On behalf of:

REPORT

Technology Needs Assessment (TNA)

For climate change adaptation in Tamil Nadu

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Abstract

This report is the outcome of a stakeholder-driven Technology Needs Assessment (TNA) for adaptation in the water and agriculture sector to identify and assess environmentally sound technologies that will, within national development objectives, reduce the impact of climate change in Tamil Nadu.

A series of consultations on TNA were held in September 2018. DA and adelphi and National Climate Change cell Tamil Nadu state (Department of Environment) were responsible for prioritization of adaptation technologies. All relevant Departments (Agriculture, Agriculture and Engineering Department, Water Resources, IMD, Groundwater), Agencies, Department of Environment, and some CSO as well as NGO representatives were part of the process.

A long-list of nineteen inventoried technologies from both water and agriculture sector was developed and after a prioritization a shortlist of adaptive technologies was agreed upon as a result of the consultations with stakeholders. For the development of the shortlist a Multi Criteria Analysis (MCA) tools was applied using criteria that were aligned with the National Water Mission and State's priorities across climate, social, institutional, environmental, cost, economic and technological benefits.

By expert judgment method with help of the guidance mentioned above, all inventoried technologies of each sector were then reduced to three technologies for each, the water and the agriculture sector.

The results for water sector are namely technologies for:

1) Construction of reservoirs intercepting rivers and interlinking for transfer of water from surplus basin to deficit basin: inland water diversion
2) Fortified / densification of network of irrigation tanks to avoid saltwater intrusion
3) Sub-surface water solutions for drinking water

For the sector of water in the agriculture sector, the three prioritized technologies are:

1) Capacity building for farmers on agronomical practices (dryland agriculture and collective farming)
2) Basin level DSS and early warning system for farmers with seasonal forecasting of droughts and selection of crops
3) Rejuvenation through De-siltation and deepening of existing water structures (irrigation tanks)

As next step, DA and adelphi will prepare project concept notes as action plans for implementation of one technology for each sector. A case study as an Annex to the concept has also been prepared.

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List of Abbreviations

CCA	Climate Change Adaptation
CSO	Civil Society Organizations
CGWB	Central Ground Water Board
DoE	Department of Environment
DSS	Decision Support System
EWS	Early Warning Systems
GIS	Geographic Information System
IEC	Information Education and Communication materials

IMD	India Meteorological Department
MCA	Multi-criteria analysis
MoEFCC	Ministry of Environment, Forest and Climate Change
NABARD	National Bank for Agriculture and Rural Development
NAPCC	National Action Plan on Climate Change
NAFCC	National Adaption Fund on Climate Change
NWM	National Water Mission
PSIR	Pressure-State-Impacts-Responses framework
SAPCC	State Action Plan on Climate Change
SSAPW	State Specific Action Plan on Water
TNA	Technology Needs Assessment

1 Introduction

1.1 Background

The project ‘Climate Change Adaptation in Rural Areas-India (CCA-RAI)’, one amongst the three projects under IGEP-RA, is being implemented under the bilateral cooperation of Ministry of Environment, Forest and Climate Change (MoEFCC) and GIZ. The project aims to integrate climate adaptation measures into the national and state development planning and strengthen the capacities of key actors at national and state levels for financing, planning, implementing and monitoring of climate adaptation measures.

During the first phase (2009 – 2014) of CCA-RAI the project, activities focused on the integration of climate change adaptation approaches in sectoral policy decisions and rural development programmes on national and state level. This project’s objective is to integrate in climate change adaptation measures into the development planning at national and state level as well as the strengthening of key actors’ capacities in planning, implementing monitoring and financing, and climate adaptation measures. This service contract is embedded in the second phase of the project (Jan, 2015-June, 2019) covering the four states of Himachal Pradesh, Punjab, Telangana and Tamil Nadu. The nodal points for climate change adaptation and mitigation in India are its subnational units i.e. the states. They have State Action Plans on Climate Change (SAPCC), based on the vision formulated by the National Action Plan on Climate Change (NAPCC) and its various missions. Post-Paris Agreement, India has also revisited the National Missions under the NAPCC in the light of the new scientific information and technological advances and identified new missions on wind energy, health, waste to energy, and coastal areas. It is also redesigning the National Water Mission and National Mission on Sustainable Agriculture (India’s NDC, 2015). However, there is a need to develop as well as understand the capacity, technology, and institutional needs to implement the SAPCC and to make its adaptation strategies possible. Under the National Water Mission (NWM), the states were asked to prepare State Specific Action Plans (SSAP) for Water Sector aligned with the SAPCC to give the NWM a roadmap to achieve the desired goals. State specific action plans for the water sector were asked to be prepared from the following twelve states in phase I – Andhra Pradesh, Assam, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, West Bengal, Tamil Nadu, Telangana, Odisha, Uttarakhand and Chhattisgarh. The four states under consideration for this project namely, Himachal Pradesh, Punjab, Telangana and Tamil Nadu, have vastly different climate change vulnerabilities and risks. Two (Telangana and Tamil Nadu) of them have already prepared their SSAPs. The nodal departments for climate change will be prioritized in each of the states for the exposure visit on demonstration of adaptation technologies.

Carrying on, the second phase of CCA-RAI (2015 – 2019) focuses on capacity building and climate change adaptation activities, technical support as well as on the development of knowledge management and outreach materials. Within this phase, the proposed technology needs assessment for adaptation in the water sector will take place. The technology needs assessment (TNA) is the first step contributing to technology development and transfer, which are of increasing priority to the international agenda to foster adaptation to climate change. The assessment of technology needs builds on various sources of information that are already available for each of the four CCA-RAI partner states: State Action Plans on

Climate Change (SAPCCs), District-level studies on climate change impact and vulnerability in the water sector of CCA-RAI project partner states and, if already available, State-specific Action Plans for Water (SSAPWs) and related documents. Throughout the assessment, the consideration of the National Action Plan on Climate Change (NAPCC) and the National Water Mission ensures that the results comply with national policies.

1.2 TNA Process

The methods applied during the TNA comprise on the one hand extensive desktop review (e.g. SAPCC, GIZ CCA-RAI vulnerability assessments, scientific literature and articles) which is complemented by stakeholder consultations with nodal agencies and relevant departments in the state in order to collect and incorporate local knowledge and expertise.

The first understanding of the vulnerabilities is done as per GIZ CCA-RAI impact assessment reports and other scientific climate vulnerability assessments and then verified and prioritised during the stakeholder consultations. Core vulnerabilities which require attention and can possibly be solved with technological interventions are identified and named **"CCA gap".** In order to sort the vulnerabilities addressed and indicate the type of solution options and scope of intervention, the CCA gaps are grouped into three specific **elements of vulnerability** which are exposure, sensitivity and adaptive capacity.

The understanding of the vulnerabilities was done as per GIZ CCA-RAI impact assessment reports and other scientific climate vulnerability assessments. These help identify the specific elements of vulnerability. The initial technology identification was mainly based on key climate change strategies that were recommended in national and state climate change action plans, state and national level water and irrigation programmes, other TNA reports and technology suggestion list compiled by Department of Science and Technology, Govt. of India- Water Technology Committee. These were further discussed with stakeholders to make judgment in the technology selection. The steps that were followed were to:

1. Analyse the climate vulnerability of the water sector in Tamil Nadu to identify the CCA gaps leading to vulnerabilities, i.e. what makes Tamil Nadu vulnerable to climate change and where is the scope for technical solutions to mitigate these vulnerabilities.
2. Investigate which technological solutions are already applied that address the impacts of the CCA gap and what other technologies could reduce vulnerability in order to adapt to climate change and close the CCA gap.

We developed a technology assessment matrix where technologies are bundled for the respective CCA gap. In this grid each technological solution is assessed against a set of criteria that characterise the technology further and help decision-makers prioritise and gauge the applicability. The assessment through different criteria (MCA approach) helps with the prioritisation of technologies and the development of a CCA technology shortlist.

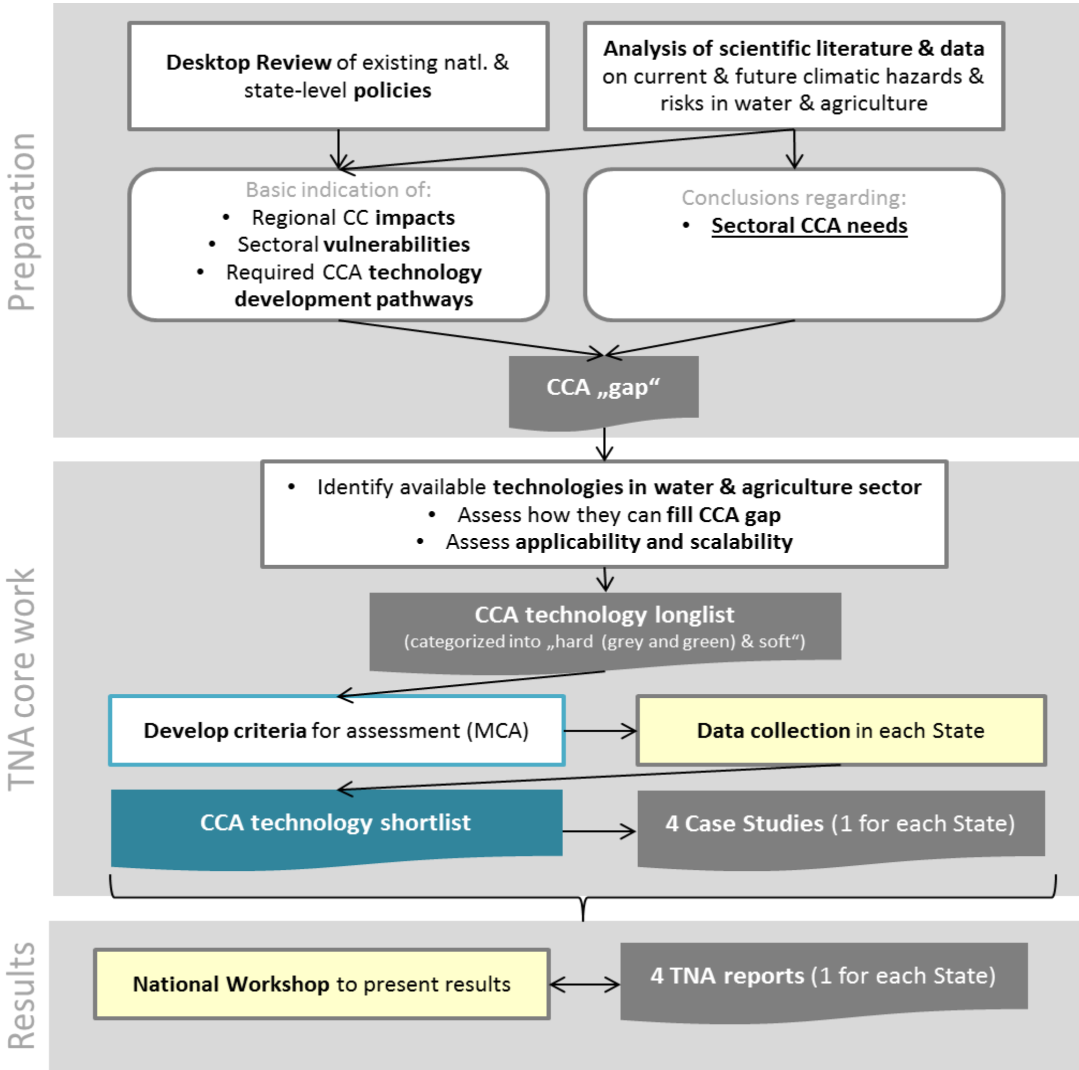

Figure 1: TNA process for this project

Source: adelphi (2018) based on Traerup and Bakkegaard (2015)

1.3 Institutional arrangement for the TNA and the stakeholder involvement in Tamil Nadu

A series of consultation on TNA were held in September 2018. DA and adelphi and the National Climate Change cell of Tamil Nadu state (Department of Environment) were responsible for prioritization of adaptation technologies. All relevant Departments (Agriculture, Agriculture and Engineering, Water Resources, IMD, Central Groundwater), Agencies, Department of Environment, and some CSO as well as NGO representatives were part of the process.

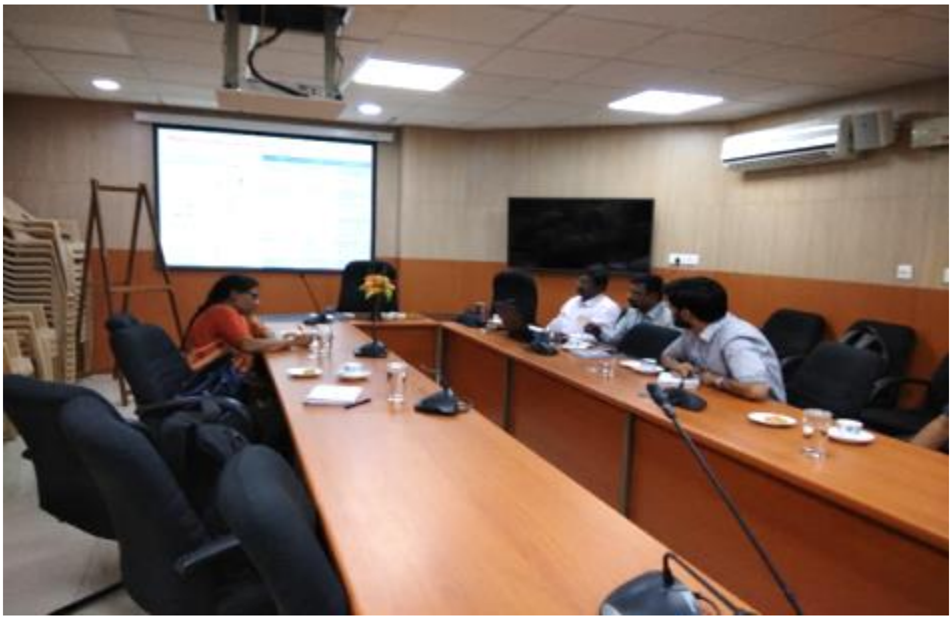

Figure 2: Stakeholder Consultation on TNA in Tamil Nadu, 2018
Source: Development Alternatives

Identification of development priorities of Tamil Nadu and prioritization of pre-selected technologies have been conducted with close involvement of relevant stakeholders. A final prioritization list of adaptive technologies was agreed upon as a result of several consultations with stakeholders, based on which a shortlist was developed using Multi Criteria Analysis (MCA). The final decision was endorsed by GIZ.

2 Vulnerability Assessment of Tamil Nadu

The Paris Agreement (2015) recognized that "*adaptation is a global challenge faced by all with local, subnational, national, regional and international dimensions*." This requires countries adapting to the impact of climate change and building the capacity to respond to and recover from climate risk; which is increasing (United Nations, 2016).

Vulnerability is described as a function of exposure to climate hazards and perturbations, sensitivity, and adaptive capacity (IPCC, 2014) and it is an established and also evolving concept for climate science and an emerging concept for policy.[1] In the light of climate change adaptation, technologies can contribute significantly to reduce vulnerability and thus avert future climate-induced losses and damages.

Understanding the climate technology needs of a country is a good starting point for effective action on climate change. IPCC Fifth Assessment Report defines vulnerability to climate change broadly as follows: "The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2014).

[1] "Vulnerability" may be defined in various ways. UNDP and GIZ describe vulnerability as a function of exposure to climate hazards and perturbations, sensitivity, and adaptive capacity (UNDP 2010).

Therefore, this study builds on previous vulnerability assessments for the state of Tamil Nadu (done by GIZ / INRM (2017)) and analyses what are the CCA gaps and which element of **climate vulnerability** (defined by the three dimensions of exposure, sensitivity and adaptive capacity) can possibly be addressed at present but also in the future. It further analyses to which extent **technological solutions** are already in place to reduce vulnerability and what are other possible technological solutions for Tamil Nadu. In the scope of this TNA the focus will be directed towards the water sector, including water in agriculture, as water resources are particularly affected by climate change impacts.

2.1 State profile of Tamil Nadu

Geography and Location

With an area of 130,000 sq km and a coastline of 1076 km, Tamil Nadu is one of the important coastal states. To its East is the Bay of Bengal and at its most Southern tip is the town of Kanyakumari, which is the meeting point of the Arabian Sea, the Bay of Bengal, and the Indian Ocean. The State can be divided broadly into two natural divisions-- the coastal plains and the hilly western areas, where average temperature in the plains varies in between 21.6 to 31.8 degrees celsius and in the hilly areas between 9.4 to 22.8 degrees celsius (TN SAPCC, 2013). Tamil Nadu is highly dependent on rainfall for its water supply and recharging of water resources, which makes the State vulnerable to the vagaries of the monsoon rains, especially the agriculture sector which is a significant contributor to the State's GDP (TN SAPCC, 2013).

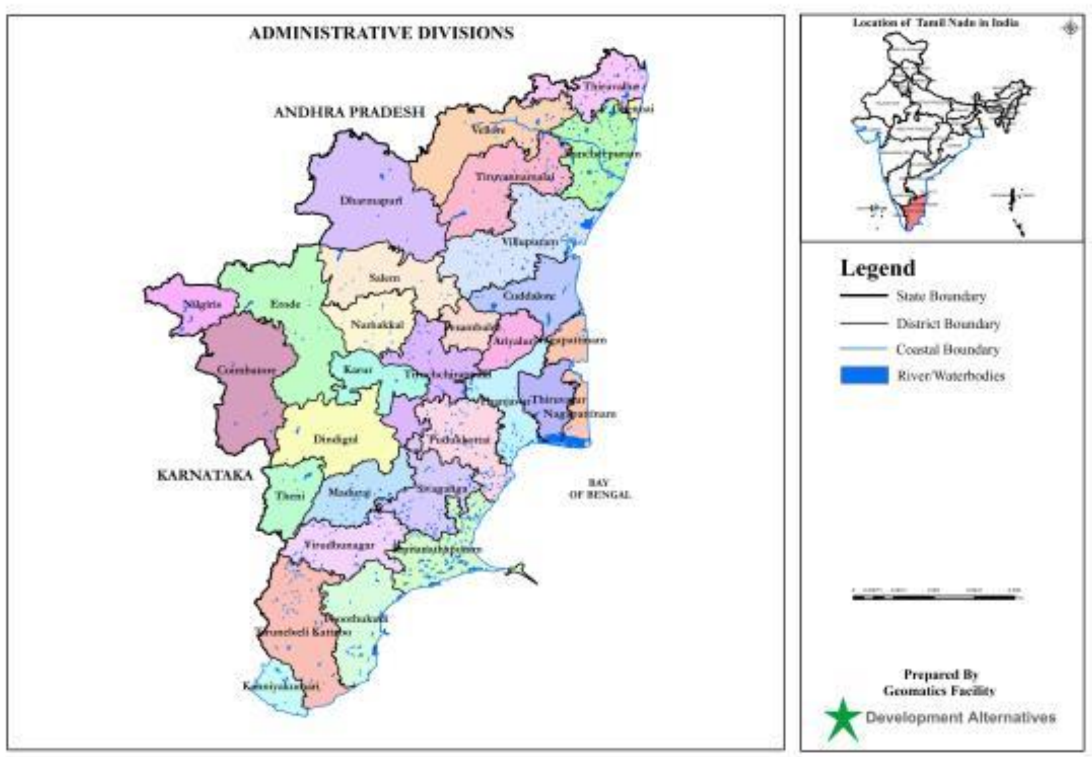

Figure 3: Map of Tamil Nadu highlighting surface water resources

Source: Development Alternatives

Climate and Temperature

GIZ / INRM (2017) carried a climate analysis study of the state using a historical data on daily temperature (maximum and minimum) and rainfall from 1951-2013 (63 years) for the State of Tamil Nadu. The study showed that mean annual maximum temperature for Tamil Nadu is 32.2 degrees Celsius with a range varying from 31.2 to 33.2 degrees Celsius, while the mean annual minimum temperature is 22.6 degrees Celsius with a range varying from 21.9 to 23.3 degrees Celsius. Average annual rainfall of Tamil Nadu State is 987 mm with a range varying from 317.4 to 1890.5 mm. The mean post monsoon (OND months) rainfall contributes the maximum to annual rainfall amounting to approximately 50 per cent for Tamil Nadu State.

Table 1: Observed Temperature and Rainfall Statistics for TN (1951-2013)

Source: GIZ / INRM (2017)

State	**Periods**	**Maximum Temperature**			**Minimum Temperature**		
		Average (°C)	Range (°C)	CV	Average (°C)	Range (°C)	CV
Tamil Nadu	Annual	32.2	31.2-33.2	0.014	22.6	21.9-23.3	0.013
	Winter (JF)	30.5	29.1-31.8	0.020	19.8	18.1-21.2	0.032
	Pre Monsoon (MAM)	34.7	33.2-36.2	0.020	23.9	22.8-24.8	0.018
	Monsoon (JJAS)	32.9	31.6-34.3	0.017	23.8	23.3-24.5	0.012
	Post Monsoon (OND)	29.8	28.7-30.9	0.016	21.4	20.5-22.5	0.019

State	**Season**	**Average Rainfall (mm)**	**Range (mm)**	**Inter-annual variation**	**Contribution to Annual Rainfall (%)**
Tamil Nadu	Annual	987	317.4-1890.5	0.28	
	Winter (JF)	33.1	0-208.1	1.38	3.4
	Pre Monsoon (MAM)	122.6	30.1-352	0.62	12.4
	Monsoon (JJAS)	340	86.3-927.3	0.48	34.4
	Post Monsoon (OND)	491.3	132.3-1006.9	0.38	49.8

The analysis of temperature data shows positive trends for both, annual maximum and annual minimum temperature, which are statistically significant (with greater than 90 per cent confidence level. This means that Tamil Nadu has clearly experienced overall warming since 1951.

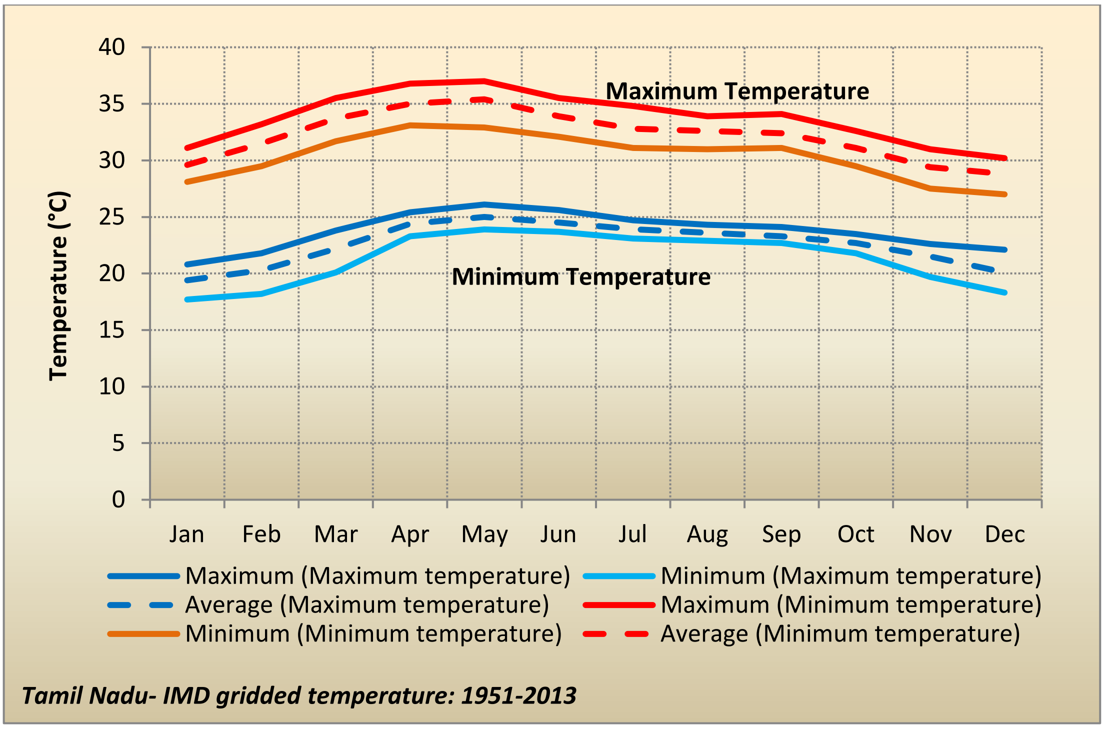

Figure 4: Observed temperature of Tamil Nadu

Source: GIZ / INRM (2017)

The analysis of annual rainfall also reveals a positive trend indicating that the total amount of rainfall each year has increased. The number of rainy days each year shows a negative trend which suggests that although Tamil Nadu experienced a slight increase in the level of rainfall, it did so in in fewer days. While both these trends are not statistically significant, more intense rain events could have huge implications for Tamil Nadu such as more severe floods, failure of rain fed crops, lesser groundwater recharge, enhanced soil erosion, etc.

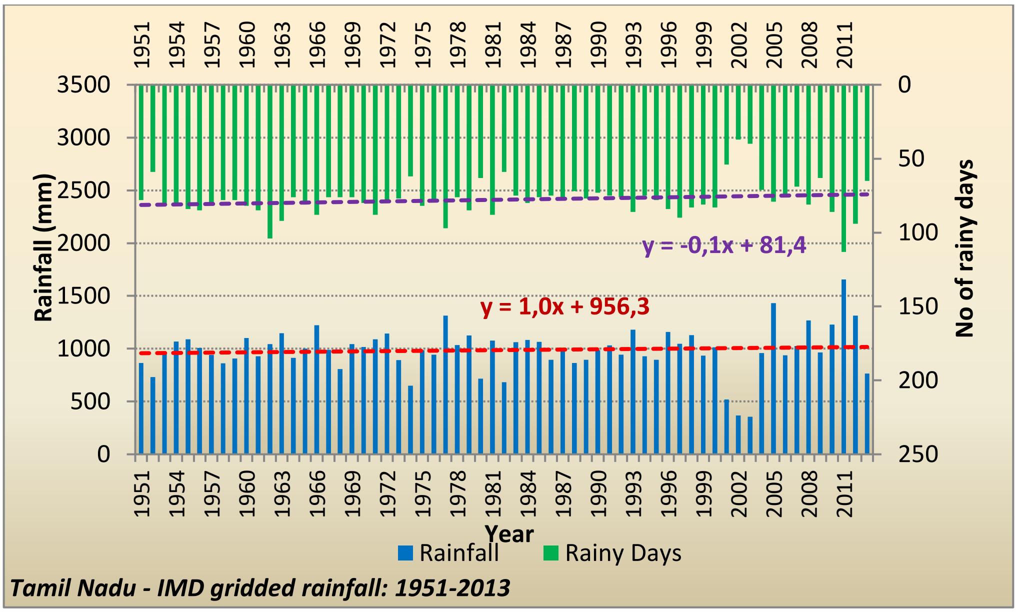

Figure 5: Observed annual rainfall and number of rainy days for Tamil Nadu

Source: GIZ / INRM (2017)

Projected Climate Change Scenario

The analysis of the projected daily temperature and rainfall under climate change scenarios shows that:

- Mean annual maximum temperature for RCP4.5 scenario is projected to increase by about 1.0 degrees Celsius by mid-century and by 1.7 degrees Celsius by end-century. For RCP 8.5 scenario it is projected to increase by about 1.2 degrees Celsius by mid-century and 3.4 degrees Celsius by end century for the State of Tamil Nadu.
- Mean annual minimum temperature for RCP4.5 scenario is projected to increase by about 1.2 degrees Celsius by mid-century and by 2.2 degrees Celsius by end-century. For RCP 8.5 scenario it is projected to increase by about 1.4 degrees Celsius by mid-century and 3.8 degrees Celsius by end century.
- Mean annual rainfall for RCP4.5 scenario is projected to increase marginally by about 4.4 degrees Celsius in mid-century and increase by about 20.5 degrees Celsius in end-century. For RCP 8.5 scenario it is projected to increase by about 6.7 degrees Celsius in mid-century and 26 per cent in end century.

The combination of higher sea levels and increased north-east monsoon precipitation will exacerbate existing drainage problems in the lower delta. General implications of temperature increase may include heat stress related health impacts, increase in energy demand for cooling, additional evaporation and evapotranspiration losses resulting in enhanced irrigation water requirement for crops. Increase in intensity of rainfall events may lead to floods, urban storms, vector borne diseases, loss of work, transport disruption, additional cost for flood proofing factories and warehouses.

Water sector

Tamil Nadu constitutes 4 per cent of India's land area and is inhabited by 6 per cent of India's population, but has only 2.5 per cent of India's water resources. More than 95 per cent of the surface water and 80 per cent of the ground water have been put into use. As there are no perennial rivers in Tamil Nadu, the agricultural, industrial and domestic activities depend largely on the ground water. Over extraction of ground water and discharge of wastes back into surface/ ground water make the water polluted (SoE Tamil Nadu, 2005).

The demand for water is increasing at a fast rate both due to increasing population and larger per capita needs triggered by economic growth in Tamil Nadu. As compared to the national average of 2200 cubic meters the per capita availability of water resources is 900 cubic meters in Tamil Nadu (TN SAPCC, 2013).

75 per cent of the total water resources are consumed by the agriculture sector. Demands from other sectors such as domestic and industries have been growing significantly. The State is heavily dependent on monsoon rains. As mentioned earlier, average annual rainfall of Tamil Nadu State is 987 mm with a range varying from 317.4 to 1890.5 mm. Since the State is entirely dependent on rains for recharging its water resources, monsoon failures lead to acute water scarcity and severe droughts.

As per the vulnerability study based on surface water and groundwater availability, crop water stress etc. conducted, seven districts namely Erode, Krishnagiri, Namakkal, Thoothukkudi, Karur, Salem and Virudhunagar are the most vulnerable districts (GIZ / INRM 2017). This is due to higher drought frequency, lower surface water availability and high crop water stress, all in North East Monsoon season. Further, Thiruvarur, Ariyalur, Nagapattinam, The Nilgiris, and Perambalur are the least vulnerable districts (GIZ / INRM 2017).

The overall water resources vulnerability of the districts is projected to decrease towards mid-and end-century as compared to the current conditions for both emission scenarios. Districts vulnerability under RCP8.5 scenario is projected to be lower as compared to RCP4.5 scenario (GIZ / INRM, 2017).

The main pressures on the water resources in Tamil Nadu are as follows:

1. Low Water Use Efficiency

The overall efficiency in surface irrigation like canals and tanks is only 40 percent (as compared to 75 percent in Israel) whereas in well irrigation it is 70 percent. Researchers opine that this level of overall efficiency can be increased to 50 to 60 percent in surface irrigation and to 85 percent in well irrigation. If the overall efficiency were increased in phases from 40 percent to 50 percent and 60 percent, this would annually save about 3,000 MCM for every 10 percent increase in efficiency (TN SAPCC, 2013).

2. Industrial Effluent Discharge and Surface Water Pollution

There are more than 3000 industrial units in Tamil Nadu which have been classified under the highly polluting or "red" category. The total effluent generated is about 6 lakh litres per day of which more than 5 lakh litre (85 per cent) is generated by large industries. About 400 units discharge directly into rivers (Angappapillai and Muthukumaran, 2012).

The effluents often flow through nallahs or open drains and reach the rivers, lakes, etc. Since the river water is used downstream for irrigation or drinking by people/livestock, contamination of the river has increasingly become a serious problem in many of the river basins of the State (Angappapillai and Muthukumaran, 2012).

3. Ground Water Pollution

With greater utilisation of water for industrial and domestic use and also due to the increased use of agricultural chemicals, ground water quality is deteriorating rapidly in the State. Diminished water quality also means that the quantum of fresh water available for particular uses is reduced, or that the water can be used only after treatment (Angappapillai and Muthukumaran, 2012).

4. Catchment Degradation

In the catchment area of most of river basin intensive farming activities are taking place. Such farming operations and deforestation have exposed the topsoil, and resulted change in runoff pattern and soil erosion affecting the reservoirs with heavy siltation (Angappapillai and Muthukumaran, 2012).

5. Siltation in Rivers and Reservoirs

The problem of siltation in reservoirs has become alarming, since the silt deposited in the reservoirs or tanks decreases the capacity of the reservoirs thereby reduces the utility of them for various purposes. The studies on the sedimentation problems carried out in 33 reservoirs in Tamil Nadu reveal that there is a loss in capacity of more than 50% in two reservoirs viz., Kundha and Glenmorgan, more than 30% capacity loss in 8 reservoirs (Angappapillai and Muthukumaran, 2012).

6. Excessive Surface and Ground Water Abstraction

Excess abstraction of water for domestic and industrial supply and agricultural uses without proper planning and priorities will adversely affect the surface water. The ground water table is being depleted year after year due to the failure of monsoon, inadequate recharge of the aquifers and excessive pumping of water from the wells over and above the annual recharge into the aquifers (Angappapillai and Muthukumaran, 2012).

80 percent of the ground water is being used out of total available. This has led to the decline in ground water table in most of the blocks (CGWB, 2015). According to the estimates seven of the 12 blocks are over-exploited and the rest semi-critical (CGWB, 2015). In comparison the water levels from 2004 to 2015, the level increased by 30% during rainy season but overall it has decreased by 70% (CGWB, 2015).

7. Eutrophication and Aquatic Weeds

Agriculture is a major factor in eutrophication of surface waters in Tamil Nadu (Angappapillai and Muthukumaran, 2012). Although both nitrogen and phosphorus contribute to eutrophication in majority of cases phosphorous is the limiting nutrient. Reservoirs, rivers, irrigation canals and drainage channels are infested with aquatic weeds, which may be submerged or floating.

8. Demand-Supply Gap

The sectoral demand for water in 2011 was 49,773 MCM, which is about 2000 MCM more than the potential availability. The demand is projected to increase to 48,766 MCM and 55,649 MCM in 2020 and 2045 respectively (TN SAPCC, 2013). The gap between supply and demand by 2020 is expected to be 5,211 MCM (11 percent) and it is likely to go up to 17 percent by 2050, if there is no intervention.

9. Decreasing Southwest Monsoon and Increasing Northeast Monsoon

For Tamil Nadu, NE monsoon season is the main rainy season accounting for about 50 percent of the annual rainfall. Coastal districts of the State get nearly 60 percent of the annual rainfall and the interior districts get about 40-50 percent of the annual rainfall. It is seen that the percentage of Northeast Monsoon rainfall to the State average rainfall, has increased from 36 percent during the year 2000 to 51 percent during the year 2011 (TN SAPCC, 2013).

10. Floods

Tamil Nadu generally receives copious rains during the Northeast monsoon. The heavy downpour in a short duration results in severe flood causing great risk of damage to life and property of the people and to the states assets like irrigation infra-structure, roads, etc. Every year coastal districts such as Cuddalore, Nagapattinam, Thanjavur and Thiruvarur are the most vulnerable to floods (Angappapillai and Muthukumaran, 2012). Urban flooding is another significant problem in Tamil Nadu. The capital city Chennai and its suburban areas are worst affected by flood every year because of improper drainage and encroachment of water bodies and waterways.

11. Droughts

Tamil Nadu, a coastal state in south India, is also prone to droughts. The climate of the state ranges from dry sub-humid to semiarid. An assessment of droughts in Tamil Nadu from 1977 to 1991 reveals recurrent drinking water shortages in major parts of the state and the Chennai city in particular (TN SAPCC, 2013).

12. Shoreline Erosion / Sea level rise

The long sandy beaches of the Cauvery delta are currently suffering from slow levels of localised erosion, the problems are largely due to the lack of sustainable supply of sand from the rivers; dams and sand mining have over time seriously reduced the supply of sand to the coast (ADB, 2011). Sea level rise will impact flooding and drainage as well as increased vulnerabilities of coastal erosion. Already quite large parts have significant drainage problems. The higher sea levels will affect the flood levels mainly in the NE monsoon and crest levels of bunds, dykes and regulators will have to be raised to meet these increased levels. Sea level rise will affect natural habitats in the estuarine rivers, the changes will affect both water levels as well as the salinity-freshwater balance.

Agriculture sector

Agriculture is the principal source of livelihood for more than 40 percent of the population for Tamil Nadu. The State achieved an all-time high record production of 10.1 million tonnes of foodgrains during 2011-12 and received the Krishi Karman Award from the Government of India. Tamil Nadu performed well ahead of other major States in terms of productivity of important crops (DEAR, 2014). It ranked second in the productivity of paddy next only to Punjab and came first in the yield of maize and oilseeds. The productivity of sugarcane in Tamil Nadu was almost double of what was obtained at the national level. The better agricultural accomplishments are the result of continued technological gains and appropriate policies (DEAR, 2014).

The annual per capita water availability in India is about 2200m3 whereas it is only about 750 m3 in Tamil Nadu. There are about 81 reservoirs, 41,127 tanks and 18.21 lakh wells in the State. The total storage capacity of 15 major reservoirs in the State is 198.38 tmcft. Against which water realization stood at 172.26 tmcft in 2011-12 (86.8%) (DEAR, 2014).

The decline in ground water table across the State is a matter of serious concern. As a result, out of 386 blocks in the State, 139 blocks are categorized as over-exploited, 33 blocks as critical, 67 blocks as semi-critical, 11 blocks as poor quality and the balance 136 blocks as safe (CGWB, 2015).

Low water use efficiency and inadequate maintenance of irrigation systems are some of the major problems that confront the management of water resources in the State. There is a need to promote participatory management of aquifers to ensure sustainable and equitable use of water. Promotion of micro-irrigation techniques, alignment of cropping patterns with the availability of water and greater involvement and empowerment of Water Users' Associations in the command areas could lead to improvement in water use efficiency (DEAR, 2014).

Vulnerabilities:

IPCC AR5 RCP4.5 projects to have high water stress in Krishnagiri, Kanniyakumari, The Nilgiris, Perambalur, Salem, Tirunelveli and Vellore districts. These districts show improvement in drought conditions towards end-century as compared to baseline. Higher water stress conditions may call for additional irrigation supplies for agriculture.

2.2 Relevant National Policies, Plans and Programmes

While there are multiple vulnerabilities listed, there are relevant policies, plans and programmes that the Tamil Nadu government has taken to address those vulnerabilities. These are important to note as they are part of the existing adaptive capacity of the state

Table 2: National level policies and their implication for the TNA

Year	Policy	Water	Agriculture	Implications for TNA (specific technologies)	Funding options under this policy
2002	National Water Policy	✓			
2014	Interlinking Of Rivers	✓			
2010	Master plan for artificial recharge	✓		Rooftop Rainwater Harvesting, shallow aquifer, percolation ponds and check dams	The total cost of recharge structures proposed in rural and urban areas of Tamil Nadu is Rs.2386 crores.
2015	Rashtriya Krishi Viskas Yojana		✓	providing soil health care assistance; • promoting Micro Irrigation to increase water use efficiency; • increasing cropping and irrigation intensity;	

2.3 Relevant State Level Policies and Schemes

This section elaborates few of the key existing projects and schemes of the Government of Tamil Nadu for addressing problems of drinking water and irrigation water supply problems.

Table 3: State level policies and their implication for the TNA

Year	Policy	Water	Agriculture	Implications for TNA (specific technologies)	Funding options under this policy
1994	Tamil Nadu Water Policy	✓	✓	• Artificial recharging of groundwater • Interlinking of rivers within the state • Cloud seeding • Rainwater harvesting • Desalination for coastal belts • Watershed management • Flood forecasting and flood plain zoning • Management Information System (MIS) for water resources	
1995	National Conservation River Action Plan (NRCP)	✓			
2007	TN Irrigated Agriculture Modernisation and Water Bodies Restoration and Management Project	✓		• 4922 tanks, 669 anicuts and 8071 km length of supply channels • Improve service delivery of the irrigation system	2547 Crores across 6 years
2011	National Action Plan on Climate Change for Cauvery delta	✓	✓	• Integrated flood and salinity management • Shore line protection • and management	Under Asian Development Bank assistance, Rs.1560 Crores in the

				• Sustainable Agriculture system	Cauvery delta area and this is an eight-year Programme (2012-2020).
2012-2017	Flood Management Programme	✓		• river management • flood control: flood protection wall/embankment • anti – erosion • drainage development	INR 10,000 crore was approved in October 2013 for XII FYP (2012-2017)

3 Deriving a longlist of CCA technology options

As a next step of the TNA process, an overview of technologies for adaptation was developed and provided to the stakeholders based on the vulnerabilities identified. Technologies were categorized in terms of the vulnerability element it addresses (i.e. exposure, sensitivity or adaptive capacity). Following are the list of technologies that were suggested during the consultation meetings based on the vulnerabilities and elements it addressed. The vulnerabilities have been mentioned by the interviewed stakeholders, references are given in case they have also been mentioned in the other strategic or planning documents. Appropriate importance was also given to technologies that were suggested by the stakeholders as required at a larger scale. The technology code, which is subsequently used when referring to individual technologies, distinguishes between technologies for the water sector (code "W) and technologies for the water *and* the agriculture sector (code "WA").

Table 4: Key Impacts of Climate Change in Water and Water in Agriculture Sector

Category	CC Impact	Description of CCA Gap	Possible Solutions/ technologies	Element of Vulnerability Addressed	Technology Code
Plain region water resources	**Flood**: Extreme weather events leading towards increase in flooding and siltation in rivers and reservoirs (TN SAPCC (2013); GIZ / INRM (2017))	The main losses occur during irrigation of fields as conveyance, run off, seepage and deep percolation. Irrigation efficiency can be increased by reducing these losses. Uneven spreading and inadequate filling of root zone are the other causes for low irrigation efficiency.	• Construction of reservoirs intercepting rivers and interlinking for transfer of water from surplus basin to deficit basin: inland water diversion	reduce exposure, reduce sensitivity	W3
			• Construction of ground water recharging structures such as check dams, recharge shafts, farm ponds, etc.	reduce sensitivity	W6
			• Construction of bed dams to divert lean stream flow into off take channels to supply water to irrigation tanks	reduce exposure, reduce sensitivity	WA8

Category	CC Impact	Description of CCA Gap	Possible Solutions/ technologies	Element of Vulnerability Addressed	Technology Code
Coastal region water resources	**Sea Level Rise**: Impacts on coastal livelihood, agriculture, surface and groundwater bodies and increased flood risk, including increased vulnerability of coastal erosion	It will affect both surface and ground water levels as well as the salinity-freshwater balance in the coastal region. Further with no significant change in annual rainfall, groundwater recharge will be largely unchanged; this compounded with over extraction of groundwater will increase salinity intrusion.	• Low cost desalination plants	increase adaptive capacity	W1
			• Sub-surface water solutions/ constructed wetlands for drinking water needs	increase adaptive capacity	W2
			• Construction and rehabilitation of tail end regulators to prevent the intrusion of saline water in channels	reduce exposure	W5
			• Fortified / densification of network of irrigation tanks to avoid saltwater intrusion	Reduce exposure	W7
			• Enforcing the ground water regulation acts to prevent seawater intrusion	reduce sensitivity	W10
Hilly region water resources	**Drought**: Groundwater table decline due to reduced recharge due to erratic rainfall (increased surface run off) (Tamil Nadu SAPCC, 2013)	There is high rainfall in the hilly region, but due to absence of water storage and proper systems for regulation leading to high run-off leading to drought in later seasons and flooding in the plain regions during rain.	• Rain water harvesting measures along the hill slopes	increase adaptive capacity	W4
			• Construction of toe grade walls to prevent degrading of stream beds and piping failures in hydraulic structures	reduce sensitivity	W8
			• Creation of subsurface dykes to prevent damage of dams	reduce exposure	W9

Category	CC Impact	Description of CCA Gap	Possible Solutions/ technologies	Element of Vulnerability Addressed	Technology Code
			• Basin level EWS and DSS for correct operation of reservoirs to address floods	reduce exposure	WA6
All geographies	**Crop Loss and Failure**: Crop loss due to drought/ less or no rainfall	Inadequate irrigation infrastructure Poor early warning systems Non-use of drought resistant/ resilient varieties. failure of rain-fed crops due to excessive rainfall in limited time period due to Limited irrigation facilities available to manage the excess water as per the agriculture water requirement	• Basin level DSS and early warning system for farmers with seasonal forecasting of droughts and selection of crops	reduce exposure	WA5
			• Capacity building for farmers on agronomical practices (dryland agriculture and collective farming)	increase adaptive capacity	WA2
			• Rejuvenation through De-siltation and deepening of existing water structures (irrigation tanks)	increase adaptive capacity	WA9
			• Drought-resistant crop varieties (biotechnology)	increase adaptive capacity	WA7
			• Alternate cropping system: short duration, less water intensive pulses, millets etc.	increase adaptive capacity	WA4
			• Modernization of Irrigation system using drip, sprinklers systems	increase adaptive capacity	WA1

Category	CC Impact	Description of CCA Gap	Possible Solutions/ technologies	Element of Vulnerability Addressed	Technology Code
			• Recycled waste/ sewerage water treatment for agriculture	increase adaptive capacity	WA3

4 Prioritising: Shortlist of CCA technology options

Water resources, already under pressure as a result of growing water demand in relation to a finite supply, will be under even greater pressure in the future as a result of climate change. This is a result of (but not limited to) three factors: the projected decrease in rainfall, increased evaporation resulting from higher temperatures, and the amplifying effect that the hydrological cycle has on climate change.

Adaptation will principally involve changes in water allocation, from uses that generate less economic or social value per unit of water consumed to uses that generate more. Therefore, all sectors that use water will be under pressure to be more water efficient, especially water in agriculture.

Improvements in irrigation efficiency are particularly important, as the irrigation sector has by far the largest use of water. Tail end check dam for medium irrigation project to reduce capacity loss could be used to compliment traditional irrigation efficiency technologies such as drip sprinklers or contour bunding etc. These technologies are linked to existing programmes and have a higher possibility of implementation at scale.

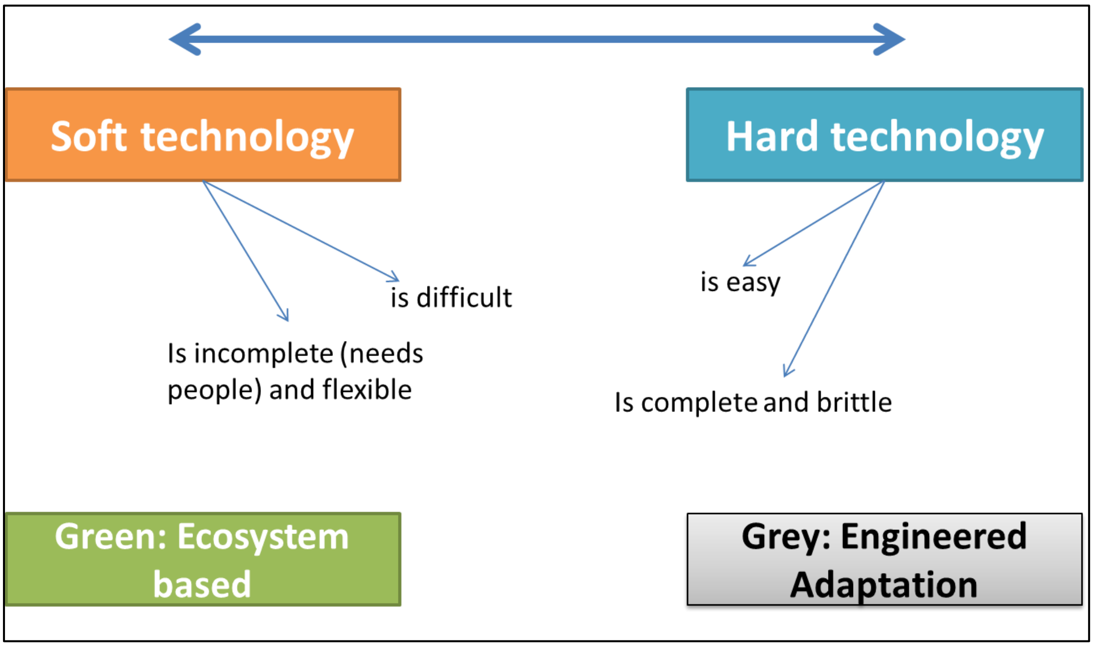

Figure 6: Types of Technologies

Source: DA adopted from Hobson (2011)

The colour coding of the technologies are based on whether they are ecosystem based adaptation (green) or engineered adaptation (grey). It is also differentiated on the basis of being a soft measure or a hard technology. In order to mitigate adverse effects of the upcoming climate change, the following long-list of adaptation measures were proposed through the consultation and literature review:

Table 5: Longlist of Technology Solutions

Water	Code	Type
Low cost Desalination plants	W1	Hard
Sub-surface water solutions / constructed wetlands for drinking water needs	W2	Hard

Construction of reservoirs intercepting rivers and interlinking for transfer of water from surplus basin to deficit basin: inland water diversion	W3	Hard
Rain water harvesting measures along the hill slopes	W4	Hard
Construction and rehabilitation of tail end regulators to prevent the intrusion of saline water in channels	W5	Hard
Construction of ground water recharging structures such as check dams, recharge shafts, farm ponds, etc.	W6	Hard
Fortified / densification of network of irrigation tanks to avoid saltwater intrusion	W7	Hard
Construction of toe grade walls to prevent degrading of stream beds and piping failures in Hydraulic Structures	W8	Hard
Creation of subsurface dykes to prevent damage of dams	W9	Hard
Enforcing the ground water regulation acts to prevent seawater intrusion	W10	Soft
Water in Agriculture Sector	**Code**	
Modernization of Irrigation system using Drip, Sprinklers systems	WA1	Hard
Capacity building for farmers on agronomical practices (dryland agriculture and collective farming)	WA2	Soft
Recycled waste/ sewerage water treatment for agriculture	WA3	Hard
Alternate cropping system: short duration, less water intensive pulses, millets etc.	WA4	Hard
Basin level DSS and early warning system for farmers with seasonal forecasting of droughts and selection of crops	WA5	Soft
Basin level EWS and DSS for Correct operation of reservoirs to address floods	WA6	Soft
Drought-resistant crop varieties (biotechnology)	WA7	Hard
Construction of Bed dams to divert lean stream flow into off take channels to supply water to irrigation tanks	WA8	Hard
Rejuvenation through De-siltation and deepening of existing water structures (irrigation tanks)	WA9	Hard

Below, brief information on the long-listed adaptation technologies for both the sectors is provided:

Description of suggested technology options to address CCA in the water sector

Low cost Desalination plants: Desalination is the removal of sodium chloride and other dissolved constituents from seawater, brackish waters, wastewater, or contaminated freshwater. The major drawbacks of current desalination processes include costs, energy requirements and environmental impacts. However, there are increasing possibilities for using renewable energy, such as solar or wind-driven desalination coupling.

Subsurface water technologies/ constructed wetlands for drinking water needs: Skimming well/subsurface water technologies is any technique employed with an intention to extract relatively freshwater from the upper zone of the fresh-saline aquifer (Rao et.al, 2006) The technologies also involved usage of multiple partially penetrating wells to enable deep injection and shallow recovery of freshwater.

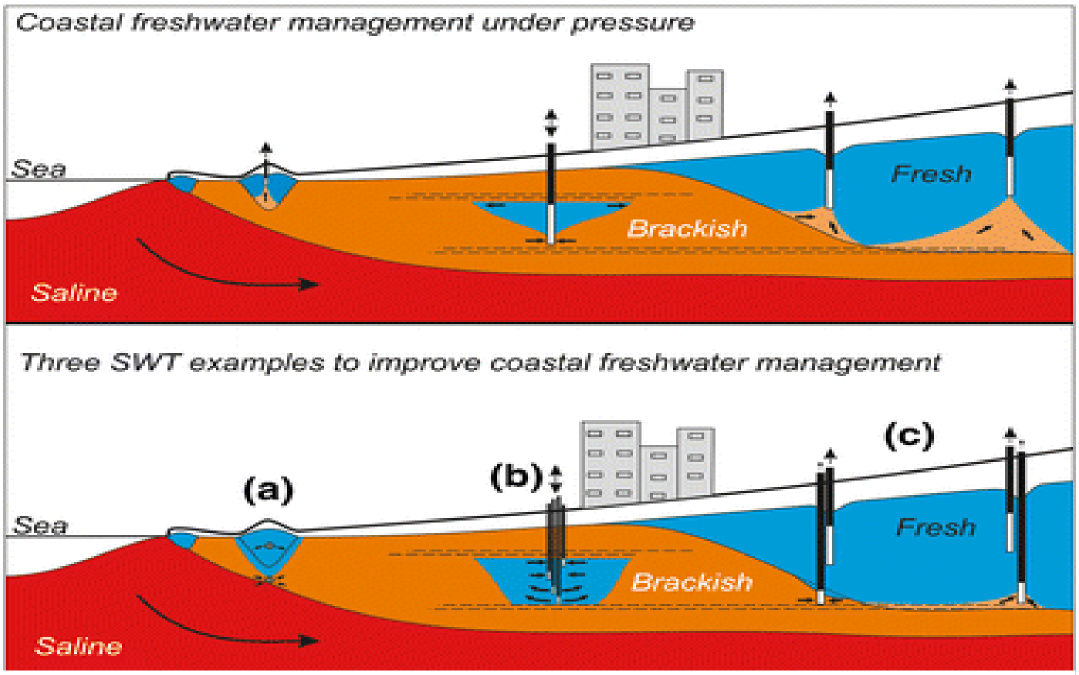

Figure 7: Three types of Sub-surface water technologies
Source: Zuurbier et.al (2016)

Construction of reservoirs intercepting Rivers and interlinking for transfer of water from Surplus Basin to Deficit Basin: inland water diversion: Inter-basin transfer is the moving of water from a watershed with a surplus (donor basin) to a watershed suffering from a shortage (recipient basin). The water is transferred primarily to alleviate water scarcity in the recipient basin and travels long distances via complex pipeline and canal systems. It supports groundwater recharge in the receiving watershed basin and alleviates negative ecosystem impacts associated with critical water shortage. It is a grey infrastructure approach that focuses on developing carriers along the edges of the river. This allows the flooding river water to eventually connecting areas where there is low chance of flooding; further augment the aquifer through developing groundwater recharge structures at the ends of the flood carriers.

Rain water harvesting measures along the hill slopes: Rainwater harvesting is a particularly suitable technology for areas where there is no surface water, or where groundwater is deep or inaccessible due to hard ground conditions, or where it is too salty or acidic. (UN Environment – DHI, CTCN, UNEP DTU, 2017) Rainwater harvesting systems, collecting the runoff from hill slopes, at regular distances can help to supply water points for irrigation, livestock and communities.

Construction and rehabilitation of tail end regulators to prevent the intrusion of saline water in channels: Tail end regulators places at end right before rivers are channelized into irrigation canals. This helps the rivers act as a drain for excess water from the field as well as sea water (Glavovic, 2015).

Construction of ground water recharging structures such as check dams, recharge shafts, farm ponds, etc.: Community farm ponds and percolation tanks including Minor irrigation systems like small and medium sized check dams are small water storages adaptation actions created in the sub-basins by bunding streams and gullies. These help store runoff water during the monsoon season and cause recharge to ground water during the next few months of dry season.

Fortified / densification of network of irrigation tanks to avoid saltwater intrusion: Irrigation tanks allow for diverting the river water through dug out earthen channels through a connective system. Due to its presence along the coastal region it helps in preventing saltwater intrusion as it contains freshwater.

Construction of toe grade walls to prevent degrading of stream beds and piping failures in Hydraulic Structures: Construction of toe grade walls as well as piping failures in hydraulic structures will help in stabilizing stream banks. This can be an ecosystem based intervention that can prevent the loss of land adjacent to a watercourse, and prevent the loss of stream bank vegetation and crops, reduce sediment loads to river streams, and control unwanted meander of a river.

Creation of subsurface dykes to prevent damage of dams: Subsurface dykes are a barrier impermeable to water that is placed underground to control the groundwater flow in an aquifer, and to raise the water table. This helps prevent siltation and loss of reservoir capacity and it is very helpful to prevent damage of dams due to soil mining and erosion.

Enforcing the ground water regulation acts to prevent seawater intrusion: The increased demographic and economic pressure on coastal areas has raised the demand for freshwater, causing over extraction in many areas of Tamil Nadu. One key to controlling saltwater intrusion is to maintain the proper balance between water being pumped from an aquifer and the amount of water recharging it. This would mean constant monitoring of the salt-water interface through groundwater regulation acts. (UN Environment – DHI, CTCN, UNEP DTU, 2017)

Description of suggested technology options to address CCA in the water and in the agriculture sector

Modernization of Irrigation system using Drip, Sprinklers systems: Drip irrigation is based on the constant application of a specific and focused quantity of water to soil crops. The system uses pipes, valves and small drippers or emitters transporting water from the sources (i.e. wells, tanks and or reservoirs) to the root area and applying it under particular quantity and pressure specifications. Managing the exact (or almost) moisture requirement for each plant, the system significantly reduces water wastage and promotes efficient use (UN Environment – DHI, CTCN, UNEP DTU, 2017).

Capacity building for farmers on agronomical practices (dryland agriculture and collective farming): These are agronomical practices that increase capacities and therefore climate resilience of farmers during drought. Dryland Agriculture refers to cultivation of crops entirely under natural rainfall without irrigation. Collective farming and communal farming are various types of "agricultural production in which multiple farmers run their holdings as a joint enterprise." That type of collective is often an agricultural cooperative in which member-owners jointly engage in farming activities.

Recycled waste/ sewerage water treatment for agriculture: Recycled water is wastewater that has been treated such that it is suitable for specific agricultural applications. It is typically used for pasture, crop or fodder irrigation. One of the most recognized benefits of wastewater use in agriculture is the associated decrease in pressure on freshwater sources. Thus, wastewater serves as an alternative irrigation source (Jaramillo and Restrepo, 2017). The prevention of water pollution would be another benefit associated with wastewater reuse in agriculture.

Alternate cropping system: short duration, less water intensive pulses, millets etc.: Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities (UN Environment – DHI, CTCN, UNEP DTU, 2017) .

Basin level DSS and early warning system for farmers with seasonal forecasting of droughts and selection of crops: An early warning system and DSS based on the rainfall being received to the basin can help provide advisory services to basin communities on what to farm, whether to go for water intensive crops or less water usage crops. Can help cope with extreme climate events at all levels of the basin and also through preventing livelihood losses

Basin level EWS and DSS for Correct operation of reservoirs to address flood: Flood EWS and DSS are specialized forecasting and early-warning systems for floods. Real-time meteorological data from remote sensing satellite radar tracking rainfall in the region and hydrological models based on local climatic and geographic conditions. Include models to predict soil moisture capacity and threshold runoff (runoff or water level needed to initiate flooding) of local streams and rivers in relation to precipitation forecasts. This also allows for making appropriate decisions regarding dam/ reservoir opening.

Drought-resistant crop varieties (biotechnology): While monocropping, the practice of only growing one crop variety year after year, leaves producers more vulnerable to pests/ climate vulnerabilities that target a specific plant variety, intercropping, by providing additional plant varieties, can help slow the proliferation of pests and climate vulnerabilities and protect yields (Pauley, 2017).

Construction of Bed dams to divert lean stream flow into off take channels to supply water to irrigation tanks: This is a measure that helps move water from rivers and running water bodies during dry season through bed dam channels for pushing water into irrigation tanks. The water in irrigation tanks can help increase ecosystem and livelihood resilience.

Rejuvenation through De-siltation and deepening of existing water structures (irrigation tanks): Irrigation tanks are a system of diverting the river water through dug out earthen channels into a series of cascading tanks designed to allow the excess water to flow out after it has reached its capacity, to care of the irrigation needs of neighbouring villages was devised to utilize the water to the fullest before it reached the sea. Further desilted soil from these tanks is high in minerals and nutrients and maybe used to fertilize the command area under the tank. This will also help in rejuvenation of the tanks by increasing their water holding capacity.

4.1 Criteria for Deriving Short List of Technologies

There is a broad variety of available CCA technologies for the water and agriculture sector in Tamil Nadu, some of them are already in place whereas others are good practices from different states or countries that could be beneficial for Tamil Nadu, too. However, the individual technologies can vary largely in the extent to which they are appropriate for addressing specific factors of vulnerability. Therefore the purpose of this TNA study is to systematically assess the identified technologies and finally assist decision-makers in the appraisal and prioritization of CCA technologies. The approach used for this TNA is based on a Multi Criteria Analysis (MCA) that reflects the variety of aspects that need to be considered for the selection of CCA technologies. Conducting an MCA entails a thorough assessment of the technologies vulnerability under different viewpoints, resulting in individual matrices for each factor of vulnerability. The assessment of pre-selected technologies was based on their contribution to sustainable development goals and to adaptation in light of climate change impact scenarios for the state. The criteria on which the assessments were based were decided involving a wider group of stakeholders and assessing National Water Mission, State Specific Action Plans on Water and other strategies from the water sector. The following criteria have been identified to be applied for prioritization of adaptive technologies

Table 6: Criteria for the short-listing of adaptation technologies in the water / agricultural sector

Criteria category	Code	Criterion	Scoring Range
Climate Benefits	A1	Efficiency of the technology to reduce vulnerability to climate change impacts. E.g. strengthening current standards of living so that in the face of adversity, households may be able to cope with the climate shock	0: very low → 10: very high
	A2	Reduction in GHG emissions, e.g. through usage of renewable energies or an energy efficiency measure	0: very low → 10: very high
Social Benefits	B1	Addresses needs for essential water requirements for human health and hygiene leading to reduced morbidity/mortality (safe clean water for drinking, water for adequate sanitation and adequate hygiene)	0: very low → 10: very high
	B2	Technology should aim to reduce inequity between social classes, gender, ethnic groups etc. and ensuring equitable water distribution	0: very low → 10: very high
	B3	Contribution to social and sustainable development (benefit to society e.g. gender sensitive, poverty alleviation, increasing food and water security)	0: very low → 10: very high
Institutional Benefits	C1	Ease of implementation, e.g. can be included in existing government programme or funding scheme including degree of coherence with Integrated Watershed Management Project, MGNREGS, PMKSY, Participatory Irrigation Management (PIM) Act	0: very low → 10: very high
	C2	Single Identified Agency for management-Convergence or viable mechanisms for coordination among various State agencies/ departments/ULBs and other stakeholders	0: very low → 10: very high
	C3	Coherence with national development policies and priority (e.g. Promotion of citizen and state actions for water conservation, augmentation and Preservation; Sensitization, inclusion of Panchayati Raj Institutions, Urban Local Bodies, Water Users Associations)	0: very low → 10: very high
Environmental Benefits	D1	Contribution of the technology to protect and sustain aquatic ecology. Protecting the diversity of the rivers and ponds where water technology adaptation takes place.	0: very low → 10: very high
	D2	Recycling /Reuse of water and/or substitute to domestic water supply	0: very low → 10: very high

Economic Benefits	E1	Involve and encourage corporate sector / industries to take up, support and promote technology as part of CSR to ensure the financial sustainability of the technology and its use.	0: very low → 10: very high
	E2	Improving economic performance in that sector through increased productivity etc. farmer income and ability to reinvest	0: very low → 10: very high
Technological Benefits	F1	Local experience exists, technology can be operated by local operators without needing external support, does not conflict with existing processes, easier technology diffusion and farmer acceptance.	0: very low → 10: very high
	F2	Technology helps in increasing beneficial output per unit of water i.e. looking at engineering and agronomic aspects in conjunction, increasing water use efficiency	0: very low → 10: very high
Cost	G1	Low cost of set-up including the costs of importation and installation.	0: very low → 10: very high
	G2	Low cost for maintenance/ operation and other running costs of the technology over time.	0: very low → 10: very high

Source: adelphi/DevAlt (2018) based on Traerup and Bakkegaard (2015)

Each technology was scored on the given criteria. Additionally, the weighting of the criteria was done through extended stakeholder consultation while keeping in context of the scoring of each technology on the criteria. The weights for each of the criterion were given as follows:

Table 7: State-specific weightage of criteria

Criterion Code	Criterion	Weightage[%]
1	Climate Benefits: Potential contribution to reduction of vulnerability to climate change and reduction in GHG emissions	**15**
2	Social Benefits: Contribution to social development priorities	**25**
3	Institutional Benefits: Implementation availability through national and state level coherence	**5**
4	Environmental Benefits: Contribution to environmental conservation priorities	**15**
5	Economic Benefits: Potential of leveraging funds from private sources as well as improving incomes	**10**
6	Technological Benefits: Potential for higher acceptability of technology	**15**
7	Cost: Potential benefits through lower costs of operation and maintenance	**15**
Total		**100%**

The technologies were scored for each criterion on a scale of 0-10. These scores were multiplied by their weightage and a final sum of the score was obtained. The top three of these from each sector were shortlisted.

4.2 Application of Criteria for deriving a short list of CCA technology options

Table 8: Multi criteria matrix for identified CCA technologies

Code	Climate Benefits		Social Benefits			Institutional Benefits			Environmental		Economic		Technological		Cost		Total scores	Total Weighted Score
Criteria Weight (total 100 %)	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	E1	E2	F1	F2	G1	G2		
	15.00%		25.00%			5.00%			15.00%		15.00%		10.00%		15.00%			
Water Sector																		
W1	7	5	7	7	7	7	6	6	6	7	6	3	5	8	4	3	5.9	5.9
W2	7	3	9	7	8	6	7	7	7	8	5	4	6	7	6	6	6.4	6.5
W3	9	6	8	8	8	7	7	7	6	5	5	9	8	9	6	6	7.1	7.1
W4	9	1	7	7	7	9	7	9	4	7	4	7	10	7	5	5	6.6	6.2
W5	10	2	7	8	7	7	6	6	6	5	4	7	7	6	5	6	6.2	6.1
W6	8	2	7	7	7	8	8	8	7	2	4	7	7	6	5	7	6.3	5.9
W7	10	4	8	7	7	8	7	8	8	6	5	7	9	7	6	6	7.1	7.0
W8	7	0	6	6	7	7	6	7	8	5	3	6	7	6	4	6	5.7	5.6
W9	6	2	6	7	6	7	7	7	7	6	4	7	7	7	5	4	5.9	5.8
W10	8	1	8	8	8	8	9	8	5	5	7	2	6	3	2	2	5.6	5.1
Water in Agriculture Sector																		
WA1	8	7	6	5	6	7	7	7	7	7	8	6	9	10	4	4	6.6	6.7
WA2	8	7	6	7	8	10	9	9	6	5	6	7	8	7	6	7	7.3	6.9
WA3	7	3	9	6	5	6	6	6	7	10	4	7	5	7	4	5	6.1	6.1
WA4	7	6	7	5	7	8	8	8	8	3	4	9	8	7	6	6	6.7	6.4

WA5	8	3	8	8	8	8	6	7	7	6	6	7	7	8	7	7	6.9	6.8
WA6	8	3	8	8	8	7	8	7	8	6	6	8	6	7	5	5	6.8	6.5
WA7	8	6	8	5	7	8	8	8	7	3	4	9	7	8	5	6	6.7	6.4
WA8	7	0	7	6	7	7	6	7	8	5	4	7	7	6	4	6	5.9	5.6
WA9	9	3	8	8	7	8	8	8	8	6	4	9	9	6	5	5	6.9	6.7

Source: adelphi/DevAlt (2018), based on Traerup and Bakkegaard (2015)

4.3 Discussion of results

The technology needs assessment for climate change adaptation was basically conducted though a participatory process with State Department officials. The assessment involved had two main steps; participatory development of a technology list and secondly prioritization of adaptation technology. The key approach used in the technology selection and prioritization process included literature review, stakeholder consultation, application of the multi-criteria, scoring and expert judgement.

The technology selection which aims to scope or screen vulnerable factors was carried out through review of the climate change vulnerability, impact status and trends in water and agriculture sector. The workshop followed the steps and methodologies for technology prioritization, as suggested in the TNA handbook (UNDP and UNFCCC, 2010) and Traerup and Bakkegaard (2015) and thus involved the use of criteria and scoring and decision on the priority technologies through stakeholders consultation.

As seen from the scoring table above the three technologies that score highest for the water sector and for water and agriculture respectively, are chosen as priority technology needs for climate change adaptation. Three technologies each for water and agriculture sector were prioritized and therefore, summarized as follows:

Table 9: List of prioritised technologies

Technology	Code	Total Cumulative scores (out of 10)	Total Weighted Score (out of 10)
Shortlist of Technologies for Water Sector:			
Construction of reservoirs intercepting Rivers and interlinking for transfer of water from Surplus Basin to Deficit Basin: inland water diversion	W3	7.1	7.1
Fortified / densification of network of irrigation tanks to avoid saltwater intrusion	W7	7.1	7.0
Subsurface water solutions/ constructed wetlands for drinking water	W2	6.4	6.5
Shortlist of Technologies for Water in Agriculture Sector:			
Capacity building for farmers on agronomical practices (dryland agriculture and collective farming)	WA2	7.3	6.9
Basin level DSS and early warning system for farmers with seasonal forecasting of droughts and selection of crops	WA5	6.9	6.8
Rejuvenation through De-siltation and deepening of existing water structures (irrigation tanks)	WA9	6.9	6.7

4.4 Prioritised technologies

In this section the individual scoring for the best technological solutions which have the highest score is justified with a description

4.4.1. Prioritised technologies for Water Sector

Option 1: W3: Construction of reservoirs intercepting Rivers and interlinking for transfer of water from Surplus Basin to Deficit Basin: inland water diversion

Technology	Construction of reservoirs intercepting Rivers and interlinking for transfer of water from Surplus Basin to Deficit Basin: inland water diversion	
Sector	Water	
Subsector	Water Augmentation	
Technology characteristics		
Introduction	Inter-basin transfer is the moving of water from a watershed with a surplus (donor basin) to a watershed suffering from a shortage (recipient basin). The water is transferred primarily to alleviate water scarcity in the recipient basin and travels long distances via complex pipeline and canal systems. It supports groundwater recharge in the receiving watershed basin and alleviates negative ecosystem impacts associated with critical water shortage. It is a grey infrastructure approach that focuses on developing carriers along the edges of the river. This allows the flooding river water to eventually connecting areas where there is low chance of flooding; further augment the aquifer through developing groundwater recharge structures at the ends of the flood carriers	
Climate related criteria		**Score**
A1: CCA Efficiency	Primarily alleviates water scarcity in the recipient basin and water travels long distances via complex pipeline and canal systems. Increases resilience through improving standards of living.	9
A2: GHG reduction	There isn't much contribution to GHG emission reduction; it may however require pumps to transfer water between basins.	6
Social criteria		
B1: Health	Increases water supply in the recipient basin to help address drinking water demands, also address equitable distribution of water among basins. Therefore helps reduce mortality/ morbidity due to unavailability of drinking water.	8
B2: Inequity	Allows for equitable distribution of water in a district/ state	8
B3: sustainable development	Provides social/ sustainable development benefits through addressing poverty alleviation, increasing food and water security	8
Institutional Benefits		
C1: refers to existing plans	Inland water diversion exists as part of the river linking programme. This is a major national and state level programme.	7
C2: clear responsibility	While the ministry of water resources and state level departments are the lead agency for this technology implementation it will	7

	require assistance of other departments and ministries such as Forests, Rural Development	
C3: coherent with policies	It is inclusive and aligns with national and state level developmental policies.	7
Environmental Benefits		
D1: Ecology / biodiversity	Watershed removal changes river dynamics and can negatively affect ecosystem balance, including water quality and flora and fauna when water being transferred is not flooding level. Supports groundwater recharge in the receiving watershed and alleviates negative ecosystem impacts associated with critical water shortage.	6
D2: Recycle, Reuse, Substitute	There isn't much scope for recycling or reuse of water; however it provides usage of excess flooding water.	5
Economic Benefits		
E1: private sector participation	Involvement of private investment hasn't been seen yet in developing such floor carriers, but can be leveraged	5
E2: productivity	Helps improve farmer incomes due to improved irrigation in recipient basin	9
Technological Benefits		
F1: experience and acceptance	High level of considerations are required before implementing the technology, there is expertise required	8
F2: water efficiency	Increases beneficial output per unit of water, improves the economic efficiency of resource use	9
Cost		
G1: investment	Implementation costs are very high (building of pipes or canals to divert water). It is also very time consuming	6
G2: O&M	Pipes and other equipment should be regularly checked, and repaired when necessary, to minimize potential transfer water loss and ensure maximum efficiency of resource use.	6

Option 2: W7: Fortified / densification of network of irrigation tanks to avoid saltwater intrusion

Technology	Fortified / densification of network of irrigation tanks to avoid saltwater intrusion	
Sector	Water	
Subsector	Coastal Zones	
Technology characteristics		
Introduction	Irrigation tanks allow for diverting the river water through dug out earthen channels through a connective system. Due to its presence along the coastal region it helps in preventing saltwater intrusion as it contains freshwater. It can control sea water intrusion by using recharge well barriers through a line of injection tubewells/ existing irrigation tanks with recharge tubes driven parallel to the coast.	
Climate related criteria		**Score**
A1: CCA Efficiency	Helps reduce exposure due to increased sea water intrusion, increases resilience of coastal communities	10
A2: GHG reduction	There is no additional GHG emissions, does not reduce emissions as well, however increased irrigation tanks do reduce energy costs from groundwater pumping	4
Social criteria		
B1: Health	Improved and sustained access to freshwater of adequate quality for domestic purposes leading improved health and safety	8
B2: Inequity	Helps address water equitable distribution for all classes of communities but requires community sensitization	7
B3: sustainable development	With less salt water intrusion increase in agriculture can help address poverty alleviation and water insecurity.	7
Institutional Benefits		
C1: refers to existing plans	Requires high level coordination between departments, such as CMWSSB, GWB, TWAD, RD&PR	8
C2: clear responsibility	While there is improved coordination between ground and surface water data, there is scope for higher coordination among departments for coastal management.	7
C3: coherent with policies	This action finds coherence in TN SAPCC as repairing, renovating and restoring existing tanks is a very high priority in the coastal region	8
Environmental Benefits		
D1: Ecology / biodiversity	Maintains freshwater coastal aquifer and further prevents sea water intrusion thereby protecting local freshwater ecosystems.	8
D2: Recycle, Reuse, Substitute	It does not add to much of recycling water or substitute domestic water supply	6

Economic Benefits		
E1: private sector participation	There hasn't been much private sector investment in this sector	5
E2: productivity	Helps improve farmer incomes due to improved agriculture in coastal regions	7
Technological Benefits		
F1: experience and acceptance	Practitioners may understand the technology, communities require awareness and sensitization as benefits are not directly felt	9
F2: water efficiency	It helps in increasing cleaner and safer water, increasing available water use efficiency	7
Cost		
G1: investment	While some irrigation tanks are already built across the coastal region, there is a need for fortification/ densification of these tanks and this may involve high costs.	6
G2: O&M	There are maintenance costs in terms of desilting the tanks to maintain its fresh water holding capacity.	6

Option 3: W2: Sub-surface water solutions for drinking water

Technology	Sub-surface water solutions for drinking water	
Sector	Water	
Subsector	Coastal Zones	
Technology characteristics		
Introduction	Skimming well/subsurface water technologies is any technique employed with an intention to extract relatively freshwater from the upper zone of the fresh-saline aquifer (Rao et. al, 2006) The technologies also involved usage of multiple partially penetrating wells to enable deep injection and shallow recovery of freshwater.	
Climate related criteria		**Score**
A1: CCA Efficiency	Helps reduce sensitivity due to increased sea water intrusion, also provides an alternative drinking water source thereby increasing resilience	7
A2: GHG reduction	Does not contribute to GHG emissions reduction; does not add to GHG emissions	3
Social criteria		
B1: Health	Improved and sustained access to freshwater of adequate quality for domestic purposes leading improved health and safety	9
B2: Inequity	Lack of alternative sources of freshwater in periods with low abstractions may lead issues of equitable water distribution	7
B3: sustainable development	Sustainable abstraction of freshwater thus securing livelihoods for local communities therefore addressing poverty alleviation, water insecurity	8
Institutional Benefits		
C1: refers to existing plans	Requires high level coordination between departments such as CMWSSB, GWB, TWAD, RD&PR	6
C2: clear responsibility	While there is improved coordination between ground and surface water data, there is scope for higher coordination among departments for coastal management.	7
C3: coherent with policies	This does allow promotion of citizen and state actions for water conservation, augmentation and preservation. But it does not feature much in state or national level plans.	7
Environmental Benefits		
D1: Ecology / biodiversity	Maintains freshwater coastal aquifer	7
D2: Recycle, Reuse, Substitute	It allows for improved recycling /reuse of water through usage of seawater. This even allows for substitution to domestic piped water supply	8
Economic Benefits		

E1: private sector participation	There is few pockets of private investment but not yet seen on a large scale.	5
E2: productivity	Helps improve farmer incomes due to improved agriculture in coastal regions; also reduces costs of drinking water	4
Technological Benefits		
F1: experience and acceptance	The technology is not yet mature in India, requires high level of technical expertise to implement	6
F2: water efficiency	Increases the water output per unit and water efficiency by helping obtain freshwater from saline water	7
Cost		
G1: investment	Operational costs of hydraulic barriers is considerable	6
G2: O&M	Requires constant monitoring of data levels including but not limited to geo-hydrological model monitoring, storage aquifer capacity	6

4.4.2. Prioritised technologies for Water in Agriculture Sector

Option 1: WA 2: Capacity building for farmers on agronomical practices (dryland agriculture and collective farming)

Technology	Capacity building for farmers on agronomical practices	
Sector	Agriculture	
Subsector	Crop Loss and Failure	
Technology characteristics		
Introduction	Dryland Agriculture refers to cultivation of crops entirely under natural rainfall without irrigation. Collective farming and communal farming are various types of "agricultural production in which multiple farmers run their holdings as a joint enterprise. " Agronomical practices that increase capacities and therefore climate resilience of farmers during drought.	
Climate related criteria		**Score**
A1: CCA Efficiency	Agronomical practices help increase adaptive capacity as they make communities less vulnerable to climate variability. In dryland agriculture, dry spell during crop duration occurs, but crop failures are less frequent. This reduces economic losses of farmers thereby providing livelihood security.	8
A2: GHG reduction	There is no direct GHG mitigation benefit, may provide some benefit if communities decide to share tractors, pumps etc.	7
Social criteria		
B1: Health	It improves health parameters by using less water for irrigation and leaving for water for other domestic needs. Collective farming my help in reducing net losses to communities.	6
B2: Inequity	Help addresses food security, and equitable distribution of resources among all levels of farmers through collective approach	7
B3: sustainable development	It can help address food security through reduction of crop failures.	8
Institutional Benefits		
C1: refers to existing plans	Is strongly supported through the Mission on Sustainable Dryland Agriculture as well as a scheme dedicated to collective farming	10
C2: clear responsibility	It is mostly under the purview of the department of Agriculture, it may also involve agriculture engineering department	9
C3: coherent with policies	Is strongly supported through the Mission on Sustainable Dryland Agriculture as well as a state level policy dedicated to collective farming	9

Environmental Benefits		
D1: Ecology / biodiversity	Helps increase usage of organic fertilizer from manure, reducing need for chemical fertilizers, improved fertility/organic content in soils	6
D2: Recycle, Reuse, Substitute	Dryland agriculture focuses on less use of water, this allows for more water availability for other purposes	5
Economic Benefits		
E1: private sector participation	Private sector investment can be considered, but it is not very apparent.	6
E2: productivity	Helps improve farmer incomes due to access to better resources and finance through collective approach	7
Technological Benefits		
F1: experience and acceptance	While pockets of practices are available large scale capacity building needs is required	8
F2: water efficiency	It is an agriculture practice and may not directly improve water efficiency however it reduces usage through alternate farming methods.	7
Cost		
G1: investment	While to develop uptake of these technologies setting up would require proper financial availability to purchase inputs; and extension education. Also development may require low cost and locally suited agricultural implements	6
G2: O&M	Maintenance cost depends on the quality of training imparted, it is also further related to continuous extension education	7

Option 2: WA 5: Basin level DSS and early warning system for farmers with seasonal forecasting of droughts and selection of crops

Technology	Basin level DSS and early warning system for farmers with seasonal forecasting of droughts and selection of crops	
Sector	Agriculture	
Subsector	Crop Loss and Failure	
Technology characteristics		
Introduction	An early warning system and DSS based on the amount of rainfall being received to the basin can help provide advisory services to basin communities on what to farm, whether to go for selection of water intensive crops or less water usage crops. Can help cope with extreme climate events at all levels of the basin and also through preventing livelihood losses	
Climate related criteria		**Score**
A1: CCA Efficiency	Early warning systems help in reducing exposure to extreme climate events. Basin level monitoring and EWS can help cope with extreme climate events at all levels of the basin (plain as well as hilly)	8
A2: GHG reduction	Does not add to or reduce GHG emissions	3
Social criteria		
B1: Health	Mitigates human fatalities, health risks and poor water and food security.	8
B2: Inequity	Does not directly reduces inequality as less loss of crops help improve living standards of all classes of farmers. Protects small holding farmers from large losses.	8
B3: sustainable development	Helps prevents agricultural losses from irrigation failures therefore help addressing livelihoods and sustainable development	8
Institutional Benefits		
C1: refers to existing plans	Mapping has already been done for Vaippar basin, could be upscaled under the Hydrology Project-II (World Bank)	8
C2: clear responsibility	Requires high level coordination/ data sharing between departments	6
C3: coherent with policies	Establishing high resolution weather monitoring is one of the strategies in the TN SAPCC, early warning systems also find place in the Disaster Management Plans	7
Environmental Benefits		
D1: Ecology / biodiversity	Improves land use practices by providing advisory on selection of crops, which can help decrease soil and land degradation.	7

D2: Recycle, Reuse, Substitute	Does not directly help in water reuse/ recycle	6
Economic Benefits		
E1: private sector participation	Private sector investment can be considered through software and technology expertise	6
E2: productivity	Helps improve farmer incomes through early preparedness, response and recovery	7
Technological Benefits		
F1: experience and acceptance	Is being implemented in one basin of Tamil Nadu but not very effectively, is not a very mature technology	7
F2: water efficiency	Increases water use efficiency by helping farmers decide which crop to farm avoiding water guzzling crops during drought season.	8
Cost		
G1: investment	There is a lack of long-term datasets, costs involved in assessment/ study of the basin which is will be the main operational costs	7
G2: O&M	Maintenance will be advisory services and monitoring of rainfall data.	7

Option 3: WA 9: Rejuvenation through De-siltation and deepening of existing water structures (irrigation tanks)

Technology	Rejuvenation through De-siltation and deepening of existing water structures (irrigation tanks)	
Sector	Agriculture	
Subsector	Water Augmentation; Soil Improvement	
Technology characteristics		
Introduction	Irrigation tanks are a system of diverting the river water through dug out earthen channels into a series of cascading tanks designed to allow the excess water to flow out after it has reached its capacity, to care of the irrigation needs of neighbouring villages was devised to utilize the water to the fullest before it reached the sea. Further desilted soil from these tanks is high in minerals and nutrients and maybe used to fertilize the command area under the tank. This will also help in rejuvenation of the tanks by increasing their water holding capacity.	
Climate related criteria		**Score**
A1: CCA Efficiency	Augments water storage, recharges aquifers for the dry season, increases climate resilience bridging seasonal (or unexpected) water shortages and stress	9
A2: GHG reduction	Does not directly contribute to GHG emissions except through reduced fertilizer use in the command area of the irrigation tank	3
Social criteria		
B1: Health	Provides water for community that can also help address water needs for adequate sanitation and adequate hygiene	8
B2: Inequity	Increases water supply for irrigation through an equitable distribution of the entire catchment area of the irrigation tank	8
B3: sustainable development	Contributes to social and sustainable development through supporting livelihoods and further addressing poverty alleviation	7
Institutional Benefits		
C1: refers to existing plans	Is supported through Irrigated Agriculture Modernisation and Water Bodies Restoration and Management project (IAMWRM)	8
C2: clear responsibility	These are divided into two departments mainly Public Works Department (30 %) and RD& PR department (70%). Requires coordination between them and irrigation department	8
C3: coherent with policies	This action finds coherence in TN SAPCC as repairing, renovating and restoring existing tanks is a very high priority in the state. Currently a new policy on using minerals has also promoted using silt in agricultural fields.	8

Environmental Benefits		
D1: Ecology / biodiversity	While it helps the local ecosystem flourish there is always a risk of vector borne diseases	8
D2: Recycle, Reuse, Substitute	Does not directly promote re-use and recycle of water, does help in the form of harvesting rainwater for later re use	6
Economic Benefits		
E1: private sector participation	Private sector investment might be difficult to obtain in rejuvenation of these tanks	4
E2: productivity	Helps improve farmer incomes due to improved irrigation; silt from tanks could help as soil fertilizer and reduce overall costs of farmers	9
Technological Benefits		
F1: experience and acceptance	Irrigation from tanks has been practiced since ages in Tamil Nadu, however still requires sensitization for uptake as it is no longer looked after	9
F2: water efficiency	Improves water efficiency through preventing groundwater usage and focus on irrigation tanks	6
Cost		
G1: investment	Desiltation and deepening of irrigation tanks is high cost, as these are on an average one km square wide and silt is more than 6 feet	5
G2: O&M	Once desilted maintenance can be done by communities if they take ownership. Requires awareness and sensitization.	5

5 Case study for Tamil Nadu: Rejuvenation of irrigation tanks

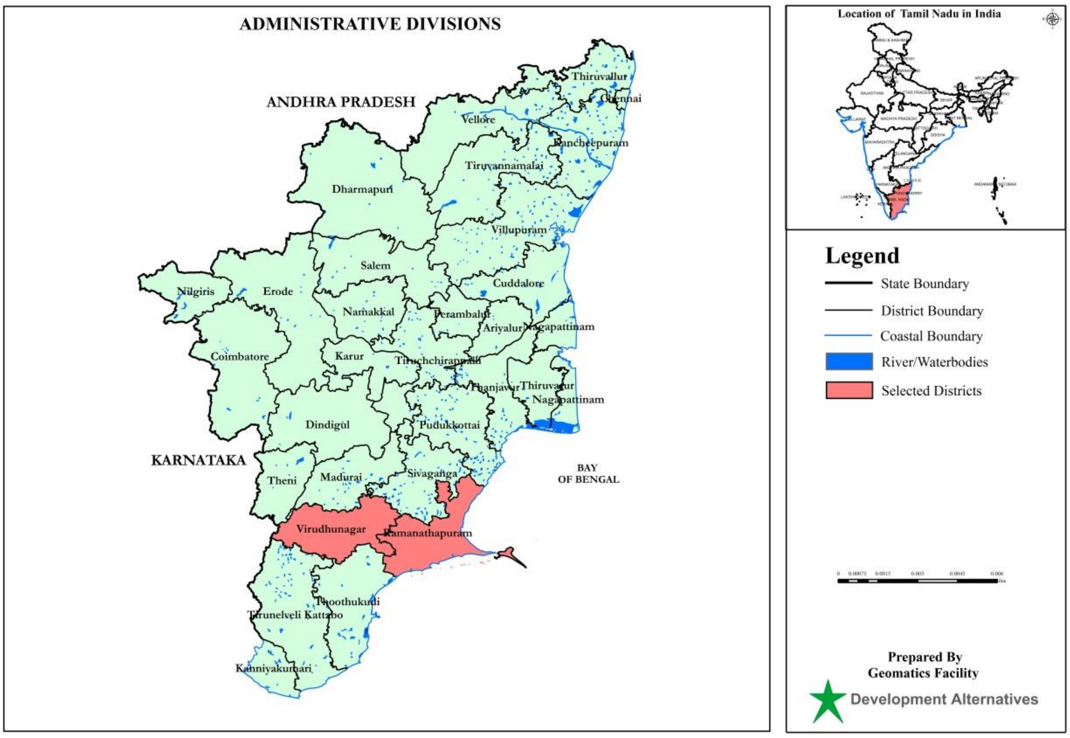

Figure 8: Ramanthapuram and Virudhunagar Districts
Source: Development Alternatives

Tamil Nadu covers an area of 130,058 sq. km, and is the eleventh-largest state in India by area and the sixth-most populous. The state was ranked sixth among states in India according to the Human Development Index in 2011, with the second-largest state economy after Maharashtra. Tamil Nadu is mostly dependent on monsoon rains, and thereby is prone to droughts when the monsoons fail. The climate of the state ranges from dry sub-humid to semi-arid.

As per the Composite Vulnerability Index (CVI) done by GIZ / INRM (2017) based on 63 indicators from social, economic, climate extremes, water resources and agriculture sectors Ramanathapuram and Virudhunagar districts fall under the very high vulnerability category. This is partly due to the very high social and economic sector vulnerability in addition to the already existing high water resource vulnerability.

Tanks are part of an ancient tradition of harvesting and preserving the local rainfall and water from streams and rivers for later use, primarily for agriculture and drinking water for communities and livestock, fish culture, recharge of ground water, control of floods etc (Gurunathan, 2006). The traditional tanks are manmade; it was built across the rivers or else to slope of the land area. Tanks have been surveyed by the Tank Restoration Scheme to fix permanent standards regarding area to be irrigated. Post this tanks are classified into Panchayat Union (PU) and Public Works Department (PWD). Panchayat tanks have a command area less than 40 ha, and the control is with the village communities. PWD having a command area of more than 40 ha and all the system tanks are maintained by PWD. This also divides the maintenance between two departments: PWD, RD&PR dept. (Gandhiraj, 2007).

The total number of irrigation tanks in India is estimated to be around 2,08,000. While around 39,366 tanks are present in Tamil Nadu. The important source of tank irrigation has been constantly decline due to other mode of irrigation, shortage of rainfall, loss of farmer interest, financial problem etc., and the traditional water management of tank irrigation largely disappeared due to modern technologies. Now the tank irrigation system is critical condition. Because farmers are more concerned about Ground water (Gandhiraj, 2007).

Tamil Nadu is a water deficit state. The state's ultimate irrigation potential is low. Traditional water harvesting structures such as tanks have become virtually defunct in Tamil Nadu. (Gandhiraj, 2007). The share of tank-irrigated area in net irrigated area (NIA) between 1990-91 and 2000-01 declined by 29.4%; and among the states, the highest decline was observed in Tamil Nadu (34%) (Palanisami, 2010). The surface water sources have been exploited to this potential and there is very little scope for further development of major and medium schemes. The impact of climate change is likely to be higher in rainfed regions, where tanks are often the major source of water storage and groundwater recharge. Hence it is important to address how best tanks could be restored so that they could act as better water storage structures.

There are several suggestions for improving tank irrigation systems, including both technological and management interventions:

- Rejuvenation of irrigation tanks through desiltation
- Building of artificial wells for aquifer storage and recovery

Rejuvenation of irrigation tanks through desiltation: Siltation happens because of people's activities. The problem is that the community is not aware about the proper use of tanks. When people cut down trees in forests, or in rain fed areas, roots of the trees cannot hold the soil, leading to soil erosion in forests, arid, or semi-arid areas. From the catchment area, the top soil or sand runs off with water, accumulates in the tank, and forms tank silt. Traditionally, tank silt was transferred from tanks to agricultural fields, but after the Green Revolution, these practices were abandoned in favor of fertilizers, and chemical manures. When tanks are not silted, their water storage capacity decreases. This leads to problems in water distribution and reduced productivity. Desilted soil from these tanks is high in minerals and nutrients and maybe used to fertilize the command area under the tank. This will also help in rejuvenation of the tanks by increasing their water holding capacity.

Building of artificial wells for aquifer storage and recovery: Even when tanks do not supply surface irrigation, they can still contribute to enhanced water storage by converting them into percolation ponds by deepening the storage area and encouraging farmers to invest in private wells in the command area. As such the PU tanks provide more scope for such conversions, as they have less inter-village variability and the number of farmers covered under such tanks is also comparatively less (Palanisami, 2010).

Expected Results:

- Increase aquifer recharge.
- Provide water for irrigation and domestic purpose
- Evaporation loss is reduced during high temperature/ seasons
- Improvement in groundwater quality'

Synergies: The MNREGS can help address nearly 2/3rds of the tanks that are under the RD&PR department. However these are smaller tanks. As part of the IAMWARM (Irrigated Agriculture Modernisation and Water Bodies Restoration and Management) project irrigation tanks were to be rehabilitated. Further under the Tamil Nadu Irrigated Agriculture Modernization Project (IAMP) the plan is to rehabilitate and modernize about 4,800 irrigation tanks. But these initiatives focussed on working on the bund itself rather than the recharging structures.

Project Concept:

Aquifer storage and recharge through recharge wells in the irrigation tanks of 2 districts (Ramanathapuram and Virudhunagar) of Tamil Nadu for building climate resilience

- Construct recharge well in the deepest part of the tank
- Sensitization of communities in order to construct the wells
- Maintenance is through the desilting of the recharge wells only
- Wells that are 5-10 feet deep

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