On behalf of:

REPORT

Technology Needs Assessment (TNA)

For climate change adaptation in Telangana

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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 impacts of climate change in Telangana.

The first TNA consultation was held in August 2018. Water and Agriculture sectors were recommended as priority sectors for adaptation. DA and adelphi and National Climate Change cell Telangana (EPTRI) state were responsible for prioritization of adaptation technologies. All relevant Departments (Agriculture, Irrigation, Rural Development, Groundwater), Agencies, EPTRI, IMD, IITH, and some CSO, NGO representatives were part of the process. Other relevant NGOs to be involved in the process are identified, and are also communicated with, as well as experts working on technology development such as CABI and Vassar Labs also attended the consultation workshop.

A final prioritization list of adaptive technologies was agreed upon as a result of the consultations with stakeholders, this long-list of inventoried technologies of each sector was prepared (22 in total for both water and agriculture sector). Further, based on which a shortlist was developed using Multi Criteria Analysis (MCA) tools using criteria that 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 3 each for both water and agriculture sector.

The results for water sector are namely technologies for:

1) Recharge Shaft for groundwater/ shaft driven technology (Aquifer recharge)
2) Conjunctive, Site specific and integrated planning for holistic approach to ground water and surface management
3) Rooftop rainwater harvesting (both house hold level and community building)

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

1) Water security plans through Water User Associations/ VWSC
2) Water Conveying Technologies: Drip irrigation systems
3) Crop Diversification: Rice to short duration millets/ pulses

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
EPTRI	Environment Protection Training and Research Institute
EWS	Early Warning Systems
GIS	Geographic Information System
IEC	Information Education and Communication materials
IMD	India Meteorological Department
MCA	Multi-criteria analysis
NABARD	National Bank for Agriculture and Rural Development
NAPCC	National Action Plan on Climate Change
NAFCC	National Adaption Fund on Climate Change
NGO	Non-Governmental Organizations
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 Project 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. Following were the steps that followed.

1. Analyse the climate vulnerability of the water sector in Telangana to identify the CCA gaps leading to vulnerabilities, i.e. what makes Telangana 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.
3. Develop 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 helps in order to prioritise them and develop a CCA technology shortlist (MCA approach).

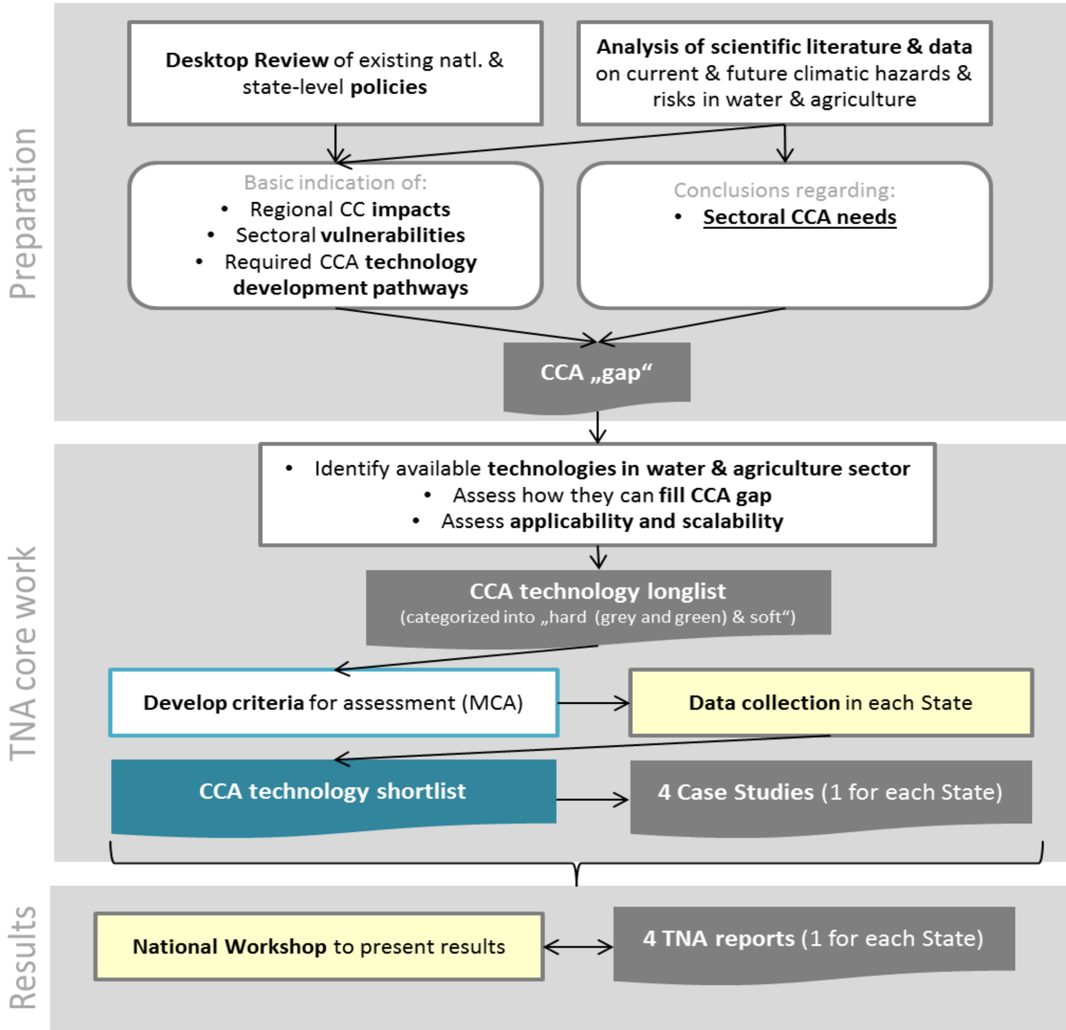


Figure 1: TNA process for this project

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

1.3 Institutional arrangement for the TNA and the stakeholders' involvement in Telangana

The first TNA consultation was held in August 2018. The list of participants is attached to this report (**Annex 1**). DA and adelphi and National Climate Change cell Telangana (EPTRI) state were responsible for prioritization of adaptation technologies.

All relevant Departments (Agriculture, Irrigation, Rural Development, Groundwater), Agencies, EPTRI, IMD, IITH, and some CSO, NGO representatives were part of the process. Other relevant NGOs to be involved in the process are identified, and are also communicated with, as well as experts working on technology development such as CABI and Vassar Labs also attended the consultation workshop. At a later stage the team may involve business sectors interested in getting new technologies and they will be involved in pilot project preparation process.

Identification of development priorities of Telangana 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) tools. The final decision was endorsed by GIZ.

Figure 2: Technology prioritization workshop in Telangana, August 2018
Source: Development Alternatives

2. Vulnerability Assessment of Telangana

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.

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 2011).

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).

Therefore, this study builds on previous vulnerability assessments for the state of Telangana (done by GIZ, INRM) 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 Telangana. 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 Telangana

Geography and Location

Situated in the South of India, Telangana is the 12th largest and 12th-most populous state in India (2011 census). The State was formed in June 2014 carved from Andhra Pradesh State. The total area of the state is 112 sq. km and it has a population of 35.2 million people (2011 census). Telangana is bordered by the states Maharashtra, Karnataka, Andhra Pradesh, Odisha and Chhattisgarh. Located on the Deccan Plateau, Telangana is a semi-arid state.

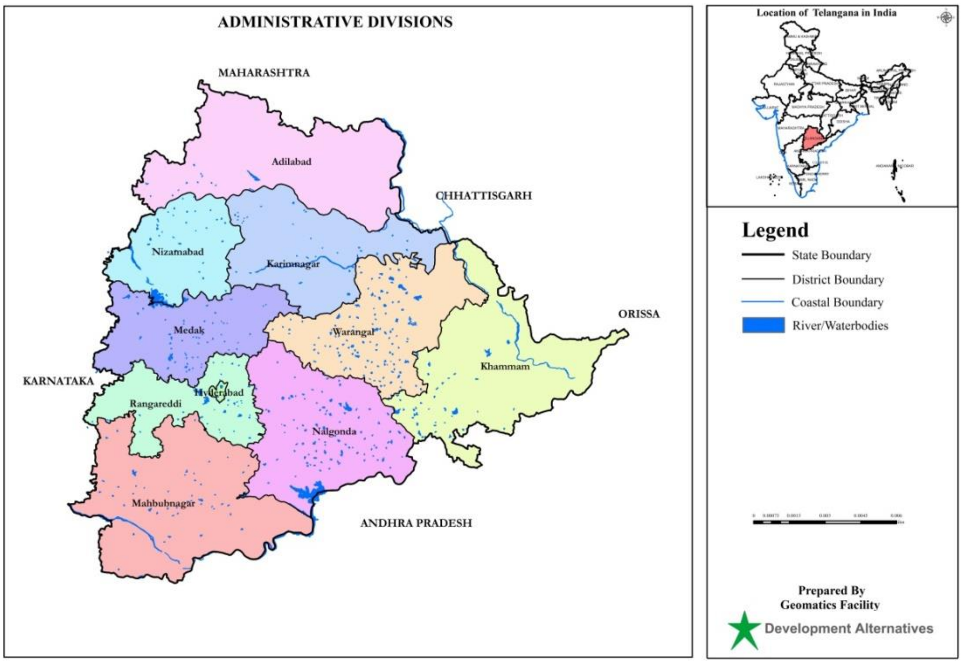
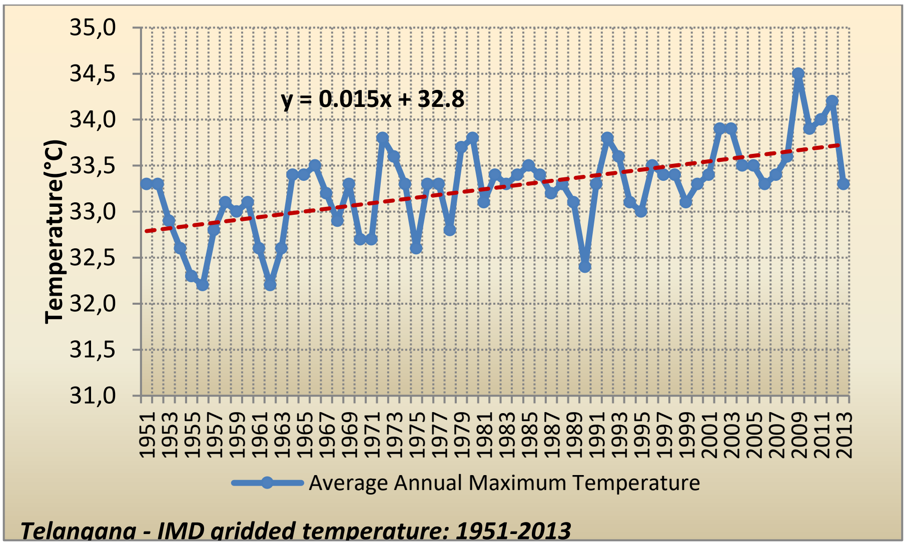


Figure 3: Map of Telangana highlighting surface water resources
Source: Development Alternatives

Climate and Temperature

The state predominantly has hot and dry climate. Nearly three quarters of the State's landscape is covered by basins of the two major rivers Godvari and Krishna and about 69 per cent of Krishna River and 79 per cent of Godavari River catchment area is in Telangana (Telangana SAPCC, 2015).

The State receives rainfall from South-West (June–September) and North–East (October–November) monsoons; however, there is large variation in the distribution of rainfall. The average annual rainfall in the state is about 906 mm, 80% of which is received from the South-West monsoon (June-September). Average annual rainfall of Telangana State is 951.2 mm with a range varying from 563.4 to 1453.2 mm. The south west monsoon (JJAS months) rainfall contributes the maximum to annual rainfall amounting to approximately 80 per cent for Telangana State (Telangana SAPCC, 2015).



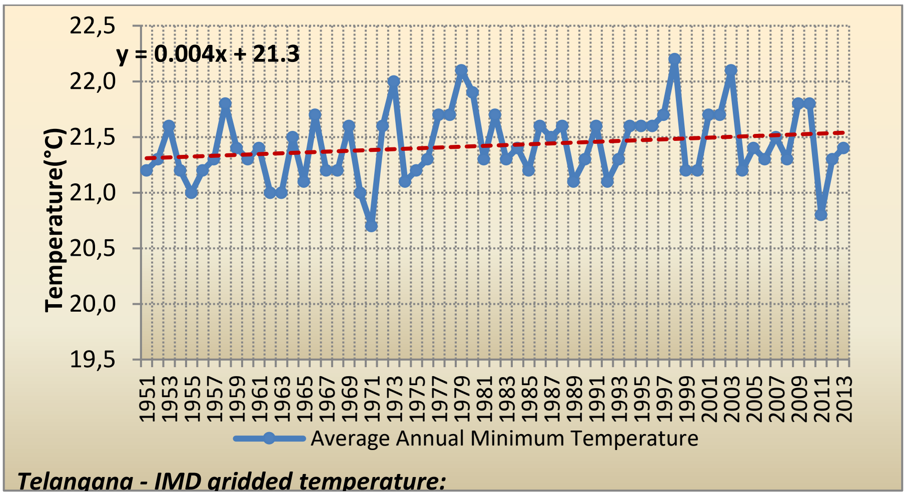


Figure 4: Observed average annual maximum and minimum temperature of Telangana (1951-2013)

Source: GIZ / INRM (2017)

Table 1: Observed Temperature Statistics for Telangana (1951-2013)

Source: GIZ / INRM (2017)

State	Periods	Maximum Temperature			Minimum Temperature		
		Average (°C)	Range (°C)	CV	Average (°C)	Range (°C)	CV
Telangana	Annual	33.3	32.2-34.5	0.014	21.4	20.7-22.2	0.015
	Winter (JF)	31.3	29.5-33.3	0.024	17.1	15.0-18.7	0.048
	Pre Monsoon (MAM)	38.5	36.8-40.2	0.020	24.4	23.2-25.8	0.023
	Monsoon (JJAS)	32.4	30.9-34.2	0.022	23.7	23.0-24.5	0.015
	Post Monsoon (OND)	30.4	28.8-32.3	0.026	18.4	16.3-20.8	0.041

Using IMD gridded daily temperature data from 1951-2013 (63 years) it was found that mean annual maximum temperature for Telangana is 33.3°C with a range varying from 32.2°C – 34.5°C. The highest value attained for maximum temperature (38.5°C) is in the pre monsoon season while its lowest maximum value (30.4°C) is attained in post monsoon season(OND) (GIZ / INRM, 2017).

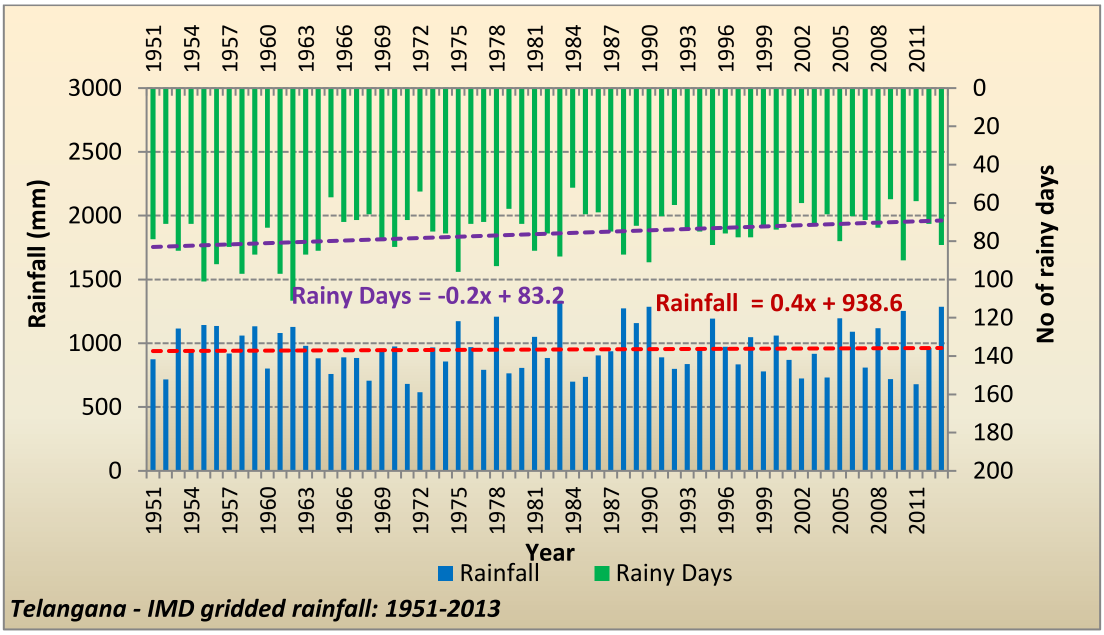


Figure 5: Observed annual rainfall and number of rainy days for Telangana

Source: GIZ / INRM (2017)

In terms of rainfall it was observed that average annual rainfall of Telangana State is 951.2 mm with a range varying from 563.4 mm-1453.2 mm over the 63 years period (1951-2013). Amongst all districts, Khammam receives the maximum average annual rainfall while Mahbubnagar receives the least. It is observed that the average rainfall deceases from north to south (GIZ and INRM, 2017).

Table 2: Observed Rainfall Statistics for Telangana (1951-2013)

Source: GIZ / INRM (2017)

State	Season	Average Rainfall (mm)	Range (mm)	Inter-annual variation	Contribution to Annual Rainfall (%)
Telangana	Annual	951.2	563.4-1453.2	0.22	
	Winter (JF)	12.9	0-79.7	1.41	1.4
	Pre Monsoon (MAM)	57.4	6.7-217.3	0.68	6.0
	Monsoon (JJAS)	758.3	400-1222.5	0.25	79.7
	Post Monsoon (OND)	122.6	5-366.6	0.65	12.9

Projected Climate Change Scenario

A CORDEX South Asia modelled climate data study or Telangana State on precipitation, maximum temperature, minimum temperature and 21 climate extremes indices was conducted by GIZ and INRM (2017). This was done for baseline (BL, 1981-2010), mid-century (MC, 2021-2050) and end-century (EC, 2071-2100). Ensemble mean of 10 RCMs at a spatial resolution of 50kmx50km was used. The CORDEX South Asia simulations with the models indicated an all-round warming over the study area. Projected increase in temperature and precipitation towards end-century was higher than that towards mid-century. Analysis of the projected daily temperature and rainfall under different climate change scenarios shows that:

- Mean annual maximum temperature for RCP4.5 scenario is projected to increase by about 1.4 degrees Celsius by mid-century and by 1.9 degrees Celsius by end-century. For RCP 8.5 scenario it is projected to increase by about 1.5 degrees Celsius by mid-century and 4.1 degrees Celsius by end-century for the State of Telangana.
- Mean annual minimum temperature for RCP4.5 scenario is projected to increase by about 1.4 degrees Celsius by mid-century and by 2.5 degrees Celsius by end-century. For RCP 8.5 scenario it is projected to increase by about 1.7 degrees Celsius by mid-century and 5.2 degrees Celsius by end-century.
- Mean annual rainfall for RCP4.5 scenario is projected to decrease marginally by about 2.2 per cent in mid-century and increase by about 12 per cent towards end-century. For RCP 8.5 scenario rainfall is projected to increase by about 5 per cent towards mid-century and 12 per cent in end- century.

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, including water in Agriculture

Surface water resources

River Godavari in the north and Krishna in the south passes through Telangana. The Godavari Basin is situated between latitude 16°16' N and 22°43' N and longitude 73°26' E and 83°07' E in the Deccan Plateau. The basin is shared with States of Maharashtra, Karnataka, Madhya Pradesh, Chhattisgarh, Andhra Pradesh and Odisha as co riparian States. River Krishna is the second largest East flowing interstate river in peninsular India, draining into the Bay of Bengal. The basin is situated between East longitudes 73°21'00" to 81°09'00" and North latitudes 13°07'00" to 19°25'00" in the Deccan plateau. The basin is shared with States of Maharashtra, Karnataka and Andhra Pradesh as co riparian States. Apart from the major rivers, there are tributaries such as Bhima, Dindi, Kinnerasani, Manjeera, Manair, Penganga, Praanahita, Musi, Taliperu etc.

Ground Water Resources of the State

Groundwater is an important resource for crop irrigation, food production and industrial as well as domestic use for urban and rural area communities. Due to failure in monsoon and economic pressure on groundwater in the region increased fast, this resulted in deeper water levels. Throughout the past history, extremes of droughts and floods could adversely affect security of water supply with population growth have caused havoc on the ground water aquifer systems in these regions. About 75% of irrigation depends on Groundwater.

Climate Impacts in the Water Sector in the State of Telangana

Although the impact of climate change on water resources has not been accurately quantified, various studies (IPCC, 2008; Eisenreich, 2005; EEA, 2007) indicate that the likely impact of climate change on water resources could contribute to further intensification of the extreme events. In the assessment carried out under the CCA RAI, the SWAT hydrological model for various rivers and their tributaries in Telangana has been run using climate scenarios for near (mid-century) and long term (end-century) periods without changing the land use. Under the moderate emission scenario (RCP4.5), for the south west monsoon season (JJAS months), a marginal change in precipitation (of -2 to 6 per cent) is projected towards mid-century. Most of the districts show an increase in surface run off contributing to stream flow indicating increase in intensity of rainfall and decrease in number of rainy days. Decrease in groundwater recharge is likely. A significant decrease in groundwater recharge is likely in the districts of Hyderabad, Nalgonda and Rangareddy. A marginal decrease in evapotranspiration is projected for all districts. Adilabad, Karimnagar and Nizamabad districts are likely to experience a higher increase in precipitation towards end-century, which may reduce the need for additional irrigation during rabi season.

Under the high emission scenario (RCP8.5), for the south west monsoon season, an increase in precipitation of 2 to 10 per cent is projected towards mid-century and end-century respectively. Most of the districts show an increase in surface run off contributing to stream flow; a marginal to significant increase is projected in ground water recharge. A marginal projected increase in evapotranspiration towards mid-century and a significant decrease towards end-century is projected. Flood discharges are projected to be more frequent. Khammam, Mahbubnagar and Nalgonda districts are likely to experience a higher magnitude of floods.

Key Issues as perceived by stakeholders:

- Hail storms have become more often, are affecting horticulture crops.
- Due to loss in vegetation, heavy run-off takes place resulting in wastage of water and soil erosion.
- Increased drought conditions can also severely affect agricultural and pastoral livelihoods and increase vulnerability and risks for farmers, and people depending on such livelihoods.
- Enhanced irrigation water requirement in future in the southern Telangana region and may increase the groundwater exploitation

Agriculture sector in Telangana

About 55.49% of Telangana state's population is dependent on agriculture & allied sectors for their livelihoods. Agriculture in Telangana is dependent is primarily rainfed. The average annual rainfall in the state is about 906 mm, 80 percent of which is received from the South-West monsoon (Agri. Action Plan of Telangana, 2016 -17).Most of the part is red gravelly soils. Also various other soil types, like chalkas, red sandy soils, dubbas, deep red loamy soils, and very deep black cotton soils also exist in Telangana. The major crops grown in Telngana are Rice, Maize Soya bean, Cotton, Chillies and Turmeric. Agriculture & allied activities contribute 15.3 % share in Gross State Value Added at current prices in 2016-17, consist of four sub-sectors viz., crop sector (53%), livestock (42%), forestry & logging (3%) and fishing & aquaculture (2%) in 2016 -17[2].

Climate Impacts in the Agriculture Sector in the State of Telangana

Agriculture is one of the critical areas vulnerable to Climate Change. Climate change in terms of rainfall variability is considered to be the greatest challenge. Both climate variability and change can lead to severe impacts on rainfed farming reducing yields and profitability. The year to year variations in South-West monsoon rainfall are directly affecting the production and productivity of rain-fed crops in Telangana. Moisture stress due to prolonged dry spells or thermal stress due to heat wave conditions also significantly affect the crop productivity when they occur in critical life stages of the crop[3].

Key Issues as perceived by stakeholders:

- Temperature fluctuations affect Rabi crops severely
- Decrease in area under crops on account of insufficient rainfall, particularly in the South-West Monsoon period.
- Dry land areas (parts of Mahabubnagar and Nalgonda) exist in the State, annual rainfall is less than 500 mm in Mahabubnagar whereas in Nalgonda annual rainfall is 560 mm and rain fed farming is not viable.
- Loss in fertility of soil in many areas due to excessive use of fertilizers and pesticides..

2 Source:Socio-economic outlook-2017 of Telangana

3 TSAPCC- http://www.moef.gov.in/sites/default/files/Telangana.pdf

2.2 Relevant Policies, Plans and Programmes

While there are multiple vulnerabilities listed, there are relevant policies, plans and programmes that the Telangana 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 3: Relevant policies and their implication for the TNA

Year	Policy	Water	Agriculture	Implications for TNA (specific technologies)	Funding options under this policy
2012	National Water Policy	✓		Climate Change adaptation and use of appropriate technology has been given special emphasis in the water policy	Integration with other ongoing schemes and programmes for watershed development (IWMP& RKSY), employment generation (MNREGA) and other projects on drinking water as well as Irrigation water
2000	National Agricultural Policy		✓	Aim of the policy is to introduce the use of more technology in farming	Programmes for agriculture infrastructure facilities including waste land development and minor irrigation
2015	Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)	✓	✓	convergence of investments in irrigation at the field level, expand cultivable area under assured irrigation, improve on-farm water use efficiency to reduce wastage of water, enhance the adoption of precision irrigation and other water saving	PMKSY has been conceived amalgamating ongoing schemes. Has funds from multiple sources

				technologies (More crop per drop), enhance recharge of aquifers and introduce sustainable water conservation practices by exploring the feasibility of reusing treated municipal waste water for peri-urban agriculture and attract greater private investment in precision irrigation system	
2007	Water Technology Initiative Programme WTI	✓		Aims to promote R&D activities aimed at providing safe drinking water at affordable cost and in adequate quantity using appropriate Science and Technology interventions evolved through indigenous efforts.	Dynamically evolves based on need for technology based solution from the users, requirement of R&D inputs by stakeholders, assessment of S&T requirements to enable achieve technology prowess in water sector etc.

2.3 Relevant State Level Projects and Schemes

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

Mission Bhageeratha[4]

The Government of Telangana launched flagship program for providing drinking water at the door step of household by name “Intintiki Nalla” under ‘Mission Bhageeratha’ for the Urban and Rural areas of Telangana by instituting the Telangana Drinking Water Supply Corporation. Under the mission the policy of the Government is to provide drinking water in all the rural and urban areas by integrating the existing water supply systems in the rural and urban areas with the Grid proposed to be developed by TDWS Corporation. The mission aims to provide piped water to 84 lakh households in the state by 2018 at a cost of 40,000 crore INR. Telangana Drinking Water Supply Corporation has set out the following objectives. The vision of the project is to ensure safe and sustainable piped drinking water supply from surface water sources and to provide each household with a tap connection.

Kaleshwaram Lift Irrigation Scheme[5]

Kaleshwaram Lift Irrigation Scheme is worth Rs 80,000 crore. This is the costliest irrigation project undertaken by any state of the country so far. It aims to irrigate 18 lakh acres of land in 13 districts, stabilising another 17 lakh acres in another seven districts – virtually covering the entire state. The scheme also intends to provide drinking water to several towns and cities of the state, especially the most important cities of Hyderabad and Secunderabad. Moreover, the irrigation project will provide water to industries in many states.

Mission Kakatiya[6]

This program is focused on restoring all the minor irrigation tanks and lakes in Telangana State, India. The programme helps in rejuvenating 46,531 tanks and lakes, storing 265 TMC water across the state in five years. The tanks and lakes are dug to remove silt for increasing water storage capacity. A lot intervention that can address climate change adaptation are being carried out such as- de-siltation of tanks, restoration of feeder channels, re-sectioning of irrigation channels, repairs to tank bunds, weirs and sluices and raising of full tank level (FTL). Further, the interventions have helped in increasing the storage capacity of tanks and other water bodies, made available water accessible to small and medium farmers, increased water retention capacity of the sources and improved on-farm moisture retention capacity.

4 Source: Mission Bhagiratha-RWS http://missionbhagiratha.telangana.gov.in/

5 https://www.kaleshwaramproject.com/

6 https://missionkakatiya.cgg.gov.in/

Other Projects

Palamuru project is expected to cost over Rs 35,000 crore. The project aims to, by lifting 90 TMC of excess water from the Srisailam reservoir during the flood season, irrigate 10 lakh acres, provide drinking water to Hyderabad and supply water for industrial use to Mahabubnagar, Nalgonda and Rangareddy districts. The project expects to use 90 thousand million cubic feet of water in 60 days from the Srisailam reservoir.[7]

The Rs 10,000 crore **Dindi project**, which was approved in 2007 and whose source is again the Srisailam reservoir, it will irrigate 3.5 lakh acres and provide drinking water in fluoride-affected Nalgonda.[8]

7 www.irrigation.telangana.gov.in/

8 http://irrigation.telangana.gov.in/icad/static/projects/dindi.html

3. Deriving a long list 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. 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 and approaches to close the CCA gap, based on stakeholder interviews and consultation meetings.

CC Impact	Description of CCA Gap	Possible Solutions/ technologies	Element of Vulnerability, and how it is addressed	Technology Code
Flood: Extreme weather events leading towards increase in flooding (there will be marginal rise in precipitation but the number of rainy days will be reduced) (SAPCC,2015 & GIZ Vulnerability Assessment,2017)	- Limitations in forecasting extreme weather events in the existing system - Poorly developed early warning systems, - Poor storm water management - Unplanned drainage systems	• Modernised EWS and advisory services using Internet of Things, Machine Learning and AI based solutions in order to predict weather events	Increase adaptive capacity	W7
		• Rain and storm water management (decentralized storm water channels/drains)	Reduce exposure	W6
		• Conjunctive, Site specific and integrated planning for holistic approach to ground water and surface management with the aim to avoid flooding	Reduce sensitivity and exposure	W1

CC Impact	Description of CCA Gap	Possible Solutions/ technologies	Element of Vulnerability, and how it is addressed	Technology Code
Drought: Groundwater table decline due to reduced recharge due to erratic rainfall (increased surface run off and increased drought) (Telangana SAPCC, 2015)	- Limited efforts for ground water recharge - Absence of centralized ground water extraction systems - No application of proper technologies for rain water harvesting to recharge ground water and augment water through wastewater treatment and other methods	• Conjunctive, Site specific and integrated planning for holistic approach to ground water and surface management	Reduce sensitivity and exposure	W1
		• Storm water management (decentralized storm water channels/drains)	Reduce exposure, Increase adaptive capacity	W6
		• Groundwater/storm water measurement Gauges	Reduce Exposure, increase adaptive capacity	W10
		• Recharge Shaft for groundwater/ shaft driven technology (Managed aquifer recharge)	Reduce Sensitivity	W4
		• Solar Pumps for pipe water supply (reducing GHG emission, improving distribution)	Reduce Exposure	W5
Deteriorated Water Quality: Frequent outbreak of health hazard due to poor water quality as a result of floods and drought (e.g. water/ vector borne diseases due to higher concentration of pollutants during drought or contamination of drinking water reservoirs during flood).	- Inadequate or poor infrastructure to supply clean drinking water during flood and drought - Poor Infrastructure or inadequate capacity to control water logging	• Household level water quality treatment	Increase adaptive capacity	W11
		• Rooftop rainwater harvesting (both house hold level and community building)	Reduce Sensitivity	W9
		• Decentralized community level waste/ sewerage water treatment recycling	Increase adaptive capacity	W2
		• Double piped drinking and household water system in rural/ urban areas	Reduce Sensitivity	W3

CC Impact	Description of CCA Gap	Possible Solutions/ technologies	Element of Vulnerability, and how it is addressed	Technology Code
		• Improved public piped drinking water supply with advanced treatment	Reduce sensitivity	W12
Crop Failure: Failure of rain-fed crops due to excessive rainfall in limited time period (GIZ vulnerability assessment,2017)	- Limited irrigation facilities available to manage the excess water as per the agriculture water requirement - Soil erosion/run off due to excessive rainfall - Absence or less knowledge of Crop Insurance	• Water Storage: individual and community farm ponds, percolation tanks	Increase adaptive capacity	WA1
		• Capacity development for the farmers and crop specific water requirement	Increase adaptive Capacity	WA9
		• Water Harvesting: check dams, contour bunding	Reduce Sensitivity	WA2
		• Water Conveying Systems: Drip sprinklers and water carrying pipes	Increase adaptive capacity, Reduce Sensitivity	WA4
		• Water Security Plans (WSPs) through VWSC/ WUAs	Increase adaptive capacity	WA7
		• Crop Diversification; Rice to short duration millets/ pulses	Increase adaptive capacity	WA5
Crop Yield: Reduced crop yield due to water loss in irrigation and increase in temperature, increase in CO_2 concentration (SAPCC, 2015)	- Insufficient irrigation technologies, Non-use of land levelling, poor water management and irrigation techniques to reduce and avoid water loss in irrigation	• Tail end check dam for medium irrigation project to reduce capacity loss	Reduce sensitivity, Increase adaptive capacity	WA11
		• Development of improved drainage, irrigation and water distribution system (including capacity building of farmers),	Increase adaptive capacity	WA5

CC Impact	Description of CCA Gap	Possible Solutions/ technologies	Element of Vulnerability, and how it is addressed	Technology Code
		• Climate resilient crop species and behavior change for change of food habits	Increase adaptive Capacity	WA6
		• Technology for de-siltation or catchment treatment to avoid siltation	Increase adaptive Capacity	W8
Crop Loss: Crop loss due to drought/ less or no rainfall	- Inadequate irrigation infrastructure - Poor early warning systems - Non-use of drought resistant/ resilient varieties. - Absence or less knowledge of Crop Insurance	• Modernised EWS and advisory services using Internet of Things, Machine Learning and AI based solutions	Reduce Exposure	W7
		• Crop Diversification; Rice to short duration millets/ pulses; Drought tolerant and early maturing rice, paddy, maize varieties	Increaseadaptive capacity, reduce sensitivity	WA5
		• Intercropping: climate resilient species	Increase adaptive capacity	WA6
		• Linking of canals and ponds or tanks (cascade)	Increase adaptive capacity	WA10
		• Storage capacity of major and medium irrigation projects need to be regained – Technology for de-siltation or catchment treatment to avoid siltation	Reduce Sensitivity, Increase adaptive Capacity	W8

4. Prioritization 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, contour bunding etc. These technologies are linked to existing programmes and have a higher possibility of implementation at scale.

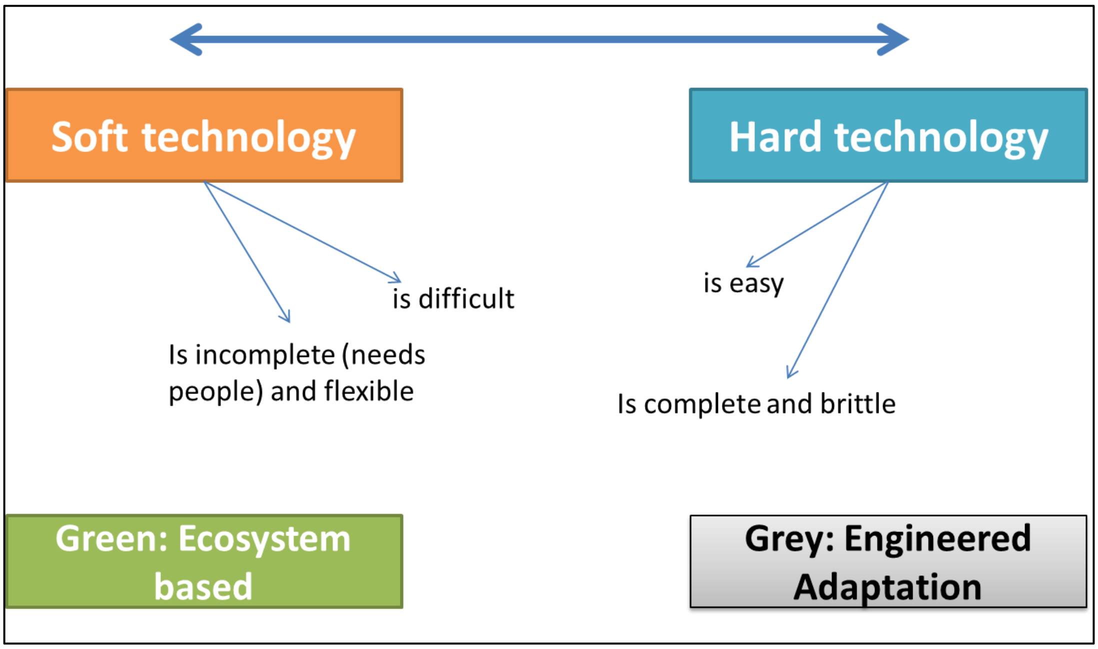


Figure 6: Types of Technologies

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: Long list of Technology Solutions

Water	Code	Type
Conjunctive, Site specific and integrated planning for holistic approach to ground water and surface management	W1	Soft
Decentralized community level waste/ sewerage water treatment recycling	W2	Hard
Double piped drinking and household water system in rural/ urban areas	W3	Hard
Recharge Shaft for groundwater/ shaft driven technology (Managed aquifer recharge)	W4	Hard
Solar Pumps for pipe water supply	W5	Hard
Rain and storm water management (decentralized storm water channels/drains)	W6	Hard
Modernised EWS and advisory services using Internet of Things, Machine Learning and AI based solutions	W7	Hard/ Soft
Technology for de-siltation or catchment treatment to avoid siltation	W8	Hard
Rooftop rainwater harvesting (both house hold level and community building)	W9	Hard
Groundwater/storm water measurement gauges	W10	Hard
Household level water quality treatment	W11	Hard/ Soft
Improved public piped drinking water supply with advanced treatment	W12	Hard
Water in Agriculture Sector	**Code**	
Water Storage: individual and community farm ponds, percolation tanks	WA1	Hard
Water Harvesting: check dams, contour bunding	WA2	Hard
Advisory for farmers for early warning of weather for farming/ irrigation practices – farmers need to be aware about the advisory and act accordingly	WA3	Hard/ Soft
Water Conveying Systems: Drip sprinklers and water carrying pipes	WA4	Hard
Crop Diversification; Rice to short duration millets/ pulses	WA5	Hard
Intercropping, climate resilient species	WA6	Hard
Water security plans through Water User Associations/ VWSC	WA7	Soft
Groundwater Dashboard advisory for Farmers	WA8	Soft
Capacity development for the farmers and crop specific water requirement	WA9	Soft
Linking of canals and ponds or tanks (cascade)	WA10	Hard
Tail end check dam for medium irrigation project to reduce capacity loss	WA11	Hard
Introduction of crop insurance to transfer/ minimize the risk of crop loss and damage	WA12	Soft

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

Description of Suggested Technology Options To Address CCA in Water Sector

Conjunctive, Site specific and integrated planning for holistic approach to ground water and surface management: Conjunctive use of groundwater and surface water in an irrigation setting is the process of using water from the two different sources for conjunctive purposes. Conjunctive use can refer to the practice at the farm level of sourcing water from both a well and from an irrigation delivery canal, or can refer to a strategic approach at the irrigation command level where surface water and groundwater inputs are centrally managed as an input to irrigation systems. Accordingly, conjunctive use can be characterised as being planned (where it is practiced as a direct result of management intention – generally a top down approach) (FAO, 1995). The conjunctive use leads to more resilience as the system does not depend on only one source.

Decentralized community level waste/ sewerage water treatment recycling: Decentralized wastewater treatment consists of a variety of approaches for collection, treatment, and dispersal/reuse of wastewater for individual dwellings, industrial or institutional facilities, clusters of homes or businesses, and entire communities. Decentralized wastewater treatment can be a smart alternative for communities considering new systems or modifying, replacing, or expanding existing wastewater treatment systems.

Double piped drinking and household water system in rural/ urban areas: This technology was recommended by the officials of drinking water department. The state has a drinking water mission called Kakatia where they supply the water using gravitation mechanism and therefore, at the consumer end the supply comes at a very slow pace. There is lot of misuse happens at the end. To address this issue the officials recommend that they can go for double piped system where one pipe can be used for drinking purpose and other pipe for supplying recycled water for household use to reduce the wastage of expensively treated drinking water and to use the recycled water in efficient manner.

Recharge Shaft for groundwater/ shaft driven technology (Managed aquifer recharge): Groundwater recharge reduce the effect of both droughts and floods on the quantitative degradation or lack of water resources due to changes in rainfall. A wide spectrum of techniques are in vogue to recharge ground water reservoir. Similar to the variations in hydrogeological framework, the artificial recharge techniques too vary widely. Depending on the hydrometeorological and soil infiltration studies this includes:

- Direct sub surface techniques (Injection wells or recharge wells)
- Combination surface – sub-surface techniques (Basin or percolation tanks with pit shaft or wells)
- Indirect Techniques (Induced recharge from surface water source) (CGWB, 2000)

Solar Pumps for pipe water supply: The Government of India is focusing on provision of piped water supply in rural areas in the 12th Five year plan. It is seen that the drinking water supply infrastructure in tribal and inaccessible habitations are not functional due to non-availability of electricity and thus, extra efforts need to be made to improve piped water coverage in these areas. The scheme is based on both the traditional hand pump method and additional pump which can be run on solar or conventional electricity is installed by using specially designed water chamber. The use of solar energy based water pumps is especially useful in areas with non-availability or erratic availability of electric power.

Storm water management (decentralized storm water channels/drains): Stormwater is water from any form of precipitation, rain, melting snow, hail or sleet that but runs off rather than soaking into the ground. This runoff collects soil, silt, pesticides, fertilizers, oil, yard waste, pet waste, litter or any other pollutant and transports it to nearby drains or ditches. Traditional stormwater management was mainly to drain high peak flows away. Unfortunately, this only dislocates high water loads. Modern approaches aim to rebuild the natural water cycle, i.e. to store runoff water (e.g. retention basins) for a certain time, to recharge ground water (e.g. infiltration basins) and to use the collected water for irrigation or household supply.

Modernised EWS and advisory services using Internet of Things, Machine Learning and AI based solutions: A modern early warning system with both hard and soft measures, as with early warning systems that combine hard measuring devices with soft knowledge and skills that can raise awareness and stimulate appropriate action. A system of flood monitoring and forecasting and timely flood warnings can prompt communities to protect crops, habitats and livestock.

Technology for de-siltation or catchment treatment to avoid siltation: The study of erosion and sediment yield from catchment is of utmost importance as the deposition of sediment in reservoir reduces its capacity, thus affecting the water available for the designated use (CGWB, 2013). De-siltation would strengthen the existing water storage structures leading to improved water security during summers and increase in groundwater table.

Rooftop rainwater harvesting (both house hold level and community building): Constructing rainwater harvesting systems can contribute significantly to addressing the climate change impacts on water quantity and quality. Rainwater harvesting (RWH) can be done at large scale by harvesting surface runoff or at smaller scale from specially prepared surfaces to catch higher quality water. Managing surface water runoffs and storing them in tanks or reservoirs can lead to a significant increase in available water resources for various purposes, depending on the management of the catchment area and the reservoir.

Groundwater/storm water measurement gauges: The measurement gauges helps in measuring quantity of water available in the storm water drain. The state officials were aslso keen to use some technology for measuring the ground water withdrawn so that they can put a sytem of excess ground water use.

Household level water quality treatment: Treatment of water at household level could include recycling and additionally it can help for identifying hazards and critical control points including source water selection and protection, water collection, water treatment and water storage, including storage vessel type and its use.

Improved public piped drinking water supply with advanced treatment: Climate proofed drinking water treatment systems and piped household connection supply provides clean and safe water even in times of extreme weather events which contaminate household level water sources like shallow tubewells or water reservoirs. Measures relate to upgrading and protecting the treatment facility and strengthening and expanding the distribution network

Description of Suggested Technology Options To Address CCA in Water in Agriculture Sector

Water Storage: individual and community farm ponds, percolation tanks: Community farm ponds and percolation tanks are small water storages or tanks created in the sub-basins by bunding streams and gullies, store runoff water during the Monsoon season and cause recharge to ground water during the next few months of dry season.

Water Harvesting: check dams, contour bunding: Minor irrigation systems like small and medium sized check dams and and strengthening through contour bunds should get the top priority attention of all to enable conservation of most of the rainfalls, received during the monsoon and use the conserved water during the lean and drought periods. These measures will stabilize the farming system, besides recharging the underground aquifers and minimizing water induced erosion and consequent silting of water bodies.[9]

Advisory for farmers for early warning of weather for farming/ irrigation practices – farmers need to be aware about the advisory and act accordingly: An advisory service that includes an early warning system that combine hard measuring devices with soft knowledge and skills that can raise awareness and stimulate appropriate action. This includes direct information sharing to farmers to not over irrigate their fields incase of a rainfall or shift cropping time in order to meet the rainfall season.

Water Conveying Systems: Drip sprinklers/ irrigation: 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)

Crop Diversification: Rice to short duration millets/ pulses: 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 (Clements et.al, 2011)

Intercropping: climate resilient species: intercropping is the practice of growing two or more crops in close proximity to one another during part or all of their life cycles. While monocropping, the practice of only growing one crop variety year after year, leaves producers more vulnerable to pests/ climate impacts that target a specific plant variety, intercropping, by providing additional plant varieties, can help slow the proliferation of pests and decrease climate vulnerabilities and protect yields (Pauley, 2017).

Water security plans through Water User Associations/ VWSC: A Water User Association (WUA) or Village Water and Sanitation Committee (VWSC) is an organisation for water management made up of a group of small and large-scale water users, such as irrigators, who pool their financial, technical, material, and human resources for operation and maintenance of a local water system, such as a river or water basin. Water Secuirty Plans developed by these groups can play a key role in integrated approaches to water

[9] Role Of Check Dams In Soil, Water Conservation & Mitigation Of Climate Change,

management that seek to establish a decentralised, participatory, multi-sectoral and multi-disciplinary governance structure (UN Environment – DHI, CTCN, UNEP DTU, 2017).

Groundwater Dashboard advisory for Farmers: A Groundwater dashboard would reveal how we could possibly quantify and potentially interpret groundwater stress. This groundwater stress in the aquifers of India would be assessed by through the groundwater footprint (GF).

Capacity development for the farmers and crop specific water requirement: Impacts of climate change will be particularly significant on smallholder farmers. Vulnerability is because smallholder farmers have low economic resilience when large variations in crop outputs occur. Capacity building processes for smallholder farmers can considerably improve their ability to engage in action for adaptation (Balaji, Ganapuram & Devakumar, 2015).

Linking of canals and ponds or tanks (cascade): This is suggested to be done through linking two or more water bodies by creating a network of manually created canals ,and providing water to the land areas that does not have water access. It is based on the assumption that surplus water in some rivers can be diverted to deficit rivers by creating a network of canals to interconnect the rivers.

Tail end check dam for medium irrigation project to reduce capacity loss: Check dams in medium irrigation projects at the tail end would help prevent loss of water in case of heavy rainfall. It could also help reduce capacity loss, and could be used to compliment traditional irrigation efficiency technologies such as Drip sprinklers, contour bunding etc.

Introduction of crop insurance to transfer/ minimize the risk of crop loss and damage: Financial insurance for extreme events can play an important role in hedging against the implications of climate change. Crop insurance provides economic support to farmers, stabilises farm income, induces farmers to invest in agriculture, reduces indebtedness and decreases the need for relief measures in the event of crop failure (Falco, Adinolfi, Bozzola & Capitanio, 2014).

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 Telangana, some of them are already in place whereas others are good practices from different states or countries that could be beneficial for Telangana, 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 high0: 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), NWM (2008) 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	**30**
3	Institutional Benefits: Implementation availability through national and state level coherence	**5**
4	Environmental Benefits: Contribution to environmental conservation priorities	**10**

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	**10**
7	Cost: Potential benefits through lower costs of operation and maintenance	**20**
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

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%		30%			5%			10%		20%		10%		10%			
Water Sector																		
W1	8	4	6	6	8	8	3	5	8	8	5	6	8	7	7	7	6.5	6.7
W2	5	1	3	3	3	7	6	6	9	10	7	2	5	9	4	4	5.3	4.6
W3	3	3	1	1	1	2	7	2	8	3	2	0	7	2	3	3	3.0	2.6
W4	9	5	8	6	7	8	8	7	8	8	7	8	6	8	7	7	7.3	7.2
W5	4	10	4	5	6	9	5	8	5	2	7	3	7	5	6	3	5.6	5.3
W6	9	2	4	5	6	8	7	8	5	7	6	7	7	7	3	3	5.9	5.3
W7	10	1	5	5	5	6	4	7	8	3	9	8	6	9	3	7	6.0	5.8
W8	7	1	6	6	6	5	7	5	8	3	5	7	6	7	4	4	5.4	5.3
W9	8	1	7	7	7	9	7	9	4	7	4	7	10	7	5	5	6.5	6.1
W10	8	1	8	8	8	8	9	8	5	5	7	2	6	3	2	2	5.6	5.3
W11	8	1	8	4	7	8	8	8	4	8	9	4	8	5	6	5	6.3	6.0
W12	6	4	8	8	7	7	8	7	7	6	6	5	8	7	5	6	6.6	6.5
Water in Agriculture Sector																		
WA1	8	2	6	6	6	8	8	8	7	7	6	8	9	6	8	6	6.8	6.5
WA2	8	1	5	5	5	8	8	8	7	5	6	9	9	6	6	6	6.4	5.9
WA3	8	1	5	5	5	6	6	6	8	3	9	8	6	10	3	3	5.8	5.3
WA4	8	8	6	5	6	8	8	8	7	7	8	7	9	10	6	6	7.3	6.9
WA5	8	6	8	5	7	8	8	8	7	3	4	9	7	8	5	6	6.7	6.5

WA6	7	6	7	5	7	8	8	8	8	3	4	9	8	7	6	6	6.7	6.4
WA7	7	5	8	8	8	8	5	8	8	8	4	7	9	7	8	6	7.1	7.2
WA8	7	1	6	6	6	7	6	7	4	7	4	6	10	9	9	9	6.5	6.5
WA9	7	5	7	6	8	7	6	7	8	5	5	7	7	7	5	5	6.4	6.3
WA10	7	1	6	6	6	8	7	8	6	8	3	6	9	5	5	5	6.0	5.6
WA11	8	1	4	3	4	4	5	4	3	2	10	6	4	4	3	3	4.3	4.0

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 factor was carried out through review of the climate change vulnerability, impact status and trends in water and agriculture sector. Initial identification of technology and prioritization was done through the consultation workshop in August 2018 and applied multi-criteria, scoring and expert judgement for assessment and decision respectively. The workshop followed the steps and methodologies for technology prioritization, as suggested in the TNA handbook (UNDP and UNFCCC, 2010) and Traerup et. al (2015) particularly technologies identification and prioritization of technologies with the use of the criteria and scoring and decision on the priority technologies through stakeholders consultation.

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

Technology	Code	Total Cumulative scores (out of 10)	Total Weighted Score (out of 10)
Shortlist of Technologies for Water Sector:			
Conjunctive, Site specific and integrated planning for holistic approach to ground water and surface management	W1	6.5	6.7
Rooftop rainwater harvesting (both house hold level and community building)	W9	6.5	6.1
Recharge Shaft for groundwater/ shaft driven technology (Managed aquifer recharge)	W4	7.3	7.2
Shortlist of Technologies for Water in Agriculture Sector:			
Water security plans through Water User Associations/ VWSC	WA7	7.1	7.2
Water Conveying Systems: Drip irrigation systems	WA4	7.3	6.9
Crop Diversification: Rice to short duration millets/ pulses	WA5	6.7	6.5

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

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

Option 1: W4: Recharge Shaft for groundwater/ shaft driven technology (Managed aquifer recharge)

Technology	Recharge Shaft for groundwater/ shaft driven technology (Managed aquifer recharge)	
Sector	Water	
Subsector	Water Augmentation	
Technology characteristics		
Introduction	Groundwater recharge reduce the effect of both droughts and floods on the quantitative degradation or lack of water resources due to changes in rainfall (El Mansouri & El Mezouary, 2015). A wide spectrum of techniques are in vogue to recharge ground water reservoir. Similar to the variations in hydrogeological framework, the artificial recharge techniques too vary widely. Depending on the hydro-meteorological and soil infiltration studies this includes: • Direct sub surface techniques (Injection wells or recharge wells) • Combination surface – sub-surface techniques (Basin or percolation tanks with pit shaft or wells) Indirect Techniques (Induced recharge from surface water source)	
Climate related criteria		Score
A1: CCA Efficiency	It reduces climate sensitivity, increases climate resilience through maximizing natural storage and increasing water supply system resilience during periods of low flows and high seasonal variability. During these periods, such as in the dry season, aquifers are intentionally recharged to recover water.	9
A2: GHG reduction	Mitigation benefits arise in cases where the groundwater recharge leads to reducing salt water intrusion and thus the usage of RO plants, their energy consumption could be reduced or even avoided	5
Social criteria		
B1: Health	The technology increases freshwater supply for activities and household use and therefore improving health parameters including reducing mortality/ morbidity due to unsafe water.	8
B2: Inequity	Water from the groundwater can be equally distributed if it is	6

	brought under the purview of WUA/ VWSC otherwise it doesn't directly address issues of equitable distribution.	
B3: sustainable development	In general the additional ground water resource which is made available can lead to sustainable development, while it cannot alleviate acute water scarcity over extended periods of time, and only available where excess water is available. It cannot be fully recommended for this criteria.	7
Institutional Benefits		
C1: refers to existing plans	The CGWB has developed the Master Plan for Artificial Recharge to Groundwater in India (2013). This has been an effort to assess the total recharge potential available in the country along with suitable designs of structures for such recharge. The Master Plan has been prepared by Central Ground Water Board in consultation with the State Governments, in view the technical and scientific aspects of recharge projects. It also collates work done under MNREGS.	8
C2: clear responsibility	There is only solely dedicated department for groundwater resource which is the CGWB, even at the state level. However, for MAR Integrated Watershed Development Department, Forest Department, Public Works Department, Horticulture Department, Roads and Buildings Department, Agriculture Department and Water Supply Departments are involved.	8
C3: coherent with policies	The Master Plan also includes community participation at Panchayat level for such work through concerned central ministries.	7
Environmental Benefits		
D1: Ecology / biodiversity	It maintains healthy environmental flows and reduces the risk of water source over-extraction and degradation. This helps in sustaining groundwater dependent ecosystems.	8
D2: Recycle, Reuse, Substitute	It creates potential for productive use of alternative water sources, such as recycled wastewater and stormwater runoff.	8
Economic Benefits		
E1: private sector participation	Depending on the kind of infiltration technology the private sector investment can be considered.	7
E2: productivity	This technology addresses water variability and shortages, thereby addressing concerns of water supply and irrigation and leads to more productiveness in the case of making a water supply resilient as well as to increase of income due to improved irrigation options some cases.	8
Technological Benefits		
F1: experience and acceptance	Water resource practitioners will easily grasp the idea of recharging the groundwater, But this technology does not directly alleviate acute water scarcity. So benefits are not directly felt, and may require awareness generation in terms of acceptance and	6

	understanding.	
F2: water efficiency	It makes use of water which is usually lost due to the runoff into the sea of evaporation and it provides improved output during water scarcity times per unit of water.	8
Costs		
G1: investment	The implementation costs are diverse. This is due to the diverse range of managed aquifer recharge (MAR) schemes Many low cost water recharge approaches are available, for example simple constructions such as trenches and pits. But injection wells and other methods may prove to higher cost.	7
G2: O&M	In general operation costs are low regarding energy and labour. There are though several common operational risks experienced by MAR schemes which might need to be addressed. These include: clogging of wells, stability of infrastructure under operating conditions, protection of groundwater quality, operation and management of the scheme, ownership of the stored water, monitoring, loss of infiltrated/injected water	7

Option 2: W1: Conjunctive, Site specific and integrated planning for holistic approach to ground water and surface management

Technology	Conjunctive, Site specific and integrated planning for holistic approach to ground water and surface management	
Sector	Water	
Subsector	Water augmentation	
Technology characteristics		
Introduction	Conjunctive use of groundwater and surface water is the process of using water from the two different sources for consumptive purposes. Conjunctive use can refer to the practice at a smaller water supply level of sourcing water from both a well and from a river, or can refer to a strategic approach at a catchment area level where surface water and groundwater resources are centrally managed with the aim of securing the availability of water resources over a longer period by making use of different sources according to their temporal availability and taking into account the SW-GW interrelation.. Accordingly, conjunctive use can be characterised as being planned (where it is practiced as a direct result of management intention – generally a top down approach) (FAO, 1995).	
Climate Benefits		Score
A1: CCA Efficiency	Conjunctive use strategies aim to increase the overall resilience of water supply by utilizing both sources of water, particularly in communities and basins with high water availability throughout the seasons (UN Environment – DHI, CTCN, UNEP DTU, 2017).The conjunctive use leads to more resilience as the system does not depend on only one source.	8
A2: GHG reduction	There is very less or no contribution to reduction in GHG emissions, in case the optimised usage leads to less pumping the energy for the pumps is reduced.	4
Social Benefits		
B1: Health	It can help address sanitation and hygiene issues in a way of providing water on a more reliable bases due to the more resilient source diversification. It does not necessarily focus on water quality issues	6
B2: Inequity	The planning approach could help in equitable distribution of the water resources that conserved/ gained through the conjunctive approach. But it can be a challenge to monitor illegal or unregistered groundwater use by rich- large land holding farmers (for example private wells) that may impact groundwater availability, regardless of management plans. Thereby impacting other smaller social classess.	6
B3: sustainable development	With addressing water quantity and augmentation this approach can also address water scarcity and poverty alleviation rising out of insufficient irrigation. It also reduces agricultural losses from interruptions in irrigation, and improves food security.	8
Institutional Benefits		

C1: refers to existing plans	NWM and other government policies do recommend a conjunctive approach to ground and surface water management. It is also suggested through the groundwater master plan (2013).	8
C2: clear responsibility	The departments concerning surface water and ground water are different. This creates issues of convergence. Even departments such as Central Water Commission do not share data or experience with each other.	3
C3: coherent with policies	A conjunctive plan on a local level would require both citizen and state approach as the panchayati raj institutions will implement these through water committees in the community. In case of a catchment are a river basin authority would be in charge.	5
Environmental Benefits		
D1: Ecology / biodiversity	Avoids aquifer and surface source over-extraction and degradation, and supports a more natural water balance where both groundwater recharge and surface water recovery is possible.	8
D2: Recycle, Reuse, Substitute	A holistic approach could take into account various grey water and possibly treated waste water streams and substitute domestic water supply usage in some cases	8
Economic Benefits		
E1: private sector participation	For the local solutions private sector investment is difficult to attract for upscaling this technology as it is very community focussed. Small pockets of CSR activities are possible. Larger projects could have infrastructural components where the private sector could be involved	5
E2: productivity	Implemented at the local level, with direct economic benefits to the community through addressing water security for irrigation and other needs.	6
Technological Benefits		
F1: experience and acceptance	In most regions water resource managers have experience with the usage of surface and groundwater sources, their efficient conjunctive use though might need to be capacitated on.	8
F2: water efficiency	It helps address water efficiency but it requires a high degree of coordination between water-users to ensure benefits are maintained and over-exploitation is avoided	7
Costs		
G1: investment	The investment would depend on the infrastructural measures to be implemented for the usage of the various water sources which could possibly be very high. In addition a sufficient level of data on both water sources is required on an regular basis in order to take the right decision on their efficient usage	7
G2: O&M	Depending on the infrastructure to be operated and maintained costs can vary, in addition continuous data updation is required which leads to monitoring costs	7

Option 3: W9: Rooftop rainwater harvesting (both house hold level and community building)

Technology	Rooftop rainwater harvesting (both house hold level and community building)	
Sector	Water	
Subsector	Water Storage, Conservation	
Technology characteristics		
Introduction	Constructing rainwater harvesting systems can contribute significantly to addressing the climate change impacts on water quantity and quality. Rainwater harvesting (RWH) can be done at large scale by harvesting surface runoff or at smaller scale from specially prepared surfaces to catch higher quality water. Managing surface water runoffs and storing them in tanks or reservoirs can lead to a significant increase in available water resources for various purposes, depending on the management of the catchment area and the reservoir.[10]	
Climate Benefits		**Score**
A1: CCA Efficiency	Rainwater harvesting can enhance the water availability at any specified location and time. Rainwater harvesting represents an adaptation strategy for people living with high rainfall variability, both for domestic supply and to enhance crop, livestock and other forms of agriculture (Barron & Calfoforo Salas, 2009).	8
A2: GHG reduction	Elevated rainwater tanks save energy as groundwater has to be pumped from underground. Thereby reducing emissions from energy.	1
Social Benefits		
B1: Health	Rainfall can provide some of the cleanest naturally occurring water that is available. Thereby reducing water-borne diseases and morbidity in 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.	7
B2: Inequity	Household level RWH can ensure equitable water distribution as every household will have access to its own share of water	7
B3: sustainable development	While it addresses water security there is little evidence for RWH addressing poverty alleviation. It reduces women travelling long distances to get water and further can help address water security. It therefore, contributes to sustainable development.	7
Institutional Benefits		
C1: refers to existing plans	State supports and provides subsidies for RWH at household and community level. The State of Telangana has infact made it mandatory to install RWH in all government offices.	9
C2: clear responsibility	Rainwater harvesting comes under the purview of Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB) in	7

[10] Adapt cap (Adelphi)

	the capital and the Municipal Administration & Urban Development department however, there is no specific department for the rural areas.	
C3: coherent with policies	Rainwater harvesting is mandated and suggested through the National Water Mission and pre-requisite for the SSAP	9
Environmental Benefits		
D1: Ecology / biodiversity	This doesn't not impact the neither positively nor negatively to ecosystem where it is adapted.	4
D2: Recycle, Reuse, Substitute	While RWH doesn't address recycling or reuse of domestic water, it allows for use of rain water in the larger hydrological cycle.	7
Economic Benefits		
E1: private sector participation	Attracting private sector investment for community level RWH has not been on a large scale except for few small pockets of CSR activities.	4
E2: productivity	RWH can help increase productivity in regions with low and irregular rainfall. It can provide a first entry point for success of development programmes from farm to regional level.	7
Technological Benefits		
F1: experience and acceptance	Farmers prefer since it is an immediate solution to the problem, and also helps as it is already exiting or known traditionally in communities.	10
F2: water efficiency	RWH improves water use efficiency as it conserves the rainwater that would've otherwise been wasted as run-off.	7
Costs		
G1: investment	The cost of rainwater harvesting systems will depend on the type of catchment, conveyance and storage tank materials used but in general the costs of rainwater harvesting systems is considered to be low (UNEP, 1997). The provision of the storage tank is the most costly element, and usually represents about 90 per cent of the total cost (WaterAid, no date).	5
G2: O&M	There are very low maintenance costs associated with RWH except for regular cleaning of storage tanks and pipelines for harvesting water. Failing to conduct regular O&M can lead to failure of the technology.	5

4.4.2 Prioritised technologies for Water in Agriculture Sector

Option 1: WA7: Water security plans through Water User Associations/ VWSC

Technology	Water security plans through Water User Associations/ VWSC	
Sector	Agriculture	
Subsector	Water Supply and Demand Management	
Technology characteristics		
Introduction	A Water User Association (WUA) or Village Water and Sanitation Committee (VWSC) is an organisation for water management made up of a group of small and large-scale water users, such as irrigators, who pool their financial, technical, material, and human resources for operation and maintenance of a local water system, such as a river or water basin. Water Secuirty Plans developed by these groups can play a key role in integrated approaches to water management that seek to establish a decentralised, participatory, multi-sectoral and multi-disciplinary governance structure..[11]	
Climate Benefits		**Score**
A1: CCA Efficiency	A Water security plan developed by WUA or VWSC can contribute to adaptation to climate change by providing a cooperative mechanism through which the following activities can be undertaken: • Monitor the impact of climate change on water resources. • Empower water users and decision-makers to manage and allocate water resources with consideration for climate change, the environment and other technical information through consultative processes. • Develop and disseminate awareness materials on the implications of climate change and various likely water resource scenarios among local authorities, decision makers, communities and the private sector. • Provide data for modelling possible environmental, economic and social impacts of climate change resulting from changes in water resources. It can prioritise investment needs for water management adaptation strategies, such as irrigation, and monitor their effectiveness.	7
A2: GHG reduction	There is no direct implication however WUA/VWSC can promote usage of solar powered pumps or gravity based irrigation systems among communities thereby leading to reduction in GHG emissions	5
Social Benefits		
B1: Health	WUA/VWSC in tandem through having common members from the Village Hygiene and Sanitation Committee members, Anganwadi and ANM can help find synergies in the WASH sector	8

[11] Adapt cap (Adelphi)

	to address health impacts through National Rural Health Mission.	
B2: Inequity	Experience has shown that these groups can also help in ensuring equitable water distribution suggest/ develop rational charges for water facilities. These are participatory and allow involvement of women and lower caste in decision-making processes.	8
B3: sustainable development	These help in addressing both poverty alleviation and water security. WUA/VWSC can help in increasing agricultural productivity and income-earning opportunities of farmers (INPIM, 2010)	8
Institutional Benefits		
C1: refers to existing plans	These are mandated to be present as part of the PRI as per the National Rural Drinking Water Programme, National Rural Health Mission.	8
C2: clear responsibility	There is a difficulty for convergence as the government has mandated that State Departments dealing with Rural Drinking Water Supply, Rural Sanitation, School Education, Health, Women and Child Development, Water Resources, Agriculture, etc. to form a State Water and Sanitation Mission (SWSM) at the State/ UT level. Further these will be translated down to village level through the Village water and sanitation committees/ WUA.	5
C3: coherent with policies	These are strongly supported and present across national priorities and programmes.	8
Environmental Benefits		
D1: Ecology / biodiversity	As a group these can ensure protection and sustenance of aquatic ecology. They can help in protecting the diversity of the rivers and ponds of the villages they exist in.	8
D2: Recycle, Reuse, Substitute	These committees can help collect money and develop a village level waste treatment to substitute for domestic water supply. But these are dependent on the financial standing and capacities of the community.	8
Economic Benefits		
E1: private sector participation	Private sector investment is difficult to attract as it is very community focussed. Small pockets of CSR activities are possible.	4
E2: productivity	As mentioned earlier these do help in improving income of farmers and increase in productivity by rationalizing water usage.	7
Technological Benefits		
F1: experience and acceptance	As these are part of already existing committees of the PRI there is easy take up once the farmers are trained and linkages with experts are built.	9
F2: water efficiency	These are soft measures and help in improving output per unit of water through improved capacities of PRIs to use existing natural water resources. Water budgeting by communities also help in	7

	planned usage.	
Costs		
G1: investment	The cost of establishing and maintaining a VWSC/WUA will depend on its size, management structure, area of operations and functions. During initial formation phase, additional financial support may be required to ensure the establishment of the VWSC/WUA. The governemnt through the 14th finance commision allows for a fixed budget for these committies.	8
G2: O&M	These groups usually levy a joining fee, and then an annual membership fee. This is in addition to the funding from the government.	6

Option 2: WA4: Water Conveying Systems: Drip irrigation systems

Technology	Water Conveying Systems: Drip irrigation systems	
Sector	Agriculture	
Subsector	Water Efficiency and Demand Management	
Technology characteristics		
Introduction	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.	
Climate Benefits		Score
A1: CCA Efficiency	It increases adaptive capacity. Drip irrigation technology can support farmers to adapt to climate change by providing efficient use of water supply. Particularly in areas subject to climate change impacts such as seasonal droughts, drip irrigation reduces demand for water and reduces water evaporation losses (as evaporation increases at higher temperatures).	8
A2: GHG reduction	In some cases if there is sufficient difference in height between the water source and the field, distribution may be gravity-based rather than pump-based (UN Environment – DHI, CTCN, UNEP DTU, 2017). Thereby reducing GHG emissions.	8
Social Benefits		
B1: Health	Drip irrigation technologies can be implemented via a water user association to improve economic benefits and reduce initial investment costs. Promoting drip irrigation contributes to efficient water use, reduces requirements for fertilisers and increases soil productivity. This could further address increased per capita food availability.	6
B2: Inequity	This technology does not directly reduce inequity between social classes, gender, ethnic groups etc. but by improving incomes does help improve financial status.	5
B3: sustainable development	With improving water efficiency, drip irrigation is suitable in areas with permanent or seasonal water scarcity	6
Institutional Benefits		
C1: refers to existing plans	Government support is available for drip irrigation through the Department of Agriculture & Cooperation, Ministry of Agriculture in January, as Centrally Sponsored Scheme later it was up-scaled to National Mission on Micro Irrigation (NMMI) and currently it is focussed under the National Mission on Sustainable Agriculture (NMSA).	8
C2: clear responsibility	It falls under one ministry/ department of agriculture and irrigation and therefore allows for a high level of convergence.	8
C3: coherent	It is currently under the Pradhan Mantri Krishi Sinchayee Yojana	8

with policies	and has financial assisstance available. It is also one of the flagship programmes of the government.	
Environmental Benefits		
D1: Ecology / biodiversity	The only environmental/ ecosystemic benefit is efficient water use. It also further does not create adverse ecosystem impacts in which it is used.	7
D2: Recycle, Reuse, Substitute	These maybe used to convey recycled water, however they do not possess a system of reuse otherwise. It however reduces usage thereby allowing water to be used for other purposes.	7
Economic Benefits		
E1: private sector participation	In terms of private investment, companies are usually focused on large land extension projects and do not cater for small and medium-sized farmers.	8
E2: productivity	Some studies have shown that help increases farmers incomes. In some applications producers' incomes rise by as much as 35% as a result of the higher yields stemming from efficient fertilizer usage, or "fertirrigation", i.e., the controlled application of nutrients with irrigation water (Dippenaar et.al, 1997).	7
Technological Benefits		
F1: experience and acceptance	Farmers prefer as it gives immediate water conservation impacts. However, it easy easily implementable/ upscalable once a clear understanding of the technical characteristics of the system and of the crop's water requirements are given.	9
F2: water efficiency	The technology's core idea is water efficiency and therefore has a very good output per unit of water.	10
Costs		
G1: investment	The main costs involved are the materials for the distribution network, including the pump, the filtering and fertilizing systems and the drip line. The cost of labour for installation is also considerable. Further training in system operation and maintenance are assumed.	6
G2: O&M	At the start capacity building costs are involved for maintenance as over time drip tape or tubing must be carefully maintained in order to avoid leaking or plugging and emitters must be regularly cleaned to avoid blockage from chemical deposits.	6

Option 3: WA 5: Crop Diversification: Rice to short duration millets/ pulses

Technology	Crop Diversification: Rice to short duration millets/ pulses
Sector	Agriculture
Subsector	Increasing crop resilience and productivity

Technology characteristics		
Introduction	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.	
Climate Benefits		**Score**
A1: CCA Efficiency	These help increase adaptive capacity. Breeding new and improved crop varieties enhances the resistance of plants to a variety of stresses that could result from climate change. These potential stresses include water and heat stress, water salinity, water stress and the emergence of new pests. Varieties that are developed to resist these conditions will help to ensure that agricultural production can continue and even improve despite uncertainties about future impacts of climate change.	8
A2: GHG reduction	These crops could be selected so as not to require extra fertilizers and pesticides thereby reducing emissions from agriculture.	6
Social Benefits		
B1: Health	Varieties with improved nutritional content can provide benefits for animals and humans alike, reducing vulnerability to illness and improving overall health. They can also help in addressing food demand	8
B2: Inequity	They can provide extra income for small and marginal land holding farmers but may not address the water usage criteria.	5
B3: sustainable development	Crop diversification does have the potential for increasing community food security. Further help address poverty alleviation in the longer run.	7
Institutional Benefits		
C1: refers to existing plans	Crop diversification is considered important by the central and state governments and they have taken several initiatives to promote it. Horticulture sector has been given highest importance considering its importance in nutrition security. Some of the important programs of the government include (a)launching of National Horticulture Mission (b)Launching of Technology Mission for the Integrated Development of Horticulture in the North-Eastern Region (c)Implementing National Agriculture Insurance Scheme (d) Operationalizing Technology Mission on Cotton (e) Provision of Capital Subsidy for construction/modernization/expansion of cold storages and storages for horticultural produce (f)Creation of Watershed Development Fund at the National level for the development of rain-fed areas (g)Infrastructure Support for Horticultural	8

	Development(h)Strengthening Agricultural Marketing (i)Seed Bank Scheme (k) Cooperative Sector Reforms etc are some examples.	
C2: clear responsibility	Crop diversification in well endowed area is more of an economic consideration, it requires support from various technical institutes besides the government. The National Agricultural Research System with its Crop and Commodity based Institutions, Natural Research Management Based Institutions and State Agricultural Universities are jointly addressing the issues connected with the crop diversification (FAO, 2001).	8
C3: coherent with policies	These are in coherence with multiple government missions and programmes and involve both PRI and state officials.	8
Environmental Benefits		
D1: Ecology / biodiversity	Excessive uses of inputs such as fertilizers and pesticides, frequent cultivation, and lack of proper erosion control systems are constant threats to the environment. As input use, particularly fertilizers and pesticides, can be controlled in crop diversification, it will be environmentally friendly and provide products of high quality free of pesticide residues for human consumption.	7
D2: Recycle, Reuse, Substitute	There is not much scope of water recycling as it is an agriculture based technology.	3
Economic Benefits		
E1: private sector participation	Private sector can help cultivators throughout the crop cycle – from improving soil health and providing the best seeds to buying the output from crop diversification.[12] However, large scale benefits are yet to be documented.	4
E2: productivity	Crop diversification provides better conditions for food security and enables farmers to grow surplus products for sale at market and thus obtain increased income to meet other needs related to household well-being. Crop diversification can enable farmers to gain access to national and international markets with new products, food and medicinal plants.	9
Technological Benefits		
F1: experience and acceptance	The main barrier to introducing new and improved crop varieties through farmer experimentation is the misconception that local species have low productivity. Further market demand can lead farmers to produce fewer crops or monocultures and to rely on chemical inputs.[13]	7
F2: water efficiency	These maybe drought tolerant or less water requiring crop varieties leading to improved outputs per unit of water.	8

[12] https://economictimes.indiatimes.com/news/economy/agriculture/how-private-sector-is-helping-cultivators-with-technology-buyback-and-improving-their-social-standards/articleshow/61989717.cms

[13] http://www.climatetechwiki.org/content/crop-diversification-and-new-varieties

Costs		
G1: investment	Costs of farmer experimentation are generally low, but results may only have local applicability. Capital investment will relate to the purchase of new seed varieties (if not available 'wild' locally) and labour time. Where farmers are implementing a project initiated by an external agency, capital costs for training, technical experts and field staff, on farm trial equipment (an experimental plot may be established), and site visits may also be required.	5
G2: O&M	Only preliminary feasibility and market research costs need to be considered in the financial requirements. Infrastructure (such as transport and storage) and marketing costs should also be considered at the start. Further profits from crop production could yield the maintenance costs in terms of buying new seeds etc.	6

5. Case study for Telangana: Smart aquifer recharge and storage in Nalgonda

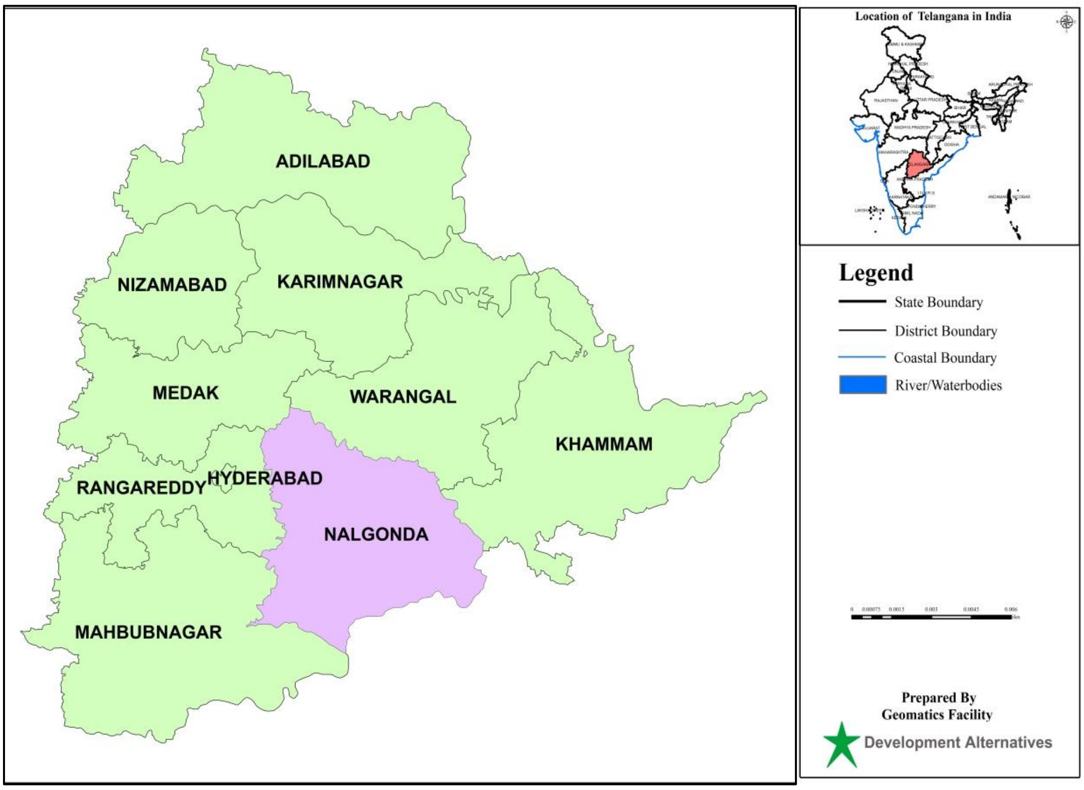


Figure 7: Nalgonda District
Source: Development Alternatives

The state of Telangana is highly vulnerable to climate change due to high monsoon variability. This has caused drought and flood affecting the food security of agriculture dependent communities and pushed the vulnerable sections (such as small and marginal land holding farmers) to margin. As per the climate change projection for the region, the temperature would breach 2°C barrier by end of the 21st century. Groundwater is highly vulnerable to the impacts of climate change more so through the change in the volume and distribution of groundwater recharge. Groundwater resources are either directly or indirectly vulnerable to the impacts of climate change and temperature. Increase in temperature is an important factor impacting the groundwater table through human stress and high evapotranspiration. The rising temperature may result in greater heat stress for people and ecosystems and it would enhance energy and water drawl, induce drought and impact food security.

Telangana is a semi-arid zone and has a predominantly hot and dry climate. The areas covered by the Deccan Plateau are characterized by hot summers with relatively mild winters. Telangana has historically been prone to drought conditions especially in Rangareddy, Mahabubnagar and Nalgonda districts. Climate is projected to increase drought occurrence in the districts like Nalgonda and Mahabubnagar which would impact not only water resources but also have a cascading effect on other dependent sectors (GIZ, 2018).

Nalgonda district is often cited as a case study of India's worsening water crisis. With fluoride content in its groundwater many times higher than permissible levels and three-fourths of its 25 lakh borewells running dry, Nalgonda is in dire need of water (Telangana SAPCC, 2015).

Smart Aquifer recharge and storage or MAR has been defined as intentional storage and treatment of water in aquifers (Dillon, et al., 2009; Sharma, et al., 2011). MAR can be broadly divided into three main groups (Central Ground Water Board, 2007): surface-spreading, run-off conservation and sub-surface structures (Saphpani, 2011). Proper understanding of the characteristics of rock types help in site selection and designing artificial recharge structures. Managed Aquifer Recharges experiences around the world have shown that it is essential that a good understanding of local hydrogeology is obtained to minimise risks and costs and ensure successful technology implementation. (Saph Pani, 2011). This highlights the importance of site selection for pilot investigations which should be chosen to represent the conditions for developing the aquifer recharge. The area recording high yield has more storage potential and hence there is scope for more recharge to ground water.

Telangana has semi-consolidated porous rock formations mainly comprising of shales, sandstones and limestones. These have moderate to moderately good yield potential upto 28 lps. The Ground Water Master Plan (2013) suggests that percolation tanks with recharge shafts as a measure for artificial recharge are suitable for this region. For the deeper aquifers recharge may be done through recharge tubewells. It is also important to capture the surplus rainfall/ storm water that the area receives. Further studies show that in the Deccan Plateau, where Telangana is located, the percolated water from artificial groundwater recharge was mostly (80%) pumped straight back by neighbouring boreholes, limiting the area of MAR influence but increases the percolation efficiency which can be helpful on the longer run (Massuel et. al, 2014). The contribution of MAR can thus be important in areas where groundwater levels are declining, but in the overall groundwater balance it will play a relatively minor role (Saph Pani, 2011).

Example from Maheswaram, Telangana:

The Maheshwaram watershed is located 30 km south of Hyderabad, the capital city of Andhra Pradesh. For more than 10 years it has been subject to research activities by the Saph Pani project partners under various national and international programs. The activities focussed on Managed aquifer recharge (MAR) through percolation tanks to increase local water availability.

The studies have shown that recharge has been possible and quantified and the advantages include the reduced evaporation losses and higher infiltration, compared to the surface tanks. Infiltration apparently also takes place through the walls of the well that often have horizontal fractures. The percolation tanks clearly enhance groundwater availability during rainy years (when rainfall and aquifer replenishment are naturally above average), but cannot be considered as a solution to bridge groundwater availability during dry years when aquifer replenishment is low. It would further require management of stored water through monitoring of water levels and regulation of groundwater abstraction.

Costs and funding of the measure:

The unit cost of each percolation tank with shaft is taken as Rs.10 lakhs. As per the Master Plan (2013) area equal to 3319 square kilometers is suitable for artificial ground recharge with a total of 275 percolation tanks feasible. To cover the entire district of Nalgonda would then require INR 27.5 crores.

Synergies:

The Mission Kakatiya is focused on restoring all the minor irrigation tanks and lakes in Telangana State, India. The programme aims to rejuvenate existing structures through desiltation as well as build new structures for water storage.

Project Concept:

Implementation of the aquifer recharge techniques in Nalgonda could help through:

- Increase water supply system resilience during low rainfall periods
- Increase freshwater supply for drinking as well as irrigation
- Improvement of water quality with soil passage (dilution of fluoride levels in the shallow aquifers) 18ppm fluoride in some areas
- Reduce potential water losses from evaporation and contamination

However, the Project plan must not solely focus on MAR techniques rather include components of capacity building and behavior change communication of WUA/ VWSC for improving groundwater management at community level.

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7. Annex 1: List of Participants for Consultation workshop organized for TNA discussions at EPTRI

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9	Y. Madhavi	Deputy Director Agriculture	Commissioner and Dept of Agriculture, Hyderabad	
10	Dr. Babu Beri	Director	Veterinary and animal husbandry dept.	
11	Datta Kiran	Consultant	GIZ	
12	J. Rajeswar	Head Climate Change and Environment	ICSD	
13	D. Srikanth	Scientist B	IMD, Hyderabad	
14.	Dr. A. Dharmaraju	Scientist B	IMD, Hyderabad	
15.	Dr. Pandith M.	Director	Ground water department, Hyderabad	
16.	Satish R.	Asst. Professor	IITH	
17.	G. Shankar	Chief Engineer (H&GW)	Department of hydrology and irrigation	
18.	M.M. Sajid	Commissioner CADA	Department of hydrology and irrigation	
19	Nikhilesh Kumar	Co-founder	Vassar Labs, Hyd	
20	T. Ramesh	Research fellow	EPTRI	

21.	M. Durgaprasad	Research fellow	EPTRI	
22.	Banibrata Choudhary	Research fellow	EPTRI	
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