time
CNRM-CM5_CSIRO-CCAM-1391M	CCAM	CNRM-CM5	CSIRO	RCP4.5, RCP 8.5	0.5X0.5	1970-2099
MPI-ESM-LR_CSIRO-CCAM-1391M	CCAM	MPI-ESM-LR	CSIRO	RCP45, RCP 8.5	0.5X0.5	1970-2099
CNRM-CERFACS-CNRM- CM5_ SMHI-RCA4	RCA4	CNRM-CM5	SMHI	RCP4.5, RCP 8.5	0.5X0.5	1951-2100
NOAA-GFDL-GFDL-ESM2M_SMHI-RCA4	RCA4	NOAA-GFDL-ESM2M	SMHI	RCP4.5, RCP 8.5	0.5X0.5	1951-2100
ICHEC-EC-EARTH_ SMHI- RCA4	RCA4	ICHEC-EC-EARTH	SMHI	RCP4.5, RCP 8.5	0.5X0.5	1951-2100
IPSL-CM5A-MR_SMHI-RCA4	RCA4	IPSL-CM5A	SMHI	RCP4.5, RCP 8.5	0.5X0.5	1951-2100
MIROC-MIROC5_SMHI-RCA4	RCA4	MIROC-MIROC5	SMHI	RCP4.5, RCP 8.5	0.5X0.5	1951-2100
MPI-M-MPI-ESM- LR_ SMHI-RCA4	RCA4	MPI-ESM-LR	SMHI	RCP4.5, RCP 8.5	0.5X0.5	1951-2100
MPI-M-MPI-ESM- LR_ MPI-CSC-REMO2009	REM O2009	MPI-ESM-LR	MPI-CSC	RCP4.5, RCP 8.5	0.5X0.5	1961-2100

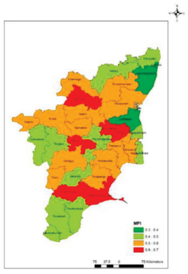
Annexure II

Spatial maps of some selected indicators

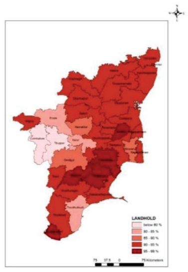
Rural Proportion



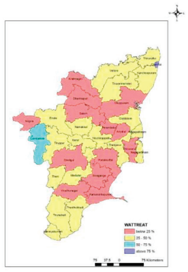
Multi Dimensional Poverty



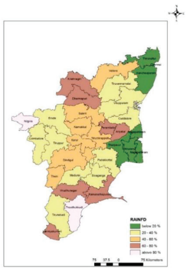
Marginal Land Holdings



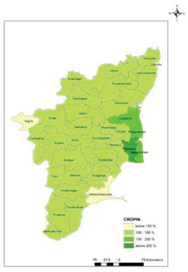
Water Access



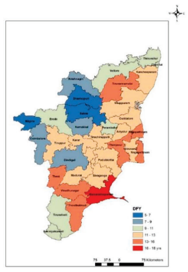
Rainfed Area



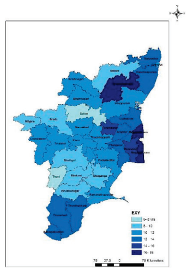
Cropping Intensity



Deficient Rainfall Years



Excess Rainfall Years



Annexure III

District wise works related to Water security under MGNREGS during 2018-19

S. No.	Districts	Soil and Water Conservation Related Works	Ground Water Recharge Related Works	Irrigation Related Works	Drainage and other Related Works	Farm Ponds
1	Ariyalur	1186	50	269	307	14
2	Coimbatore	1975	32	47	32	1
3	Cuddalore	4059	18	98	43	10
4	Dharmapuri	1731	23	164	23	3
5	Dindigul	2444	519	74	198	2
6	Erode	2377	67	310	57	3
7	Kanchipuram	1011	190	180	746	15
8	Kanyakumari	983	21	28	16	0
9	Karur	3445	246	147	60	2

S. No.	Districts	Soil and Water Conservation Related Works	Ground Water Recharge Related Works	Irrigation Related Works	Drainage and other Related Works	Farm Ponds
10	Krishnagiri	3988	40	327	3	2
11	Madurai	2305	63	353	218	5
12	Nagapattinam	521	79	434	168	8
13	Namakkal	1352	144	404	390	1
14	Perambalur	1320	62	192	180	22
15	Pudukkottai	994	83	407	100	8
16	Ramanathapuram	3399	79	103	183	3
17	Salem	2753	25	451	173	3
18	Sivagangai	2273	49	163	158	7
19	Thanjavur	1296	4	1289	51	11
20	The Nilgiris	470	8	30	88	0
21	Theni	561	2	123	32	0
22	Thoothukkudi	1321	79	102	287	16
23	Trichirappalli	7523	69	279	70	11
24	Thirunelveli	2394	164	258	301	39
25	Tiruppur	4537	39	446	17	4
26	Thiruvallur	1925	127	119	65	3
27	Thiruvannamalai	3834	93	188	129	13
28	Thiruvarur	84	43	173	182	24
29	Vellore	2729	900	222	168	13
30	Villupuram	4633	39	700	44	14
31	Virudhunagar	964	25	138	217	4

Annexure IV

District wise works under Kudimaramathu scheme during 2019-20 and DRIP project

Districts	DRIP	Kudimaramathu 2019-20
Ariyalur	1	12
Chennai		45
Coimbatore	4	36
Cuddalore	5	10
Dharmapuri	5	34
Dindigul		80
Erode	4	65
Kancheepuram		38
Kanyakumari	9	16
Karur	1	33
Krishnagiri	5	
Madurai		135
Nagapattinam		82
Namakkal		19
Perambalur		14
Pudukottai		66
Ramanathapuram		70
Salem	3	20
Sivagangai		109
Thanjavur		117
The Nilgirs	22	

Districts	DRIP	Kudimaramathu 2019-20
Theni	8	30
Thiruvallur		30
Thiruvarur		95
Thoothukkudi		37
Trichirappalli	2	88
Thirunelveli	12	185
Tiruppur	4	135
Thiruvannamalai	5	37
Vellore	5	53
Villupuram	5	73
Virudhunagar	1	65

Annexure V

District wise artificial recharge works done by TWAD board

District	Artificial Recharge structure _TWAD Board							
	Check dam	Percolation ponds	Recharge pits	Recharge trenches	Ooranis	Defunct Bore wells	Recharge shafts	RRWH
Ariyalur	107			3	9			10
Chennai								
Coimbatore	181	26			3	3	110	40
Cuddalore	119	2	3		5	5	17	25
Dharmapuri	356		3		6	3		25
Dindigul	843	2	24		5	30		30
Erode	223	19			I	5	145	24
Kancheepuram	153	120		I	15	5		15
Kanyakumari	13							45
Karur	346				5	6	215	25

District	Artificial Recharge structure _TWAD Board							
	Check dam	Percolation ponds	Recharge pits	Recharge trenches	Ooranis	Defunct Bore wells	Recharge shafts	RRWH
Krishnagiri	546	2			14	19		30
Madurai	444	3			9		42	50
Nagapattinam			10	91	5		119	46
Namakkal	390			I	4	5		
Perambalur	152	19	13		10		14	30
Pudukkottai	7	45	19	169	15		40	17
Ramanathapuram	58		51	25	427			50
Salem	769				5	3		
Sivagangai	67		16	24	126		10	24
Thanjavur	6	2	46	166	5	4	71	24
The Nilgirs	6							100
Theni	442	2			5			

District	Artificial Recharge structure _TWAD Board							
	Check dam	Percolation ponds	Recharge pits	Recharge trenches	Ooranis	Defunct Bore wells	Recharge shafts	RRWH
Thiruvallur	368				13	15		41
Thiruvarur				168	9		39	26
Thoothukkudi	102	10			7	5	50	
Trichirappalli	264	3	l	3	5	3		27
Thirunelveli	220	54	3		5	28		30
Tiruppur	267	25			4	2		41
Thiruvannamalai	546	39			9	24		31
Vellore	744	6			6	7		29
Villupuram	336	2	86		7	5		50
Virudhunagar	347				18			

Annexure VI
Photographs