On behalf of:

REPORT

Technology Needs Assessment (TNA)

For climate change adaptation in Punjab

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Abstract

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

A series of consultation on TNA were held in July 2018. TARA, adelphi and Punjab State Council for Science and Technology (PSCST) were responsible for prioritization of adaptation technologies. All relevant departments such as Water Resources, Soil And Water Conservation, Meteorology, Horticulture, Health and Rural Development were a part of the process.

A final prioritization list of adaptive technologies was agreed upon as a result of the consultations with stakeholders, this long-list of fifteen inventoried technologies from both water and agriculture sector was developed. Further, a shortlist was developed using Multi Criteria Analysis (MCA) tools by using the 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 and with help of the guidance of experts from the different departments, all inventoried technologies of each sector were then reduced to three technologies for each, the water and the agriculture sector.

The results for water sector are namely technologies for:

1) Flood Channels in rivers for groundwater recharge
2) Flash flood guidance system
3) Groundwater extraction and monitoring

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

1) Modernization of irrigation system using drip systems
2) Direct seeded rice
3) Capacity building of farmers on agronomical practices(timely transplantation of paddy and collective farming)

As next step, TARA 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.

Contents

List of Figures

List of Tables

List of Abbreviations

CCA	Climate Change Adaptation
CSO	Civil Society Organizations
CGWB	Central Ground Water Board
DSS	Decision Support System
EWS	Early Warning Systems
GIS	Geographic Information System
IEC	Information Education and Communication materials
IMD	India Meteorological Department
MCA	Multi-criteria analysis
MoEFCC	Ministry of Environment, Forest and Climate Change

NABARD	National Bank for Agriculture and Rural Development
NAPCC	National Action Plan on Climate Change
NAFCC	National Adaption Fund on Climate Change
NWM	National Water Mission
PSCST	Punjab State Council for Science and Technology
PSIR	Pressure-State-Impacts-Responses framework
PSAPCC	Punjab State Action Plan on Climate Change
SSAPW	State Specific Action Plan on Water
TNA	Technology Needs Assessment

1. Introduction

1.1 Background

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

During the first phase (2009 – 2014) of CCA-RAI the project, activities focused on the integration of climate change adaptation approaches in sectoral policy decisions and rural development programmes on national and state level. This project’s objective is the integration of climate change adaptation measures into the development planning at national and state level as well as the strengthening of key actors’ capacities in financing, planning, implementing and monitoring 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 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 - if already available: State Specific Action

Plans for Water (SSAPWs) and related documents Throughout the assessment, the consideration of the National Action Plan on Climate Change (NAPCC) and the National Water Mission ensures that the results comply with national policies.

1.2 TNA Process

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

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

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

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

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

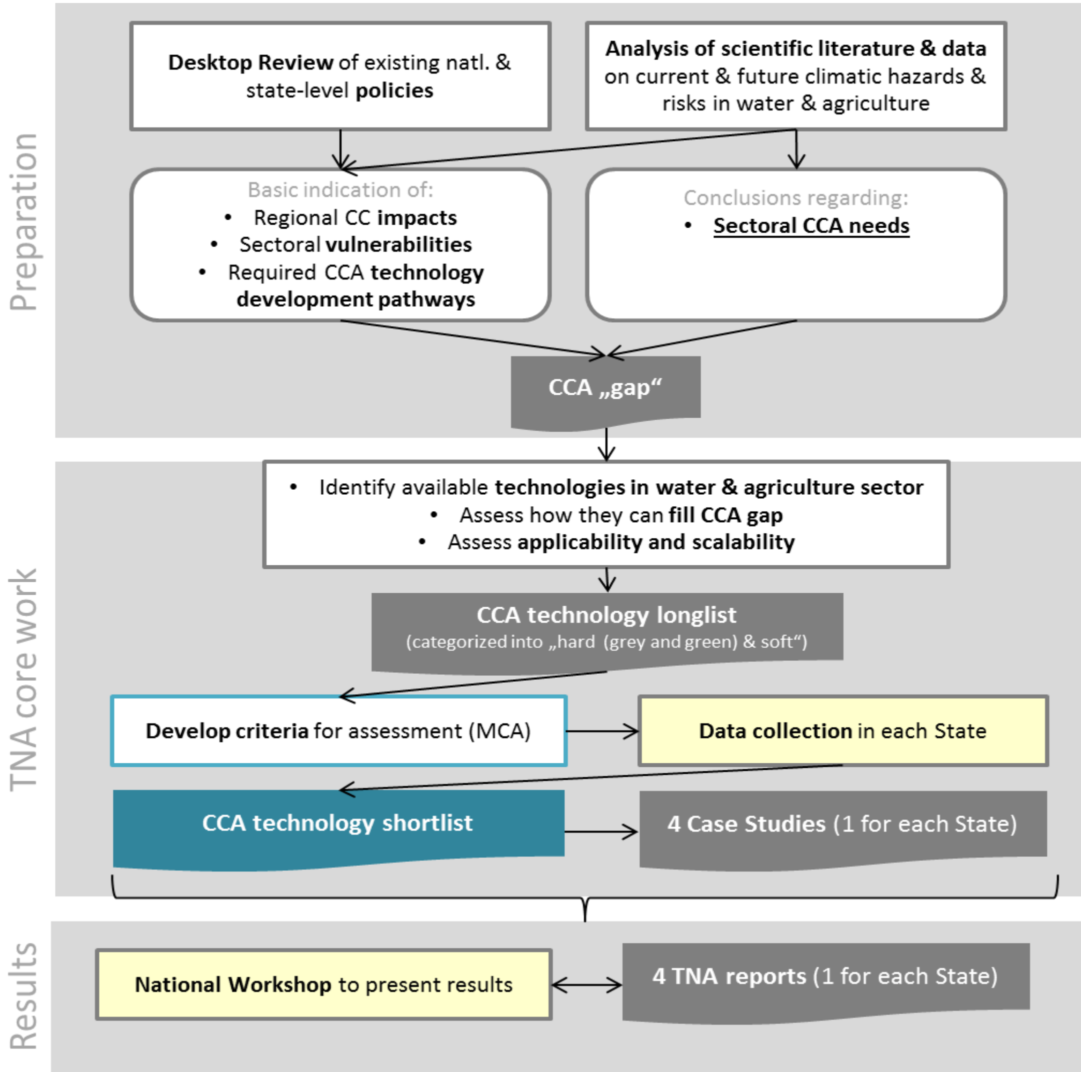

Figure 1: TNA process for this project

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

1.3 Institutional arrangement for the TNA and the stakeholder involvement in Punjab

A series of consultation on TNA were held in July and November 2018. All relevant Departments (Agriculture, Rural development and Panchayat Raj, dept. of fisheries, water resources, soil and water conservation,health,animal husbandry, meteorology) were consulted in order to finalize the technologies and develop the long list and the shortlist.

Figure 2: Stakeholder Consultation in Punjab

Source: Development Alternatives

Identification of development priorities of Punjab 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.

2. Vulnerability Assessment of Punjab

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

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

Understanding the climate technology needs of a country is a good starting point for effective action on climate change. IPCC Fifth Assessment Report defines vulnerability to climate change broadly as follows: "The propensity or predisposition to be adversely affected.

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

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 Punjab (done by GIZ / INRM, 2017) and analyses what are the CCA gaps and which element of **climate vulnerability (**defined by the three dimensions of exposure, sensitivity and adaptive capacity**)** can possibly be addressed at present but also in the future. It further analyses to which extent **technological solutions** are already in place to reduce vulnerability and what are other possible technological solutions for Punjab. 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 Punjab

Geography and Location

The state of Punjab covering an area of 50,362 sq km., is located in north-western India between latitudes 29.30 N to 32.32 N and longitudes 73.55 E to 76.50 E. The state is bordered by Jammu and Kashmir in north, Himachal Pradesh in northeast, Haryana in south, and Pakistan in west. The state presently has 5 division, 82 sub divisions and 22 administrative districts.The state is subdivided into three parts namely Malwa, Majha and Doaba. Malwa region covers major part of the state and comprises of cities like Ludhiana, Patiala, Sangrur, Bathinda and Mohali. The main districts of the Majha region include Amritsar, Gurdaspur and Tarn Taran. Doaba is one of the most fertile regions in the state and was the centre of the Green Revolution in India, This region includes some big cities such as Jalandhar, Kapurthala, Hoshiarpur, Nawanshahar and Phagwara. As of 2011, Punjab has 22 districts and a population of 27.7 million (Census, 2011). The state is predominantly an agrarian state and more than 62% of the population lives in rural areas.

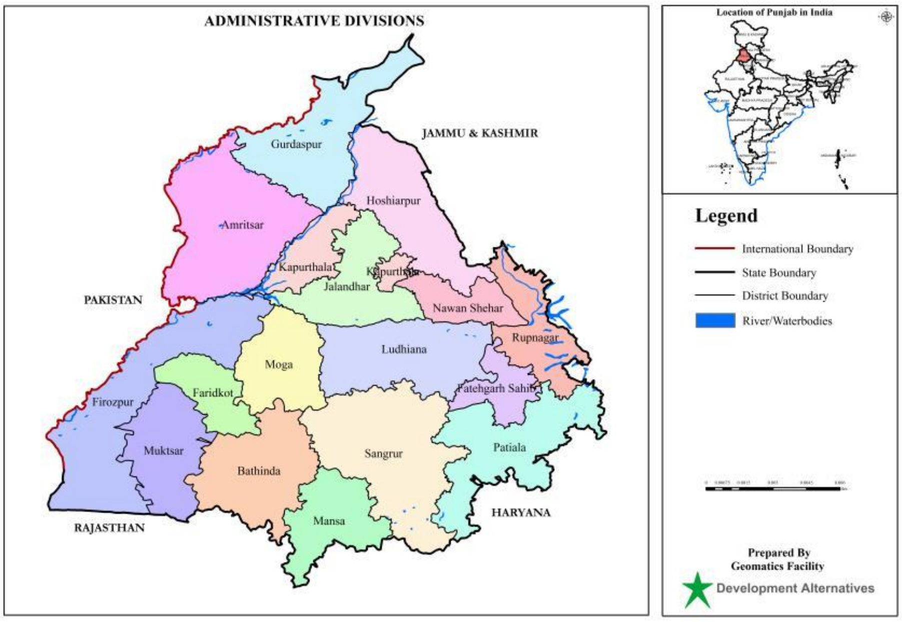

Figure 3: Map of Punjab highlighting surface water resources (Rivers/waterbodies)
Source: Development Alternatives

Climate and Temperature

The climate of Punjab is mainly influenced by the Himalayas in the north and the Thar Desert in the south and south-west. The periodic circulation of the moist air masses from the south-east and north-western sectors decides the occurrence of two wet periods each followed by a dry period. The presence of Himalayas in the north greatly modifies the temperature. As the distance from the Himalayas increases the temperature also increases, whereas rainfall decreases. In general, summers are hot and winters are cool.

Long term monthly (1951-2013) maximum and minimum temperature summary of Punjab state is shown in Table 1. Mean annual maximum temperature for Punjab is 29.8°C with a range varying from 28.2°C – 31.0°C (GIZ / INRM, 2017).

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

Source: GIZ / INRM (2017)

State	Periods	Maximum Temperature			Minimum Temperature		
		Average (°C)	Range (°C)	CV	Average (°C)	Range (°C)	CV
Punjab	Annual	29.8	28.2-31	0.017	16.0	15.2-17.2	0.029
	Winter (JF)	20.3	18.2-23.1	0.055	6.2	4.3-9	0.137
	Pre Monsoon (MAM)	32.9	29.1-36.7	0.039	17.2	15.4-19.5	0.051
	Monsoon (JJAS)	34.7	33.5-36.9	0.019	24.1	23.2-25.1	0.019
	Post Monsoon (OND)	26.5	22.7-27.8	0.032	10.7	9.1-12.3	0.072

The districts in the Western Zone namely, Moga, Bhatinda, Mansa, Muktsar and Sangrur shows relatively higher maximum temperature as compared to the districts in the other parts of the State in all four seasons.

The districts in the Western and Western plain Zone namely, Firozpur,Moga, Bhatinda, Mansa, Muktsar and Sangrur shows relatively higher minimum temperature as compared to the districts in the other parts of the State in all four seasons as can be observed. Temperature is increasing from North to South.

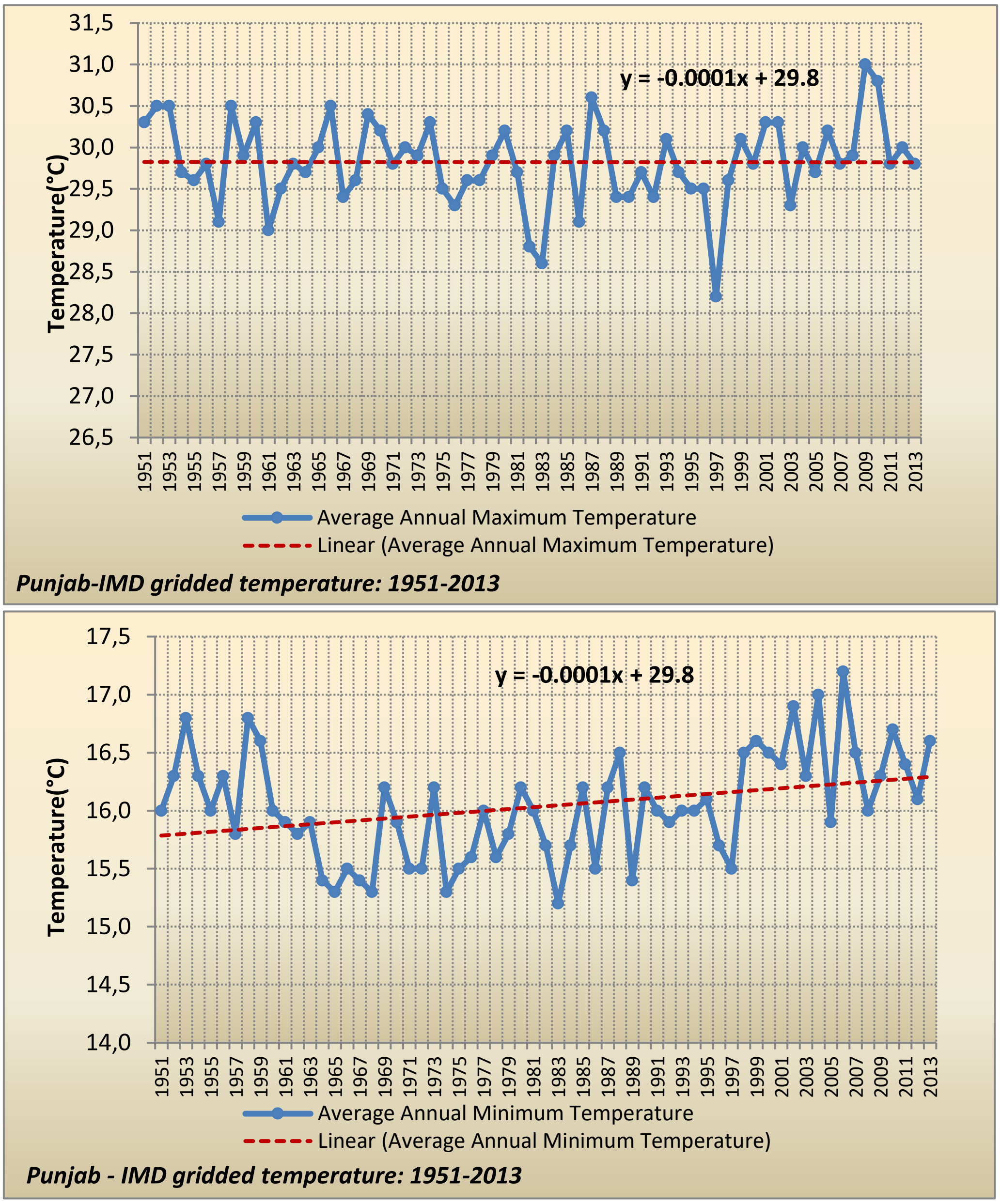

Figure 4: Observed average annual maximum and minimum temperature of Punjab (1951-2013)

Source: GIZ / INRM (2017)

There is not much temporal variation observed across the districts of Punjab in maximum and minimum temperature as is evident from the mean maximum and minimum temperature (GIZ / INRM, 2017). However, variability in minimum temperature is higher than that of the maximum temperature.Temporal variability in North districts of the State is little higher as compared to the other districts for minimum and maximum temperature.

As per the interpretation of Figure 3, there is a positive trend in both mean annual maximum temperature and mean annual minimum temperature is observed for Punjab State.The change per year for annual maximum temperature is negligible while for annual minimum temperature is 0.01°C (GIZ / INRM, 2017). It shows a positive trend for annual maximum temperature is statistically not significant while for minimum temperature trend is statistically significant. (GIZ / INRM, 2017).

Rainfall

Average annual rainfall of Punjab State is 707.4 mm with a range varying from 332.3 mm - 1304.9 mm over the 63 years period (1951-2013) (GIZ / INRM, 2017). The coefficient of variation in annual rainfall lies in the range of 0.21 to 0.36 (21% to 36%) across the districts of Punjab thus marginal variability is observed across the districts (GIZ / INRM, 2017).

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

Source: GIZ / INRM (2017)

State	Season	Average Rainfall (mm)	Range (mm)	Inter-annual variation	Contribution to Annual Rainfall (%)
Punjab	Annual	707.4	332.3-1304.9	0.30	
	Winter (JF)	56.5	4.9-181	0.73	8.0
	Pre Monsoon (MAM)	58.7	7.7-226.1	0.77	8.3
	Monsoon (JJAS)	553.6	192.8-1150.8	0.35	78.3
	Post Monsoon (OND)	38.7	0.1-387.8	1.60	5.5

Rainfall analysis for the period 1951-2013 in Figure 4 shows a negative trend and rainy days shows positive trend for Punjab State. However, as per GIZ / INRM (2017) the trend is statistically not significant for annual rainfall and rainy days. Thus assuming that rainfall has decreased but rainy days have increased it implies that the intensity of rainfall has decreased over the period for the State (GIZ / INRM, 2017).

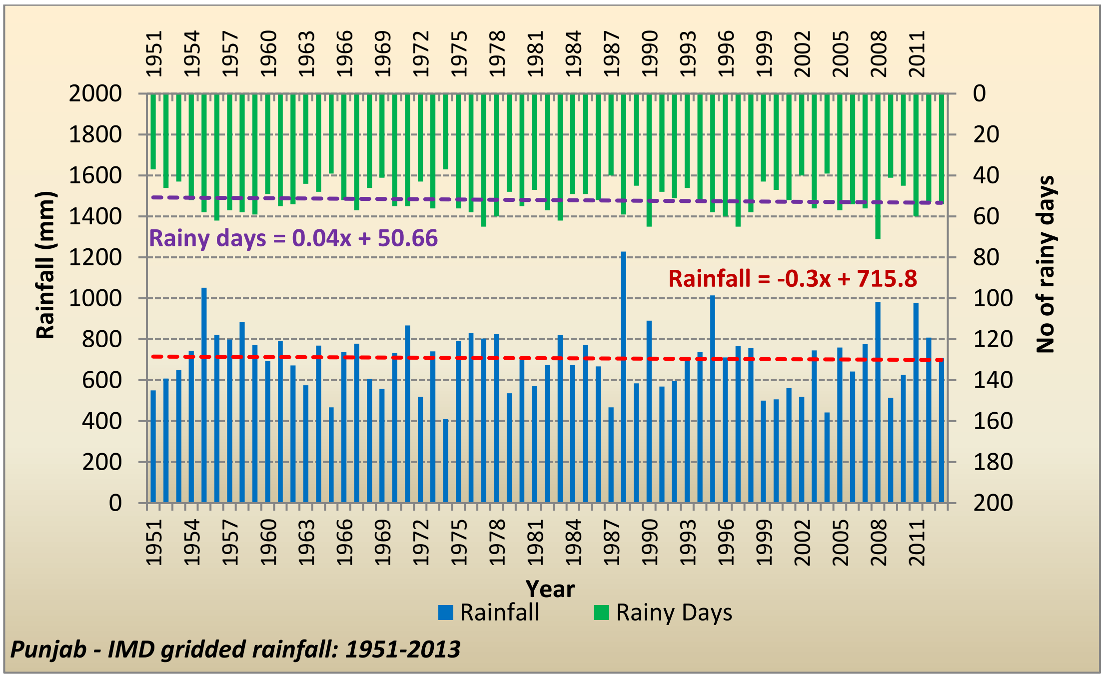

Figure 5: Observed annual rainfall and number of rainy days for Punjab

Source: GIZ / INRM (2017)

Projected Climate Change Scenario

The CORDEX South Asia modelled climate data on precipitation, maximum temperature, minimum temperature and 21 climate extremes indices have been analysed for Punjab State and its 20 districts 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 has been used. The CORDEX South Asia simulations with the models indicate an all-round warming over the study area.Projected increase in temperature and precipitation towards end-century is higher than that towards mid-century. The summary for three time periods-BL, MC and EC is as follows:

- Average annual maximum temperature for IPCC AR5 RCP4.5 scenario is projected to increase by about 1.2°C towards mid-century and by 2.1°C towards end-century and the average annual minimum temperature is projected to increase by about 1.3°C towardsmid-century and by 2.5°C towardsend-century (GIZ / INRM, 2017).
- Average annual rainfall for IPCC AR5 RCP4.5 scenario is projected to increase by 5.4% towards mid-century and increase by about 12.5% towards end-century while for IPCC AR5 RCP8.5 scenario it is projected to increase marginally by about 9.8% towards mid-century and 12.8% towards end-century for the State. Thus the percentage of the projected rainfall increase is low towards MC and EC for both the climate scenarios (GIZ / INRM, 2017).

Water sector

The state of Punjab constitutes 1.5 percent of India’s land area but produces nearly 20 percent of the nation’s wheat and 12 percent of its rice (PSAPCC, 2012). The state has highest acreage of irrigated land. Primarily an agrarian state, the highest proportion of water in the state is used for agriculture purpose which is more resource intensive in Punjab due to the annual rice/wheat cropping. The state is endowed with rice water resources traversed by four major rivers, i.e. Sutlej, Beas, Ravi and Ghaggar.The total stretch of these rivers is about 1830 km (PSAPCC, 2012). The wetlands, lakes and ponds scattered all over the State constitute an important part of the State’s surface water resources. The average number of glaciers that feed into the Sutlej river is estimated to be 935 covering an area of 1234 sq. kms with an estimated ice volume of 77 NCM. (PSAPCC, 2012)

Punjab has a developed and interlinked 14500 kms long Canal System. This system is more than a century old. The upper Bari Doab Canal from river Ravi at Madhopur, Sirhind Canal from river Sutlej at Ropar, Eastern Canal & Bikaner Canal from river Sutlej at Hussainiwala headwork date back to pre-independence era. The seven canal systems constituting Sirhind Canal System, Sirhind Feeder System, Eastern Canal System, upper Bari Doab Canal System, Bhakra Canal System, Bist Doab System and Shah Nehar System together have a culturable command area (CCA) of 30.88 lakh ha. (Water resource development and management in Punjab, 2018)

Table 3: Details of main canal system in Punjab

Source: Department of Irrigation, Govt. of Punjab

Sr. No.	Name of Canal system	Length in KM of Main Canal	Discharge at Head in Cs	CCA lac Hectare
1	Sir hind Canal	59.44	12620	13.59
2	Bist Doab Canal	43.00	1408	1.99

3	Upper Bari Doab Canal	42.35	9000	5.40
4	Sir hind Feeder	136.53	5264	3.60
5	Eastern Canal	8.02	3197	2.16
6	Bhakra Main line	161.36	12455	3.81
7	Shah Nehar Canal	24.23	875	0.33

Punjab is dotted with a large number of large and small lakes, ponds and pools which are an important part of the State's surface water resources. A large number of pools of water are found in the intervening tracts of the Sutlej and the Buddha Nala. Some of these have a linear shape and have a length of about 2-3 kilometers in each case. These water bodies are the remnants of the abandoned channels of the major streams. Also, a number of ox-bow lakes are found in the abandoned courses of the Sutlej. The ponds, which are sporadically distributed over the whole of the upland plain, are local depressions filled with rainwater; they are used for bathing the cattle, and for providing drinking water to them. The State has 4952 village ponds which includes 1821 ponds having an area of more than 2.5 ha each and 3131 ponds with an area less than 2.25 ha. (N.S. Tiwana, 2007)

Ground Water Resources of the State

Due to failure in monsoon and economic pressure on groundwater in the region increased fast, this resulted in deeper water levels. Excessive drilling of groundwater has resulted in drying up of many old aquifers which may take many years to recharge. 79 percent of the groundwater assessment divisions (blocks) in the state are now considered 'over exploited' and 'critical' with extraction exceeding supply. (Columbia Water Centre, Earth institute, n.d.)

Groundwater resource estimation of Punjab state has been carried out as per GEC 1997 methodology shows that the net ground water resources of Punjab State are 20.35 BCM, whereas net draft was 34.66 BCM, leading to ground water deficit of 14.31 BCM. The state of ground water development for the State was 170% and the State as a whole falls under **"over exploited"** Category. The status of the State's Ground Water Resources is provided in table 4 (CGWB, 2010)

Table 4: Status of Ground Water Resources of Punjab

Source: CGWB, 2010

Dynamic Ground Water Resources	
Annual Replenishable GW Resource	20.35 BCM
Net Annual GW Availability	34.66 BCM
Annual Ground Water Draft	14.31 BCM
Ground Water Deficit	9.719 BCM
Stage of Ground Water development	170 %
Ground Water Development & Management	
Over Exploited	64 blocks in 1964; 110 Blocks out of 138 blocks in 2009.
Critical	3 Blocks in 2009
Semi-critical	2 Blocks

Additional Ground water problems	
Water logged area	200,000 ha
Water contamination level	
Salinity (EC > 3000 μS/cm at 25 ° C)	Firozepur, Faridkot, Bathinda, Mansa, Muktsar, Sangrur(Area ~1 million ha)
Fluoride (>1.5 mg/l)	Amritsar, Bathinda, Faridkot, Fatehgarh Sahib, Firozepur, Gurdaspur, Mansa, Moga, Muktsar, Patiala, Sangrur.
Chloride (> 1000 mg/l)	Firozepur, Muktsar.
Iron (>1.0 mg/l)	Bathinda, Faridkot, Fatehgarh Sahib, Firozepur, Gurdaspur, Hoshiarpur, Mansa, Rupnagar,Sangrur.
Nitrate (>45 mg/l)	Bathinda, Faridkot, Fatehgarh Sahib, Ferozepur, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Mansa, Moga, Muktsar, NawanShaher, Patiala, Rupnagar, Sangrur

In terms of groundwater resources, the Dynamic Groundwater Resources Report 2011 of the Central Groundwater Board has made the following observation :

- Though replenishable resources is abundant but there has been indiscriminate withdrawals of ground water leading to over exploitation.
- Decline in water level of more than 2 m has been observed due to deficient rainfall. The Groundwater Year Book (2013-14) mentions that in some pockets, more than 4 m fall has been observed while in some areas rise in the range of 2-4 m has been observed. In terms of water level fluctuation decadal mean (Aug/Nov 2002- 2012; Jan 2004 to Jan 2013), Punjab has seen decline in water levels by more than 4 m (Central Ground Water Board, 2014)
- The Stage of Groundwater development is more than 100%, which implies that in the states the annual ground water consumption is more than annual ground water recharge.
- Number of Over-exploited and Critical administrative units are significantly higher (more than 15% of the total assessed units).
- The reason for over-exploitation is indiscriminate extraction of ground water mainly for irrigation purpose.

The main pressures on water resources in Punjab can thus be summarized as follows:

1. Depleting water Table due to over extraction

The estimated Net Annual Ground Water Availability of State has been assessed to be 21.44 bcm. Net annual draft of the State has been estimated to be 31.16 bcm. The present ground water development in the State is 145%. Out of 137 blocks, 103 blocks are overexploited, 5 blocks are critical, 4 blocks are semi critical and only 25 blocks are in safe category (CGWB, 2010).

2. Severe water logging and salinisation

The state has distinct hydrogeological settings**,** high yielding fresh groundwater region in the northern and central districts and saline groundwater region in the south western districts.

The south western districts irrigated by the sirhind canal such as Muktsar, Fazlika,Bhatinda and Faridkot mostly faces severe problem of water logging and increase salinity. Seventy percent of the south western region are canal irrigated but there is prevelence of excess irrigation in these areas and recharge from irrigation distribution network causes rise in water table in these regions. This causes salt to rise in these regions due to capillary action resulting in high salinity. This hinders the growth of crops growing in the water logged conditions as the soil pores in the root zone gets saturated and restricts normal aeration at the root zones. As per the govt. Reports there are about 2 lakh ha of land that is water logged and have become unproductive (Report Of The High Level Expert Group on Water Logging in Punjab, 2013)

3. Groundwater contamination

The state tops the list of having higest quantity of Nitrates, Cadmium and Chromium. Punjab accounts for 88 percent of the total habitations in the country that are adversely affected with presence of heavy metals. Though no single point of source for these contamination has been identified, howver, the most significant and widespread source of contamination is discharge from agricultural and urban wastelands which has high concentrations of nutrients, metals, pesticides,micro organisms and other organic chemicals. (Gupta, 2014)

4. Contamination of water bodies with industrial effluents

Industrial effluents generated from the 5 mega towns of the state i.e. Ludhiana, Jalandhar, Amritsar, Bhatinda and Patiala pollutes the natural environment besides that a huge amount of municipal solid waste is being generated and disposed off into water bodies without treatment. High concerntration of heavy metals such as lead, cadmium, chromium, copper, cynide and nickel has been found around the industrial hubs like Ludhiana, Amritsar, Kapurtala and Mandi Gobindgarh. Study conducted by ICMR (Indian Council of Medical Research) has indicated high incidence of cancer disease in the Malwa region which is the highest fertilizer consuming region of the state. (Suneel Pandey, 2015)

5. Low water use efficiency

The overall efficincy in surface irrigation like canals and tanks is only 38 percent. Though 73% of area is irrigated by tube wells but large portion of these water resource is going waste without being utilised judiciously. The water use efficiency for groundwater is only 55 percent and for drinking water is 60 percent which is much lower as compared to the international standards which are 75 percent and 90 percent respectively. (Sharma, 2015)

6. Floods

Flash floods are common in all the major river basins in India, the state of Punjab has seen two major floods during 1993 and 1998 and it faces floods in varrying intensity every year. According to the State Disaster Management Plan (SDMP) report 2010-11, the area affected by floods in the year 1960 was around 4,638 sq. kms which increased to 218,337 sq. kms in 2010. The intensity has significantly increased owing to the effect of climte change and associateed variability in the monsoons. The southern areas of Punjab being the most vulnerable to flash floods. The flooding may be attributable to poor maintenance of embankments,poor maintenance of canals,inadequate drainage systems, lack of early warning systems and lack of vegetative covers (SDMP, 2011) .

Agriculture Sector

Agriculture sector is the highest contributor of Gross State Domestic Product of Punjab. Agriculture is the principal source of livelihood for more than 80 percent of the population for Punjab. The major crops of the state are wheat, rice, sugarcane, bajra, potato and groundnut. Around 2 million tons of wheat is being produced in the state every year which is 20 percent of the total annual production of wheat of India.

The total cropped area of the state is 7,875 ha, 83 percent of its area is under cultivation with cropping intensity of 189 percent. The annual per capita availability of water in India is about 1,545 cubic meters. The central groundwater board has categorized Punjab as over exploited state with 84.1% of the assessed units in overexploited critical or semi critical state. Though there has been an increase in number of water resources still there is a water deficit of 1.28 M ha m (Gupta, 2014).

The decline in ground water table across the State is a matter of serious concern. As a result, out of 138 blocks, 93 blocks are in the dark category. With continuous rotation of wheat and paddy based cropping pattern, the soil and water quality has degrated and depleted (PSAPCC, 2012). Increase pressure on the soils for higher production has resulted in loss if soil fertility and natural coping capacity to tolerate stress due to disease and pest infestation.

Low water use efficiency, indiscriminate use of chemicals and inadequate maintenance of irrigation systems are some of the major problems that confront the management of water resources in the State. There is a need to micro-irrigation techniques, alignment of cropping patterns with the availability of water, encouraging direct seeded rice and greater involvement and empowerment of community groups that can work towards improvement in water use efficiency. The groundwter will continue to be used to enhance the agriculture production, ensuring food security by meeting the food demand of the country, however, it would be equally importatnt to restore sustainability in farming systems through a change in cropping pattern, ensure quality monitoring and make conjunctive use of surface and groundwater (PSAPCC, 2012).

2.2. Relevant National Policies, Plans and Programmes

While there are multiple vulnerabilities listed, there are relevant policies, plans and programmes that the Punjab 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 5: National level policies and their implication for the TNA

Year	Policy	Water	Agriculture	Implications for TNA (specific technologies)	Funding options under this policy
2002	National Water Policy	✓			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
2014	Transbasin diversion of rivers	✓		Aims to address the reduction in flow in the Ravi-Beas rivers systems and receding groundwater table	
2006	Pradhan Mantri Krishi Sinchai Yojana			• improve on-farm water use efficiency to reduce wastage of water • enhance the adoption of precision-irrigation and other water saving technologies (More crop per drop)	Total allocation of Rs 50 thousand crore (2016-2020) , Treatment of dark zone areas Rs 410 crores

				• enhance recharge of aquifers introduce sustainable water conservation practices	
2006	Centrally sponsored scheme on micro irrigation under PMKSY	✓	✓	Drip and sprinkler irrigation system, subsidy for installation of micro irrigation systems	
2008	Surface water Monitoring under the MINAR(Monitoring of Indian Aquatic Resources) scheme (National Water Quality Monitoring)	✓		• Organic pollution of water bodies Monitoring water quality	
2015	Rashtriya Krishi Vikas Yojana	✓	✓	providing soil health care assistance; • promoting Micro Irrigation to increase water use efficiency; • increasing cropping and irrigation intensity	

2.3. Relevant State Level Projects and Schemes

This section elaborates few of the key existing projects and schemes of the Government of Punjab for addressing problems of irrigation, drinking water and agriculture

Table 6: State level policies and their implication for the TNA

Year	Policy	Water	Agriculture	Implications for TNA (specific technologies)	Funding options under this policy
2000-01	Accelerated Irrigation Benefit Programme	✓	✓	• In 2018, current irrigation potential of Rehabilitation of Ist Patiala Feeder and Kotla Branch Project in Punjab. Target irrigation potential: 68.82 tha	
2008	Punjab State water policy	✓	✓	• Artificial recharging of groundwater • Interlinking of rivers within the state • Cloud seeding • Rainwater harvesting • Desalination for coastal belts • Watershed management • Flood forecasting and flood plain zoning • Management Information System (MIS) for water resources • Equitable distribution/water sharing mechanisms • Agronomic practices/change in cropping patterns	
2008	The Punjab Water Mission	✓	✓	• integrated water resource management at a basin level within the state for conserving water, minimizing wastage and for ensuring equitable	

				distribution of the resource. • focused approach to augment ground water especially in problematic/over exploited areas • Manage water use efficiency • Establish adequate institutional support for efficient water resource augmentation, conservation, distribution and governance through development of basin level Integrated Water Management plans.	
2008	Punjab Mission on sustainable Agriculture	✓	✓	• Promote crop diversification, manage resource residue • Promote resource conservation of soil, water and energy • Develop cultivars and germplasm	
2009	Accelerated Rural water supply programme	✓		• Access to safe and clean drinking water in rural areas • Control on over extraction of groundwater • Traditional water management practices	
2009	Punjab Preservation of Subsoil Water Act		✓	• Regulation of transplantation dates for paddy to preserve subsoil water	
2015	Green Punjab Mission		✓	• Research and focus on agroforestry promotion • Undertake capacity building activities to integrate scientific principles of forest management in working plans and management plans	

				• Strengthen biodiversity conservation measures in the forests.	
2015-16	Project for promotion of micro irrigation in Punjab , NABARD	✓	✓	• Addl. 25% Subsidy in addition to GOI subsidy of 50% is being provided to farmers for installation of Drip, Micro Sprinkler & Sprinkler Irrigation systems in all districts.	
2016	NABARD Scheme for construction of sub surface drainage	✓		• Control of flood and water logging • Construction of inceptor drain, feeder drain	

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 7: Key Impacts of Climate Change in Water and Water in Agriculture Sector

CC Impact	Description of CCA Gap	Possible Solutions/ technologies	Element of Vulnerability Addressed	Technology Code
Flood: Punjab is the most vulnerable state to floods (Flood vulnerability Index, 2018). Floods cause substantial damage to the land, percolation of standing water takes a lot of time, leading to water logging and salinity. The water logging in the south western region of Punjab has intensified due to heavy precipitation.	Extreme events like floods not only result in economic loss but loss of the life and livelihoods. Water logging condition prevails due to excess surface water. Excess precipitation results in runoff as the soil becomes saturated, it may also carry untreated pollutants such as sediments, residues, pesticides etc. into the surface water bodies. With heavy precipitation likelihood of flash floods may increase.	• Flash flood guidance systems for forecasting and early warning which can be used to predict potential flash floods and thus enhance preparedness	Reduce exposure, reduce sensitivity, increase adaptive capacity	W6
		• Flood channels in rivers for groundwater recharge	reduce sensitivity, reduce exposure	W7
		• Storm water harvesting in plain region	Reduce sensitivity, reduce exposure	W2

CC Impact	Description of CCA Gap	Possible Solutions/ technologies	Element of Vulnerability Addressed	Technology Code
Groundwater depletion: Impact on the aquifer and surface source due to over extraction thus affecting the natural water balance	Excessive drawing of groundwater degrades the water balance between groundwater and surface water recovery.	• Conjunctive use of surface and groundwater	Increase adaptive capacity	W5
		• Groundwater extraction and monitoring	Reduced exposure	W4
		• Storm water harvesting in plain regions	Reduce Exposure, Increase adaptive capacity	W2
Variability in Rainfall and droughts: Spatial variation in precipitation is observed in the state with some areas receiving higher rainfall and some areas with deficit rainfall. Drought days have extended by 23-46 days within the lower Sutlej basin (PSAPCC, 2012)	Climate shifts and shift in precipitation intensity will affect groundwater continuity thus altering groundwater recharge.	• Construction of groundwater recharging structures such as check dams, recharge shafts, farm ponds etc.	Increase adaptive capacity	W3
		• Rainwater harvesting from surface and roof tops	Increase adaptive capacity	W1
Low water use efficiency in agriculture	Inadequate irrigation infrastructure; Poor early warning systems; Non-use of less water intensive crops; Lack of awareness on water efficient technologies and its dissemination; Lack of incentives for growing water efficient crops/adopting efficient technologies	• Modernization of irrigation system using drip systems	Reduce exposure, reduce sensitivity	WA1
		• Capacity building for farmers on agronomical practices (timely transplantation of paddy, collective farming)	Increase adaptive capacity	WA2

CC Impact	Description of CCA Gap	Possible Solutions/ technologies	Element of Vulnerability Addressed	Technology Code
		• Recycled waste water use for agriculture	Increase adaptive capacity	WA4
		• Direct seeded rice	Increase adaptive capacity	WA5
		• Alternate cropping system: discourage rice wheat based cropping pattern, promote millets, pulses	Increase adaptive capacity	WA6
		• Introduce pricing regulation for use of irrigation water and energy	Reduced exposure	WA3
		• Irrigation efficiency and information systems using precision tools	Increase adaptive capacity	WA7
		• Soil conservation measures to prevent erosion(Conservation tillage)	Increase adaptive capacity	WA8

4. Prioritising: Shortlist of CCA technology options

Water resources, already under pressure as a result of growing water demand in relation to a finite supply, will be under even greater pressure in the future as a result of climate change. This is a result of (but not limited to) three factors: the projected decrease in rainfall, decreased availability resulting from over extraction, and the amplifying effect that it has on the overall ecosystem.

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 water use efficiency in agriculture sector is particularly important in Punjab's context which is by far the largest consumer of water. Thus the improvement in efficiency through change in practices such as direct seeding instead of transplanting in paddy to building resilient farming communities by building their capacities to reducing the water loses by use of modern irrigation systems.

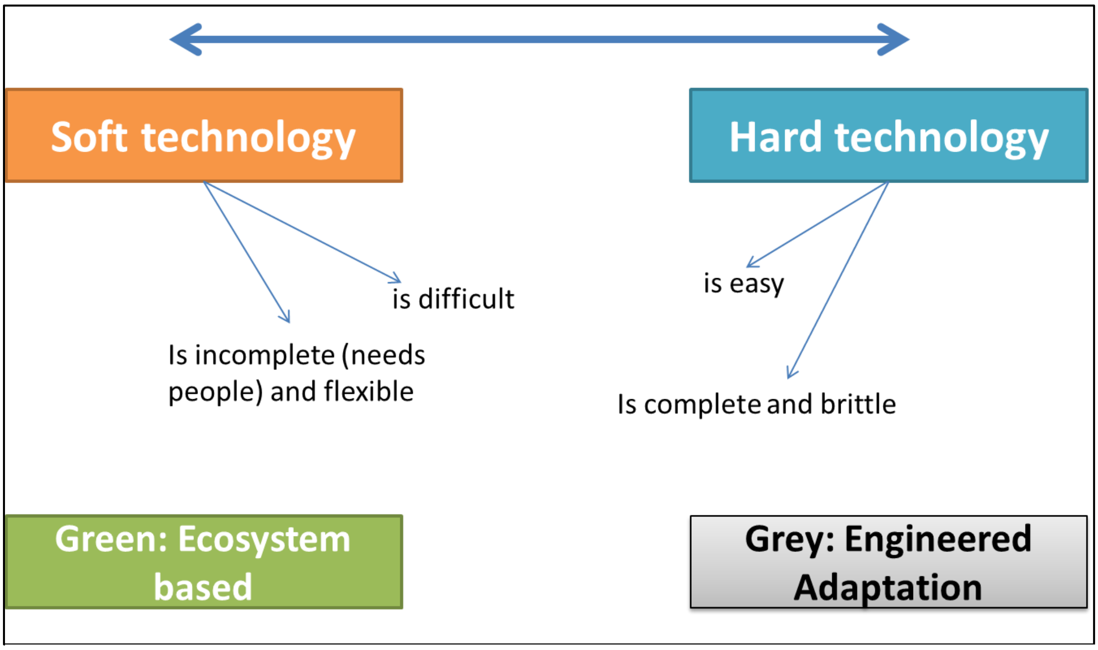

Figure 7: Types of Technologies

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 8: Long list of Technology Solutions

Water	Code	Type
Rainwater harvesting from ground surface and rooftop	W1	Hard
Storm Water harvesting in plain region	W2	Hard
Construction of ground water recharging structures such as check dams, recharge shafts, farm ponds, etc.	W3	Hard
Groundwater extraction and monitoring	W4	Hard/Soft
Conjunctive use of Groundwater and Surface water	W5	Soft
Flash Flood guidance system	W6	Hard/Soft
Flood Channels in rivers for groundwater recharge	W7	Hard
Water in Agriculture Sector		
Modernization of Irrigation system using Drip, Sprinklers systems	WA1	Hard
Capacity building for farmers on agronomical practices (Timely transplantation of paddy and collective farming)	WA2	Soft
Introduce Pricing regulation for use of irrigation water and energy	WA3	Soft
Recycled waste water reuse for agriculture	WA4	Hard
Direct seeded Rice	WA5	Soft
Alternate cropping system: discourage rice and wheat crop, less water intensive pulses, millets etc.	WA6	Soft
Irrigation efficiency and information systems using precision tools	WA7	Hard
Soil conservation measures to prevent erosion (Conservation tillage)	WA8	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

Rainwater harvesting from ground surface and rooftops: 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.

Storm Water harvesting in plain region: Storm water is water from any form of precipitation, rain, melting snow, hail or sleet that 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 storm water 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. (Gibb, 2013).

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

Groundwater extraction and monitoring: Groundwater monitoring involves various methods to locate suitable quality and quantity groundwater for extraction. Prospecting and extraction methods depend on the desired water quality and its final utilization, and can include hydrogeological investigations, geophysical surveys, remote sensing assessments, and the more simple method of investigating already existing well sites in the area and their depths and characteristics. These analyses in particular look at remote sensing data from satellites that provide planners with information on geophysical conditions that can be linked to Geographical Information Systems (GIS) to map and identify potential prospecting zones. (UN Environment – DHI, CTCN, UNEP DTU, 2017).

Conjunctive use of surface and ground water: 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). The conjunctive use leads to more resilience as the system does not depend on only one source.

Flash flood guidance systems: Flash flood guidance systems are specialized forecasting and early-warning systems for flash floods. Flash floods occur on short time and spatial scales, which makes them challenging to predict using traditional flood forecasting methods, such as monitoring river water levels. Flash floods are very quickly formed making them more deadly than any other type of flood. Flash flood guidance systems are designed to provide forecasters with data that allows them to predict a potential flash flood (usually a few hours before it hits), and produce an early warning to increase preparedness (UN Environment – DHI, CTCN, UNEP DTU, 2017).

Flood Channels in rivers for groundwater recharge: In Punjab, the river basin is characterized by large intra-seasonal variations in discharge, resulting in frequent floods and low discharge in dry periods. This technology allows for developing flood carriers in these rivers that carry the excess water, during floods to areas with less water. This allows the flooding river water to eventually connecting areas where there is low chance of flooding; further augment the aquifer through developing groundwater recharge structures at the ends of the flood carriers.

Description of Suggested Technology Options To Address CCA in Agriculture Sector

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

Capacity building for farmers on agronomical practices (delay in transplantation of paddy and collective farming): To escape the period of high evapotranspiration demand, the government of Punjab through the sub soil water act 2009 has enforced a mandatory delay in transplanting paddy beyond 10th June to conserve groundwater resource. This would save water from overdraft during the months of very high temperature (March-May). Collective farming and communal farming are various types of "agricultural production in which multiple farmers run their holdings as a joint enterprise." That type of collective is often an agricultural cooperative in which member-owners jointly engage in farming activities.

Introduce pricing regulation for use of irrigation water and energy (Progressive pricing): Introducing a Regulatory framework on the energy consumption and water use in irrigation sector in form of pricing may limit the abstraction from shallow aquifers. It is required to maintain a sustainable water extraction regime from shallow aquifers that do not exceed the recharge rate. One key to control the balance is by enforcing suitable pricing regulation combined with improved groundwater management mechanisms which includes elements of monitoring and scientific assessments. The pricing regulations may follow a progressive pricing. This is an instrument to manage water demand and help reduce excessive consumption through an economic dis incentive (UNEP-DHI-Centre on water and environment, 2017)

Recycled waste water reuse for agriculture: water reuse is the use of treated wastewater (or reclaimed water) for a beneficial purpose. (Asano et al., 2007). water reclamation and reuse contributes to climate change adaptation by allowing water resources to be diversified and conserved. Using reclaimed water for applications that do not require potable water can result in greatly decreased depletion of protected water sources and prolong their useful lifespan. water can be recycled and applied to permeable land surfaces or directly injected into the ground for the purpose of recharging groundwater aquifers and preventing saline intrusion in coastal areas.

Direct Seeded Rice: Direct seeding is the use of pre germinated seeds or seedlings directly planted in field or broadcasted in flooded field. Metra-Corton et al., (2000) showed that direct seeding resulted in a 16-54% reduction in methane emissions compared to that of transplanted rice seedlings.Direct seeding technique has proven to be less labor intensive than the transplanting techniques (Climate Tech wiki , n.d.)

Alternate Cropping system: Alternate cropping system refers to the cultivation of other less water intensive crop rather than the traditional rice wheat based cropping patterns. Addition of new crops to the farm taking into account the different return from the value added crops to the complementary marketing opportunities is an adaptation strategy against climate change. Growing less water intensive crop and resilient crops helps farmers to save input cost incurred during irrigation. Further changing climate can directly affect the productivity of crops thus it would be necessary to redesign alternative cropping system at ecosystem level by effectively utilizing the natural resources and stabilizing farm returns and productivity.

Irrigation efficiency and information systems using precision tools: Precision farming tools can complement crop diversification as well as enhance irrigation efficiency by matching agricultural inputs (water) and practices based on exact need of the crop at a particular stage while minimizing the losses by improving accuracy and efficiency of inputs. Precise application helps in protecting the soil health and environment.

Soil conservation measures to prevent erosion (Conservation tillage): The main objective of soil moisture conservation is to minimize the amount of water lost from the soils through evaporation (water loss directly from the soil) and transpiration (water loss occurring through the plants) – or combined, the evapotranspiration. Preserving the soil moisture helps in minimizing the irrigation needs of crops. Conservation tillage is completely eliminating the tillage to maintain healthy soil organic levels which increases the soils capacity to absorb and retain water. Conservation tillage is a specific type of such approach where crop residue is left on the soil to reduce evapotranspiration, and protect soil surface from wind, sun and heavy rain impacts. (Awanish Kumar, 2015)

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 Punjab, some of them are already in place whereas others are good practices from different states or countries that could be beneficial for Punjab 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 9: Criteria for the assessment 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 Panchayat Raj Institutions, Urban Local Bodies, Water Users Associations)	0: very low → 10: very high
Environmental Benefits	D1	Contribution of the technology to protect and sustain aquatic ecology. Protecting the diversity of the rivers and ponds where water technology adaptation takes place.	0: very low → 10: very high
	D2	Recycling /Reuse of water and/or substitute to domestic water supply	0: very low → 10: very high
Economic Benefits	E1	Involve and encourage corporate sector / industries to take up, support and promote technology as part of CSR to ensure the financial sustainability of the technology and its use.	0: very low → 10: very high
	E2	Improving economic performance in that sector through increased productivity etc. farmer income and ability to reinvest	0: very low → 10: very high
Technological Benefits	F1	Local experience exists, technology can be operated by local operators without needing external support, does not conflict with existing processes, easier technology diffusion and farmer acceptance.	0: very low → 10: very high
	F2	Technology helps in increasing beneficial output per unit of water i.e. looking at engineering and agronomic aspects in conjunction, increasing water use efficiency	0: very low → 10: very high
Cost	G1	Low cost of set-up including the costs of importation and installation.	0: very low → 10: very high
	G2	Low cost for maintenance/ operation and other running costs of the technology over time.	0: very low → 10: very high

Source: Adelphi/DevAlt (2018) based on Traer up 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 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.

Table 10: 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	**20**
2	Social Benefits: Contribution to social development priorities	**25**
3	Institutional Benefits: Implementation availability through national and state level coherence	**5**
4	Environmental Benefits: Contribution to environmental conservation priorities	**15**
5	Economic Benefits: Potential of leveraging funds from private sources as well as improving incomes	**10**
6	Technological Benefits: Potential for higher acceptability of technology	**15**
7	Cost: Potential benefits through lower costs of operation and maintenance	**10**
Total		**100%**

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		
	20.00%		25.00%			5.00%			15.00%		10.00%		15.00%		10.00%			
Water Sector																		
W1	9	1	7	7	7	9	7	8	4	7	4	7	10	7	5	5	6.5	6.3
W2	8	1	7	6	7	8	8	8	6	7	3	8	7	7	6	6	6.4	6.1
W3	7	2	4	7	7	7	7	7	7	7	5	8	9	6	6	6	6.4	6.2
W4	7	4	8	7	7	6	7	8	7	6	5	7	7	9	5	6	6.6	6.6
W5	8	3	6	6	8	7	3	6	8	7	5	6	8	7	7	7	6.4	6.5
W6	9	4	8	8	8	7	8	8	8	3	4	7	7	6	6	7	6.8	6.7
W7	8	4	8	7	7	8	8	8	8	7	5	7	8	7	5	6	6.9	6.8
Water in Agriculture Sector																		
WA1	8	8	6	5	6	7	8	8	7	7	8	6	9	10	6	6	7.2	7.2
WA2	8	8	6	7	8	9	9	8	6	5	6	7	8	7	6	7	7.2	7.0
WA3	6	9	3	7	6	8	8	8	7	7	5	6	10	6	9	7	7.0	6.8
WA4	7	3	9	6	5	6	6	6	7	10	4	7	5	7	4	5	6.1	6.1
WA5	10	9	6	6	7	10	9	9	6	6	6	6	7	9	5	6	7.3	7.2
WA6	8	6	8	5	7	8	8	8	7	3	4	9	7	8	5	6	6.7	6.5
WA7	7	6	3	7	6	7	7	7	7	7	6	6	6	9	7	6	6.5	6.4
WA8	7	6	5	6	6	6	7	6	7	7	5	7	8	6	5	5	6.2	6.2

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. The workshop followed the steps and methodologies for technology prioritization, as suggested in the TNA handbook (UNDP, 2010) and Traerup and Bakkegaard (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:

Table 11: List of prioritised technologies

Technology	Code	Total Cumulative scores (out of 10)	Total Weighted Score (out of 10)
Shortlist of Technologies for Water Sector:			
Flood Channels in rivers for groundwater recharge	W7	6.9	6.8
Flash flood guidance systems	W6	6.8	6.7
Groundwater extraction and monitoring	W4	6.6	6.6
Shortlist of Technologies for Water in Agriculture Sector:			
Modernization of Irrigation system	WA1	7.2	7.2
Direct seeded Paddy	WA5	7.3	7.2
Capacity building of farmers on agronomical practice(timely transplanting and collective farming)	WA2	7.2	7.0

4.4. Prioritised technologies

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

4.4.1 Prioritised technologies for Water Sector

Option 1: W7: Flood Channels in rivers for Groundwater recharge

Technology	Flood Channels/subsurface drainage in rivers/canals for groundwater recharge	
Sector	Water	
Subsector	Water Augmentation	
Technology characteristics		
Introduction	In Punjab, the river basin is characterized by large intra-seasonal variations in discharge, resulting in frequent floods and low discharge in dry periods. This technology allows for developing flood carriers in these rivers that carry the excess water, during floods to areas with less water. This allows the flooding river water to eventually connecting areas where there is low chance of flooding; further augment the aquifer through developing groundwater recharge structures at the ends of the flood carriers.	
Climate related criteria		**Score**
A1: CCA Efficiency	Primarily alleviates water scarcity during dry periods and may require water travels through canal systems.	8
A2: GHG reduction	There isn't much contribution to GHG emission reduction, it may however may require pumps to transfer water from flood plains.	4
Social criteria		
B1: Health	Increases water supply during dry period to help address drinking water demands. Therefore helps reduce mortality/ morbidity due to unavailability of drinking water.	8
B2: Inequity	Can allow for equitable distribution of water in a district/ state if excess flood water is stored and later transferred.	7
B3: sustainable development	Provides social/ sustainable development benefits through addressing poverty alleviation, increasing food and water security	7
Institutional Benefits		
C1: refers to existing plans	Punjab Water Mission, Mission on Sustainable Habitats, and the SAPCC suggest flood management plans in both Urban and rural habitats to prevent flooding. These plans also support installation of drainage tubewells and revival of percolation wells (shallow wells used for irrigation).	8
C2: clear responsibility	While the ministry of water resources and state level departments are the lead agency for this technology implementation it will require assistance of other departments and ministries such as Forests, Rural Development	8
C3: coherent with policies	Flood Management Programme, Flash flood control programme, NABARD scheme for construction of subsurface drainage suggests for works along river Sutlej, Beas, Ravi and its tributary Ujh.	8

Environmental Benefits		
D1: Ecology / biodiversity	Supports groundwater recharge in the nearby areas and alleviates negative ecosystem impacts associated with critical water shortage. It also mitigates flood impacts.	8
D2: Recycle, Reuse, Substitute	There isn't much scope for recycling or reuse of water; however it provides usage of excess flooding water.	7
Economic Benefits		
E1: private sector participation	Involvement of private investment hasn't been seen yet in developing such floor carriers, but can be leveraged	5
E2: productivity	Helps improve farmer incomes due to improved irrigation and availability of groundwater in near river basins.	7
Technological Benefits		
F1: experience and acceptance	High levels of considerations are required before implementing the technology, there is expertise required. Research and small scale demonstration plots have shown that reclamation is possible, but these remedies are either very expensive or their effect is not accurately known.	8
F2: water efficiency	Increases beneficial output per unit of water, improves the economic efficiency of resource use	7
Cost		
G1: investment	Implementation costs are very high (building of pipes or canals to divert water). It is also very time consuming	5
G2: O&M	Pipes/ canals and other equipment should be regularly checked, and repaired when necessary, to minimize potential transfer water loss and ensure maximum efficiency of resource use.	6

Option 2: W6: flash flood guidance systems

Technology	Flash flood guidance systems
Sector	Water
Subsector	Early warning; Disaster preparedness

Technology characteristics		
Introduction	Flash flood guidance systems are specialized forecasting and early-warning systems for flash floods. Flash floods occur on short time and spatial scales, which makes them challenging to predict using traditional flood forecasting methods, such as monitoring river water levels. Flash flood guidance systems are designed to provide forecasters with data that allows them to predict a potential flash flood (usually a few hours before it hits), and produce an early warning to increase preparedness (UN Environment – DHI, CTCN, UNEP DTU, 2017).	
Climate related criteria		**Score**
A1: CCA Efficiency	Increases resilience through early preparedness, response and recovery.	9
A2: GHG reduction	Does not contribute much to climate change mitigation, through GHG emission reduction	4
Social criteria		
B1: Health	Mitigates human fatalities, health risks, and health risks, as well as infrastructure damage, resulting from floods. Helps mitigate flash floods through issuing warning messages.	8
B2: Inequity	While it doesn't contribute much to water distribution it provides for equal protection to all social classes/ ethnic groups	8
B3: sustainable development	Reduces costs related to post-flood rehabilitation and rebuilding, Strengthens overall flood management, including preparedness, response and recovery leading to overall prevention of poverty post-climate disasters	8
Institutional Benefits		
C1: refers to existing plans	Is usually under the purview of the disaster risk management plan of Punjab although early warning system not mentioned in the SAPCC it is considered as an important issue by the Disaster Management Plan	7
C2: clear responsibility	Training forecasters is required, requires departmental data sharing between CWC, IMD and RD. It further needs involvement of State Disaster Management Authority	8
C3: coherent with policies	This is covered under the flash flood control programme, that is suggested under the SAPCC	8
Environmental Benefits		
D1: Ecology / biodiversity	Mitigates damage to ecosystems (e.g. forests, high biodiversity value areas); timely notice for gated dam water release, reducing	8

	damage to surrounding ecosystems.	
D2: Recycle, Reuse, Substitute	It does not add much to recycling water or substituting domestic water supply.	3
Economic Benefits		
E1: private sector participation	Provides opportunities for climate risk insurance, this can help leverage private sector investment	4
E2: productivity	Helps improve farmer incomes through avoiding major losses during disasters,	7
Technological Benefits		
F1: experience and acceptance	Is being implemented through forecasting but not very effectively, is not a very mature technology. However, some expertise exists for uptake.	7
F2: water efficiency	It focuses on reducing exposure to extreme climate impacts therefore does not affect the water use efficiency	6
Cost		
G1: investment	Relatively expensive implementation/installation costs in terms of data required and also requires high technological expertise/ training	6
G2: O&M	Maintenance would be in the form of data maintenance and advisory services	7

Option 3: W4: Groundwater extraction and monitoring

Technology	Groundwater extraction and monitoring	
Sector	Water	
Subsector	Groundwater management	
Technology characteristics		
Introduction	Groundwater monitoring involves various methods to locate suitable quality and quantity groundwater for extraction. Prospecting and extraction methods depend on the desired water quality and its final utilization, and can include hydrogeological investigations, geophysical surveys, remote sensing assessments, and the more simple method of investigating already existing well sites in the area and their depths and characteristics. These analyses in particular look at remote sensing data from satellites that provide planners with information on geophysical conditions that can be linked to Geographical Information Systems (GIS) to map and identify potential prospecting zones. (UN Environment – DHI, CTCN, UNEP DTU, 2017).	
Climate related criteria		**Score**
A1: CCA Efficiency	Integrated surface and groundwater use through close monitoring increases sustainability and resilience of the water supply. It also prevents degradation of these resources that are strained by over-exploitation	7
A2: GHG reduction	There is no specific GHG emission reduction except reduced use of diesel powered motors to extract water.	4
Social criteria		
B1: Health	Increases water supply and water security in communities with limited freshwater availability, minimizes need for water treatment therefore providing health benefits to communities	8
B2: Inequity	The technology allows for better usage of water, including extraction by private/ public sources. This allows for reducing inequities between social classes, gender, ethnic groups etc.	7
B3: sustainable development	As it increases water supply and water security in communities with limited freshwater availability it also adds to reducing impacts of poverty as well as reducing water insecurity.	7
Institutional Benefits		
C1: refers to existing plans	Requires high level of regulatory and legal framework systems in order to monitor private bore wells, this currently absent in Punjab. This will require new frameworks which are very difficult to develop and monitor.	6
C2: clear responsibility	While groundwater falls under the purview of the Central Groundwater Board (CGWB), monitoring may require additional support from the state government.	7
C3: coherent with policies	Punjab Preservation of Subsoil Water Act, 2009, even CGWB has proposed new schemes on artificial recharge and aquifer mapping	8

	and management, the State Government is providing 50% subsidy to individual farmers for laying of RCC Underground Pipe Line System to avoid groundwater usage.	
Environmental Benefits		
D1: Ecology / biodiversity	Alleviates pressures on existing surface or ground water sources, and avoids their degradation.	7
D2: Recycle, Reuse, Substitute	There is no direct reuse, recycling of water, however, as it careful planning of use of water, it avoids creating waste water for recycling.	6
Economic Benefits		
E1: private sector participation	Small pockets of CSR activities are possible. Larger projects could have infrastructural components where the private sector could be involved.	5
E2: productivity	Increases water supply and water security in communities with limited freshwater availability	7
Technological Benefits		
F1: experience and acceptance	Poor extraction coordination for multiple wells can lead to water table depletion and salinization. So it requires training and capacity building for effective implementation. Also requires sensitization of communities.	7
F2: water efficiency	It helps address water efficiency as water exploitation is avoided.	9
Cost		
G1: investment	Initial investments maybe high as it requires a good overview of existing wells and boreholes, which can be difficult to obtain as many are done on an ad-hoc basis or without acquiring the necessary permissions in Punjab.	5
G2: O&M	Data needs to be maintained constantly for aquifer prospecting and extraction. This will require building or setting up extra structures.	6

4.1.2. Prioritised technologies for Agriculture Sector

Option 1: WA1: Modernization of Irrigation system using drip systems

Technology	Modernization of irrigation system using drip systems	
Sector	Water	
Subsector	Water efficiency and demand management	
Technology characteristics		
Introduction	Improving irrigation efficiency aims at minimizing water use within the agricultural sector while continuing to maintain optimal crop productivity rates. One such method to incrase irrigation efficiency is the drip irrigation. Drip irrigation allows for the optimal usage of water and fertilizers through their application close to crop roots. This is achieved by delivering small water flows at low pressure through a variable number of emission points, called drippers, and at a high application rate, which saves water. Water is saved in two ways: it is made to seep into the soil without evaporating or running off, and it is delivered at the root zone, just where the plants need it. The system is easy to design and set up and it generally consists of a water source, a pumping unit, a fertilization unit, filters, the distribution network and the drippers.	
Climate related criteria		**Score**
A1: CCA Efficiency	Efficient water use is the primary ecosystem benefit of drip irrigation technology. Drips have been able to reduce water consumption by up to 70% as compared to conventional irrigation systems. In addition to that efficient fertiliser usage through ‘ fertigation’ helps in avoiding over doses of fertilisers	8
A2: GHG reduction	There is very less or no contribution to reduction in GHG emissions, in case the optimised usage less consumption of electricity	8
Social criteria		
B1: Health	It can help address the issue of over usage of fertilisers that has many health impacts. Thus, efficient fertilizer usage as per the crop and soil profiles can help in reducing application wastage	6
B2: Inequity	Controlled release of water can help in reducing the wastage, however, the initial cost of installation of drip is very high and requires qualified technicians to install the systems, and improper installation would result in water deficiencies. Thus from equity aspects this technology may not be economically feasible for small holder farmers.	5
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.	6

Institutional Benefits		
C1: refers to existing plans	The project for promotion of micro irrigation in Punjab supported by NABARD and various micro irrigation project in the state supports the establishment of drip, micro and sprinkler irrigation systems. Additional 25% subsidy in addition to the GoI subsidy under PMKSY is provided to farmers	7
C2: clear responsibility	The monitoring of the Centrally sponsored scheme for micro irrigation is under the Ministry of agriculture and farmers welfare, implementation responsibility is delegated to state's horticulture department which allocates district wise and block wise responsibilities to respective line departments (Block level agriculture and horticulture offices)	8
C3: coherent with policies	RKVY, Centrally sponsored scheme for Micro irrigation, Project for matching irrigation water availability and demand for improved productivity through efficient on farm water management, NABARD supported project for promotion of micro irrigation in Punjab	8
Environmental Benefits		
D1: Ecology / biodiversity	Drip irrigation when complemented with other techniques such as integrated nutrient management, hydroponics, organic agriculture etc. can increase the crop portfolio which can increase the natural biodiversity of the region.	7
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	7
Economic Benefits		
E1: private sector participation	Private sector investment is necessary for up scaling the technology through community based institutions. Private sector investment can also be leveraged through the CSR funds	8
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	Initial investment cost is high. There is a high risk of obstruction of the emitters and consequently of uneven irrigation. Hence it is necessary to include a filtering system suitable for the characteristics of the water used. The most successful cases are obtained when farmers have a clear understanding of the technical characteristics of the system and of the crop's water requirements.	9
F2: water efficiency	It helps address water efficiency but it requires a high degree of technical assistance and installation supports.	10
Cost		

G1: investment	The main inputs are the materials for the distribution network, including the pump, the filtering and fertilizing systems and the drip line. In addition to that training and capacity building of farmers on operation and maintenance of drip systems would also be required	6
G2: O&M	Monitoring is required so as to ensure that there is no obstruction or clogging. Further, the water quality should also be checked so that there is no clogging of pores.	6

Option 2: WA5: Direct seeded Rice

Technology	Direct Seeded Rice	
Sector	Water in Agriculture	
Subsector	Water use efficiency in agriculture	
Technology characteristics		
Introduction	Direct seeding is the process of sowing in which pre germinated seeds/seedlings are directly planted in soil or broadcasted in flooded fields. This method uses water more efficiently than the conventional method of sowing and is proven to be less labour intensive. This method is especially beneficial in areas where there is labour shortage during the transplanting season. In case of delay in monsoon or shortage of water, DSR gives the farmer flexibility to take up direct sowing of paddy with a suitable duration variety to fit into the left over season. DSR is also economically beneficial for farmers as various constraint in conventional methods like higher water and labour demand, nursery raising cost, uprooting and transplanting are avoided. (Direct seeding(Rice))	
Climate related criteria		**Score**
A1: CCA Efficiency	Direct seeded rice aims to reduce methane emissions due to a shorter flooding period and decreased soil disturbance compared to transplanting rice seedlings. It has been a common cultural practice in the state to transplant 30 days old seedlings , howver that requires more water and requires more time for land preparation. As per the study conducted by Ko and Kang (2000) significant reduction in methane emmission could be achieved by direct seeding on wet soils(8%) and dry soils(88%). Direct seeding can be done by sowing of pre-germinated seed into a ouddled soil(wet seeding) or standing water(water seeding) or prepared seedbed(dry seeding)	10
A2: GHG reduction	There is contribution to reduction in GHG emission. As rice is responsible for 10% of GHG emissions from agriculture which is even higher in developing countries (16%). Direct seeding has prooved to reduce methane emmissions significantly.	9
Social criteria		
B1: Health	There is no direct health effects observed in this technology except that it is faster and less labour intensive than transplanting	6
B2: Inequity	While the technology has impact on resource use efficiency by saving energy, water, labour and input cost, the adoption of technology is purely dependent on the farmers but is not restricted by the land holdings as it gives similar results for a small and marginal farmers and large farmers	6
B3: sustainable development	In direct seeding plants are not subject to stresses such as being pulled from the soil and establishing fine rootlets. The conventional system of transplanting requires standing water on the field , with direct seeding seeds are sown and sprouted directly onto the field thus saving large volumes of water (75%	7

	water saved than the conventional approach)	
Institutional Benefits		
C1: refers to existing plans	Rising interest in conservation agriculture and integrated crop and resource management and shifting focus from productivity approach of agriculture to resource resiliency approach has boosted research on Direct seeded rice. PAU has been conducting intensive research on this technology and aims to transfer it to farmer's field through large scale demonstrations.	10
C2: clear responsibility	The agriculture department should be responsible for validating the results of direct seeded rice from resource efficiency point of view. Other departments like the water resource can incorporate it into their integrated water management projects, rural development department can uptake the work of dissemination	9
C3: coherent with policies	A local level would require both citizen and state approach as the rural development dept. along with support of CSO s' and research institutions will implement these through producer organisations or farmer Interest groups. .	9
Environmental Benefits		
D1: Ecology / biodiversity	Puddling has an effect on the bio physical properties and succeeding non rice crops, therefore shifting to dry DSR under no till or zero till conditions can help in reduction of weed growth, reduction of percolation losses of water and nutrients along with improved nutrient availability.	6
D2: Recycle, Reuse, Substitute	A holistic approach could take into account concept of conservation agriculture (zero tillage/ reduced tillage) followed by row seeding. Use of recycled waste water can be integrated so as to minimise the overall water use for paddy cultivation.	6
Economic Benefits		
E1: private sector participation	For the local solutions private sector investment is difficult to attract for up scaling 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	6
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	No negative effect on the yield has been observed, however, farmers need to be sensitized of other ecological and environmental issues and benefit analysis covering different aspects such as soil structure, better soil physical conditions, less drudgery.	7
F2: water efficiency	It helps address water efficiency but it requires a high degree of capacity building of farmers by large scale scientific demonstrations on their field to help them understand the benefits. This technology is more of a change in behaviour of farmers who are used to the traditional system of cultivation.	9

Cost		
G1: investment	The total economic cost of cultivation of DSR is 20.4% less than the transpalnted rice. (ClimateTechWiki, n.d.) According to Wassmann and Pathak (2007) (ClimateTechWiki, n.d.), costs of emissions saving through direct seeding was found to be more than US$35 per tCO2e saved.	5
G2: O&M	No extra operational cost involved except following the package of practices. However, upscaling this technology would require capacity building and trainings of farmers which involves cost.	6

Option 3: WA2: Capacity building for farmers on agronomical practices (timely transplantation of paddy and collective farming)

Technology	Capacity building for farmers on agronomical practices (timely transpalnting and collective farming)	
Sector	Water in Agriculture	
Subsector	Adaptation	
Technology characteristics		
Introduction	A notification under the Punjab sub soil water act, 2009 delays the transplanting of paddy so as to save water to meet the other requirements in the state. This is a move to check the drastic reduction in groundwater during the months from March-May. Allowing the transplantation to match with the onset of monsoon would help by giving time for recharge of groundwater. Collective farming is based on the principle of social ownership which helps to improve upon the inefficiency of the previous methods of agriculture and to boost agricultural production for self-sufficiency. The farmers pool in all their resources like land, livestock and labour.	
Climate related criteria		**Score**
A1: CCA Efficiency	Primarily addresses issue of water scarcity during the peak temperature months also checks the high rate of extraction of ground water	8
A2: GHG reduction	There isn't much contribution to GHG emission reduction except an indirect effect which might be due to reduction in energy for running the irrigation system as water requirement in the field would be more at higher temperatures. Additionally, a 20 days' reduction between sowing and harvesting time may prompt farmers to use new technologies and newer shorter duration varieties which are less resource intensive.	8
Social criteria		
B1: Health	The water saved would be used to meet the domestic and industrial demand of the state.	6
B2: Inequity	The water saved by adopting the technique may be used in other sectors like domestic use, industry or other economic activities thus allowing equitable distribution of water.	7
B3: sustainable development	Adaptation measure to check the depletion of groundwater and its extraction. Sustainable harvesting of groundwater would boost the state's ecology	8
Institutional Benefits		
C1: refers to existing plan	The Punjab state farmers commission, 2007 has taken the initiative to draft the legislation entitled 'Act to provide for preservation of sub-soil water in the state of Punjab 'and later in 2009 it was changed into an act called The Punjab preservation of sub soil water Act, 2009. The purpose of this act was to ensure the delay in transplanting of rice till mid-June for saving the groundwater resources. (Singh, 2009)	9

C2: clear responsibility	While the act is in place mooted by the Punjab state pollution control Board and Punjab Agricultural University. State agriculture department works to sensitize the farmers on the threat to ecology due to indiscriminate groundwater extraction, however, there is no clear mechanism of monitoring to check illegal sowing.	9
C3: coherent with policies	The government of Punjab has enacted an act to save the groundwater in Punjab for which the government has prohibited sowing of paddy nursery before 10th of May. Convergences with various other Govt programmes such as RKVY, PMKSY etc. can be made for capacity building and sensitisation workshops.	8
Environmental Benefits		
D1: Ecology / biodiversity	Supports groundwater recharge in the nearby areas and alleviates negative ecosystem impacts associated with critical water shortage	6
D2: Recycle, Reuse, Substitute	There isn't much scope for recycling or reuse of water but the capacity building modules can be aligned with the efficient water use aspects	5
Economic Benefits		
E1: private sector participation	Involvement of private investment hasn't been seen yet can be leveraged for capacity building and sensitization programmes	6
E2: productivity	Helps improve farmer incomes due to improved availability of water during the critical growth stages as transplantation is aligned with the onset of monsoon.	7
Technological Benefits		
F1: experience and acceptance	High levels of considerations are required before implementing the technology as delay in sowing may have effect on the yield of paddy and may affect the quality due to high moisture content during harvesting. Farmers have to shift from long duration varieties to medium and shorter duration varieties	8
F2: water efficiency	Increases beneficial output per unit of water, improves the economic efficiency of resource use, enahnces availabiliy of power for irrigation	7
Cost		
G1: investment	Implementation cost is not that high, however, research and trails need to be done for short duration and less water intensive varieties. Additionally, technology transfer would require intensive capacity building and training programmes for farmers	6
G2: O&M	Ongoing researches are required on developing short duration varieties giving high or equal yields so that farmers do not incur any production related losses.	7

5. Case study for Punjab: Flood carriers/ diversion canals for groundwater recharge

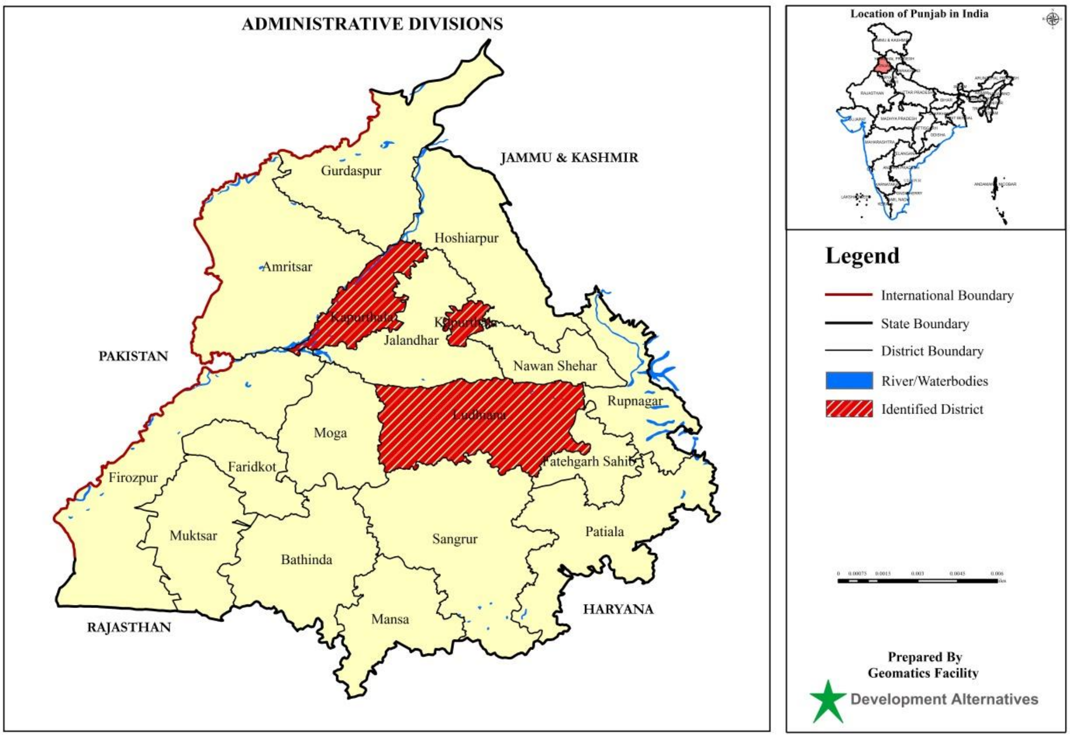

Figure 4: Ludhiana and Kapurtala Districts

Source: Development Alternatives

In Punjab, the river basin is characterized by large intra-seasonal variations in discharge, resulting in frequent floods and low discharge in dry periods. The carrying capacity of rivers have also deteriorated. The state has about 400 drains with a total length of 11,181 km which cover an area of 47,918 km^2. With the completion of this vast drainage system and the construction of embankments along rivers in the past, flooding of low lying areas in the state due to overflow and spilling of rivers and nalas has been checked to a great extent. Immense efforts are afoot to regulate and control the floods (Sharma, Chopra, Verma & Thomas, 1996). However, in the years of above normal rainfall flooding takes place as the drainage system has been designed to pass only a portion of the high flood discharge (Sharma, Chopra, Verma & Thomas, 1996). Recently, Ministry of Home Affairs (2018) in its ongoing study on flood vulnerability index rated Punjab among the Most vulnerable to flood (MHA, 2018).

As per Sharma, Chopra, Verma & Thomas (1996), the causes of the flooding in Punjab are:

i. Poor maintenance of Dhusi Bundhs/embankments along the river resulted in a number of breaches at weak and vulnerable patches.
ii. Lack of maintenance of canal and choe banks by the drainage department resulting in breaches at a number of places.
iii. Inadequate drainage system designed to pass only a portion of high flood discharge.
iv. Choking of drains and syphons by silting and growth of weeds.
v. Lack of vegetative cover in the catchment area of rivers, streams and choes resulting in excessive run-off (storm water) and sediments.
vi. Blockage of natural watercourses by the construction of roads or railway tracks and/or laying of canals across the natural gradient.

vii. Unattended, inadequate and faulty storm water drainage systems in towns.
viii. Lack of preparation for prompt reinforcement of 'weak or vulnerable patches' in river and canal banks and prompt plugging of breaches in Dhusi Bundhs.
ix. Lack of proper warning and communication systems in the districts. Had these facilities been there better monitoring could have been achieved and people could have had much more time to save their belongings and move to safer places.
x. Lack of contingency plans on the part of concerned departments and district administration.

Tamil Nadu case study

A good example for Punjab would be Tamil Nadu with its flood diversion canals.Tamil nadu had developed a massive inter basin network of canals that divert water towards lakes, ponds, tanks and reservoirs. This intricate network of canals not only diverts water from flood areas to less flood areas for irrigation purpose but also directs domestic water into the town. This canal system has helped in controlling flood condition as well as inter basin transfer of water for crop management has been made possible. Tamil Nadu receives around 45000 cusecs of water per day from the Cauvery which is sufficient to flood the lower riparian area but due to the canal system around the Cauvery and Bhavani basin it didn’t flood. This canal system has also resulted in equitable water distribution across the state. A project of linking the Thamirabarani, Karumeniyar and Nambiyar rivers by excavating a new flood carrier canal from the existing Kannadian channel has started in the state with an aim of carrying water to the drought prone areas. With the funding assistance from the accelerated irrigation benefit programme under the drought prone development programme,the flood carrier canal from the kannadian channel is expected to carry surplus water to the drought prone areas of Sathankulam, Thisaiyanvilai.

Flood Channels/subsurface drainage in rivers/canals for groundwater recharge: In Punjab, the river basin is characterized by large intra-seasonal variations in discharge, resulting in frequent floods and low discharge in dry periods. This technology allows for developing flood carriers in these rivers that carry the excess water, during floods to areas with less water. This allows the flooding river water to eventually connecting areas where there is low chance of flooding; further augment the aquifer through developing groundwater recharge structures at the ends of the flood carriers.

Expected Results:

- Increased surface water supply for agriculture
- Increased ground water level
- Increase ground water availability for drinking as well as irrigation
- Reduce excess water losses during extreme water events/ floods
- Diversion structures are very effective in reducing sediment erosion, retaining runoff, and encouraging groundwater infiltration.
- Diversion structures enable the use of water that normally would run off.
- Diversion structures provide some in-stream control of erosion and sedimentation.
- Diverted water may serve as a source for groundwater recharge.
- Water velocities in river channels are reduced.
- Retention of runoff may contribute to biodiversity and ecosystem restoration by reducing erosion and retaining water on the land surface.
- Soil fertility is improved by retaining water on the land surface and reducing soil loss.

Synergies: Various centrally sponsored schemes such as PMKSY, Accelerated area development programme can be used for construction of dams and diversion canals. This can be led by irrigation department, rural development, district administration and other technical institutions in the state specialising in water resource management.

Project Concept:

A project on developing a flood carrier canal could be in Ludhiana and Kapurtala, drawing form successful examples from Tamil Nadu. Following are the few steps that may be followed in order to develop an intervention:

- Mapping of the area keeping as per the hydrology, run-off, reservoir level, likely submergence area, command area, geology, geography, soil, drainage network etc.
- Use of GPS to identify the river flows, elevation etc.
- Capacity building of communities to manage the structures post project period
- Construction of flood carrier structures across the rivers, possibly at the meandering zones.
- Monitoring and evaluation

6 Bibliography

Asano, T., Burton, F., Leverenz, H., Tsuchihashi, R., Tchobanoglous, G. (2007). Water Reuse: Issues, Technologies, and Applications.

Awanish Kumar, A. K. (2015). Conservation agriculture:concepts,principles and methodologies . *Global Journal of multidisciplinary studies* .

Census (2011). Government of India.

Central Ground Water Board (2014). Ground water year book – India 2013-14.

Climate Tech wiki . (n.d.). Retrieved from climatetechwiki.org: https://www.climatetechwiki.org/technology/direct-seeding#Introduction

Columbia Water Centre, Earth institute. (n.d.). Retrieved from water.columbia.edu: http://water.columbia.edu/research-themes/water-food-energy-nexus/water-agriculture-livelihood-security-in-india/punjab-india/

CTCN. (n.d.). Retrieved from https://www.ctc-n.org/technologies/drip-irrigation: https://www.ctc-n.org/technologies/drip-irrigation

Direct seeding (Rice). (n.d.). Retrieved from ctc-n.org: https://www.ctc-n.org/technologies/direct-seeding-rice

Dynamic Groundwater Resources Report (2011), Central Ground Water Board.

Gibb, T. (2013). Managing stormwater in urban and rural areas. Retrieved from https://www.canr.msu.edu/news/managing_stormwater_in_urban_and_rural_areas_part_1

GIZ / INRM (2017). Climate Change Vulnerability Assessments for Punjab. New Delhi : Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, India.

GoI, NAPCC (2008). National Action Plan on Climate Change. New Delhi: Ministry of Environment, Forest and Climate Change, Government of India.

CGWB (2011). Ground water scenario of Punjab. Retrieved from cgwb.gov.in: http://cgwb.gov.in/gw_profiles/st_Punjab.htm

Hobson, G. (2011). Dron's balance between hard and soft technologies - seeking the Goldilocks moment. Retrieved from http://edtech-insights.blogspot.com/2011/11/drons-balance-between-hard-and-soft.html

IPCC (2014): Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

MHA (2018) in Thakur, P. (2018). Punjab tops govt's flood vulnerability index - Times of India. Retrieved from http://timesofindia.indiatimes.com/articleshow/64692977.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

N.S. Tiwana, N. J. (2007). *State of Environment.* Punjab state council of science and technology .

Punjab state action plan on climate change - PSAPCC (2012). Retrieved from moef.nic.in: http://www.moef.nic.in/sites/default/files/sapcc/Punjab.pdf

SDMP (2011). Punjab State Disaster Management Plan.

Report Of The High Level Expert Group on Water Logging in Punjab (2013). Government Of India. Planning Commission.

Sharma, P., Chopra, R., Verma, V., and Thomas, A. (1996). Technical Note Flood management using remote sensing technology: the Punjab (India) experience. *International Journal Of Remote Sensing*, *17*(17), 3511-3521.

Sharma, V. (2015). Irrigation efficiency of Punjab, Haryana low. *The Tribune*.

Singh, K. (2009). Act to Save Groundwater in Punjab:Its impact on water table,electricity subsidy and environment . Punjab state farmers commission .

Suneel Pandey, J. K. (2015). Industrial and urban waste management in Punjab . TERI,Global Green Growth Institute.

Traerup, S. L. M. and Bakkegaard, R. K. (2015). Evaluating and prioritizing technologies for adaptation to climate change – A hands on guidance to multi-criteria (MCA) and the identification and assessment of related criteria. UNEP DTU Partnership. Copenhagen.

UNEP – DHI, CTCN, UNEP DTU. (2017). Climate Change Adaptation Technologies For Water. UN Environment – DHI, CTCN, UNEP DTU.

UNDP (2010). Handbook for conducting technology needs assessment for climate change. UNDP. New York.

United Nations (2016). Paris Agreement (pp. 1-27). Paris: United Nations

Wassmann, R. and Pathak, H. (2007). Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. Generation of technical coefficients. *Agricultural Systems* 94 (4).

Water resource development and management in Punjab (2018, December 6). Retrieved from department of irrigation, Government of Punjab: http://irrigation.punjab.gov.in/OldVersion/Index.html