On behalf of:

REPORT

# Technology Needs Assessment (TNA)

## For climate change adaptation in Himachal Pradesh

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## Imprint

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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 Himachal Pradesh.

A series of consultation on TNA was held in July 2018. DA and adelphi and National Climate Change Cell Himachal Pradesh, Department of Environment, Science and Technology (DEST) state were responsible for prioritization of adaptation technologies.

All relevant Departments (Agriculture, Horticulture, Rural Development, and Groundwater), Department of Environment, Science & Technology, IMD, CWC, and some CSO and NGO representatives were consulted as part of the process. At a later stage the team may involve business sectors interested in understanding new technologies that will be involved in pilot project preparation process.

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

By expert judgment method with help of the guidance mentioned above, all inventoried technologies of each sector were then reduced to 3 technologies for each, the water and the agriculture sector.

The results for water sector are namely technologies for:

1) Flash flood guidance systems (including cloud burst)
2) Source water (watershed) protection
3) Decentralized community level water recycling/ reuse

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

1) Water Conveying Systems: surface, drip, sprinkler and low cost hybrid systems
2) Climate Resilient Varieties: higher temperature growing apples
3) Spring Shed Development and Management

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

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# List of Abbreviations

| | |
|---|---|
| **CCA** | Climate Change Adaptation |
| **CSO** | Civil Society Organizations |
| **CGWB** | Central Ground Water Board |
| **DoA** | Department of Agriculture |
| **DoH** | Department of Horticulture |
| **DSS** | Decision Support System |
| **EWS** | Early Warning Systems |
| **GIS** | Geographic Information System |
| **HPFD** | Himachal Pradesh Forest Department |

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

# 1. Introduction

## 1.1 Project Background

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

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

Carrying on, the second phase of CCA-RAI (2015 – 2019) focuses on capacity building and climate change adaptation activities, technical support as well as on the development of knowledge management and outreach materials. Within this phase, the proposed technology needs assessment for adaptation in the water sector will take place. The technology needs assessment (TNA) is the first step contributing to technology development and transfer, which are of increasing priority to the international agenda to foster adaptation to climate change. The assessment of technology needs builds on various sources of information that are already available for each of the four CCA-RAI partner states: State Action Plans on Climate Change (SAPCCs), District-level studies on climate change impact and vulnerability in the water sector of CCA-RAI project partner states and, if already available, State-specific Action Plans for Water (SSAPWs) and related documents. Throughout the assessment, the consideration of the National Action Plan on Climate Change (NAPCC) and the National Water Mission ensures that the results comply with national policies..

## 1.3 Institutional arrangement for the TNA and the stakeholders' involvement in Himachal Pradesh

A series of consultation on TNA consultation was held in July 2018. DA and adelphi and National Climate Change cell Himachal Pradesh, Department of Environment, Science and Technology (DEST) state were involved in the prioritization of adaptation technologies.

All relevant Departments (Agriculture, Horticulture, Rural Development, Groundwater), Department of Environment, Science & Technology, IMD, CWC, and some CSO, NGO representatives were consulted as part of the process. At a later stage the team may involve business sectors interested in understanding new technologies that will be involved in pilot project preparation process.

Identification of development priorities of Himachal Pradesh, and prioritization of pre-selected technologies was conducted with close involvement of relevant stakeholders. A final prioritization list of adaptive technologies was agreed upon as a result of several discussions conducted with stakeholders, based on which a shortlist was developed using MCA tools. The final decision was endorsed by GIZ.


**Figure 1: DA and adelphi conducting a stakeholder consultation**

Source: DA (2018)

## 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 Himachal Pradesh to identify the CCA gaps leading to vulnerabilities, i.e. what makes Himachal Pradesh 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.

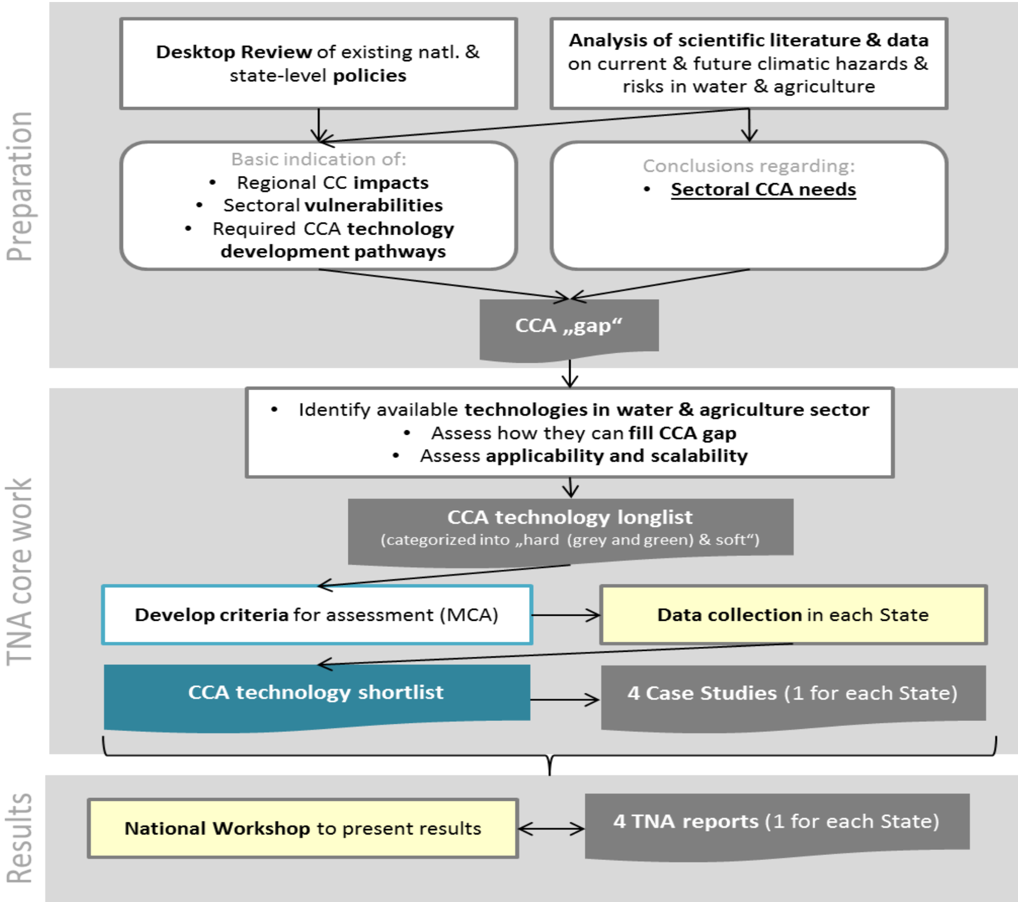



**Figure 2: TNA process for this project**

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

# 2. Vulnerability in Himachal Pradesh

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

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

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

Therefore, this study builds on previous vulnerability assessments for the state of Himachal Pradesh (done by GIZ and 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 Himachal Pradesh. 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 Himachal Pradesh

### Geography and Location

Himachal Pradesh is a relatively young state, having been granted full statehood in 1971. It is a relatively small state, both in terms of population and size. The population of Himachal Pradesh is 68,56,509 as per the Census of India, 2011, it represents 0.57 per cent of India's total population. About 90 per cent of the population resides in rural areas. The population of the State increased by 17.53% between the years 1991–2001 and decreased by 12.81 % in 2011 (GOHP, 2012).

Himachal Pradesh is largely mountainous with the exception of small pockets bordering Punjab and Haryana. The state comprises hilly terrain, perennial rivers, and significant forest cover. Himachal is situated in the western Himalayas. Covering an area of 55,673 kilometres (34,594 miles), Himachal Pradesh is a mountainous state with elevation ranging from about 350 meters (1,148 ft.) to 6,000 meters (19,685 ft.) above the mean sea level (GOHP, 2012). The drainage system in the State is well developed and forms the part of the Indus and the Ganges River basins of India. The major rivers which either originate or pass through HP are the Satluj, Ravi, Beas, Chenab and Yamuna. These rivers are perennial and are fed by snow and rainfall. They are protected by an extensive cover of natural vegetation (GOHP, 2012).


**Figure 3: Administrative Map of HP showing various districts**

Source: DA (2018)

HP has performed well in socio-economic indicators with per capita income, human development index, health, and educational income higher than India's average (CRGGS, 2015). Himachal Pradesh has rapidly evolved in terms of economic growth. The net state domestic product of the State and per capita incomes has shown a steady increasing trend. The secondary sector showed healthy signs of industrialization and modernization (CRGGS, 2015). Tourism is also contributing the economy as HP has the natural capital and resources for being a tourist destination. The economy of the State is dependent on sectors like the hydroelectric power generation, horticulture, agriculture, forestry and tourism etc. and these sectors are assumed to be under threat in the present scenario of changing climate.

## Climate

The State comprises of four different Agro-climatic Zones this is due to the varying altitudes that make the temperature diverse. (GOHP, 2012):

- **Shivalik Hill Zone**: It lies between 350 to 900 meters above mean sea level. It occupies about 35% of the geographical area and about 40% of the cultivated area of the State. The climate in this zone is of sub-humid tropical type.
- **Mid Hill Zone**: This zone is present between 900 meters to 1,800 meters above mean sea level and has a warm and mild temperate climate. It occupies about 32% of the total geographical area and about 37% of the cultivated area of the State.
- **High Hill Zone**: This zone lies from 1,801 to 2,400 meters above sea level with humid temperate climate and alpine pastures. This zone covers about 35% of the geographical areas and about 21% of the cultivated area of the State. cool and temperate
- **Cold Dry Zone**: This is most hilly zone that is more than 2,400 meters above mean sea level and occupies about 8% of the geographical. It covers 2% of the total cultivated area of the State. cold alpine and glacial

In the context of understanding the climate trends in Himachal Pradesh, both precipitation (rainfall & snowfall) and temperature are considered significant parameters.

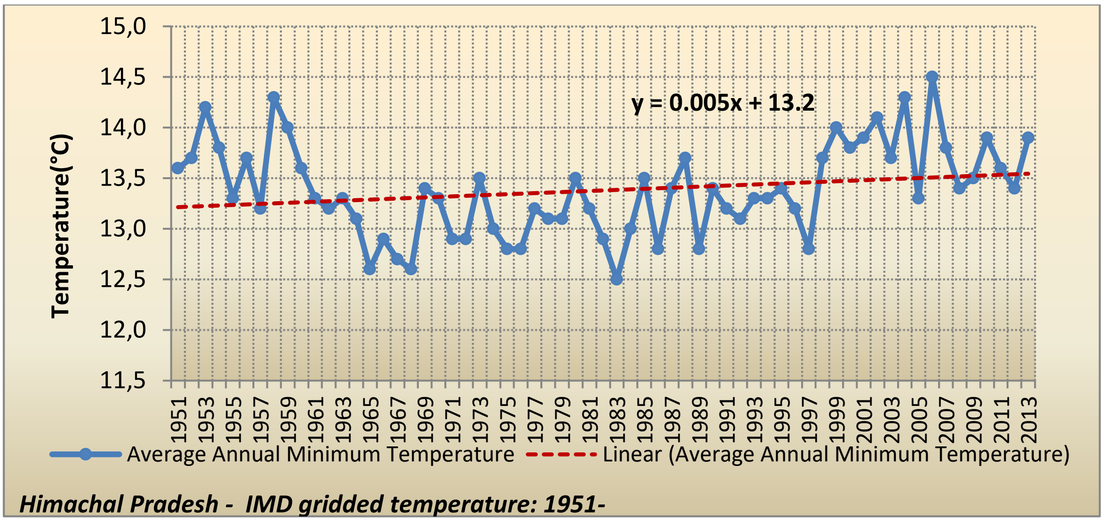
A study conducted by GIZ and INRM (2017) shows that present mean annual maximum temperature for the State of Himachal Pradesh is 25.9 degrees Celsius with a range varying from 24.5 to 27.1 degrees Celsius. While the mean annual minimum temperature is 13.4 degrees Celsius with a range varying from 12.5 to 14.5 degrees Celsius for the past year. Average annual rainfall of HP State is 1284.2 mm with a range varying from 704.7 to 2062.8 mm. The south west monsoon (JJAS months) rainfall contributes the maximum to annual rainfall amounting to approximately 66 per cent for Himachal Pradesh State (GIZ and INRM, 2017).

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

Source: GIZ and INRM (2017)

| State | Periods | Maximum Temperature | | | Minimum Temperature | | |
|---|---|---|---|---|---|---|---|
| | | Average (°C) | Range (°C) | CV | Average (°C) | Range (°C) | CV |
| **Himachal Pradesh** | Annual | 25.9 | 24.5-27.1 | 0.020 | 13.4 | 12.5-14.5 | 0.034 |
| | Winter (JF) | 16.9 | 14.9-19.6 | 0.065 | 4.7 | 2.9-7.5 | 0.165 |
| | Pre Monsoon (MAM) | 28.3 | 24.7-31.9 | 0.045 | 14.1 | 12.3-16.2 | 0.061 |
| | Monsoon (JJAS) | 30.7 | 29.6-32.7 | 0.019 | 20.6 | 19.7-21.6 | 0.023 |
| | Post Monsoon (OND) | 23.0 | 19.7-24.2 | 0.035 | 8.8 | 7.6-10.1 | 0.077 |

The analysis of temperature data shows positive trends for both, annual maximum and annual minimum temperature. However, both trends are not statistically significant as they are similar to what is expected with increasing GHG emissions i.e. 1.4°C rise for both maximum and minimum temperature by mid-century. Additionally, the trend of warming since 1951 was not clear during the study (GIZ and INRM, 2017).



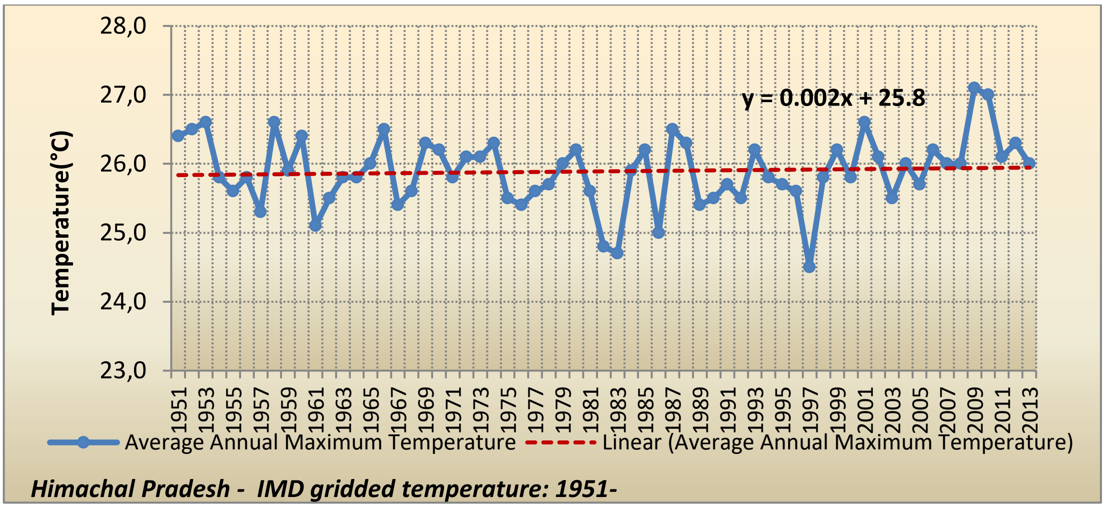




**Figure 4: Observed average annual maximum and minimum temperature of Himachal Pradesh (1951-2013)**

Source: GIZ and INRM (2017)

The analysis of annual rainfall reveals a negative trend indicating that the total amount of rainfall received has been decreasing. The number of rainy days also shows a negative trend. Both trends are statistically significant meaning that rainfall and rainy days have both clearly declined since 1951 in Himachal Pradesh (GIZ and INRM, 2017).

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

Source: GIZ and INRM (2017)

| State | Season | Average Rainfall (mm) | Range (mm) | Inter-annual variation | Contribution to Annual Rainfall (%) |
|---|---|---|---|---|---|
| **Himachal Pradesh** | Annual | 1284.2 | 704.7-2062.8 | 0.24 | |
| | Winter (JF) | 156 | 34.1-479.7 | 0.54 | 12.1 |
| | Pre Monsoon (MAM) | 192.9 | 49.5-545.6 | 0.53 | 15.0 |
| | Monsoon (JJAS) | 849.2 | 352.9-1504.1 | 0.32 | 66.1 |
| | Post Monsoon (OND) | 86.1 | 3.7-444.7 | 0.95 | 6.7 |

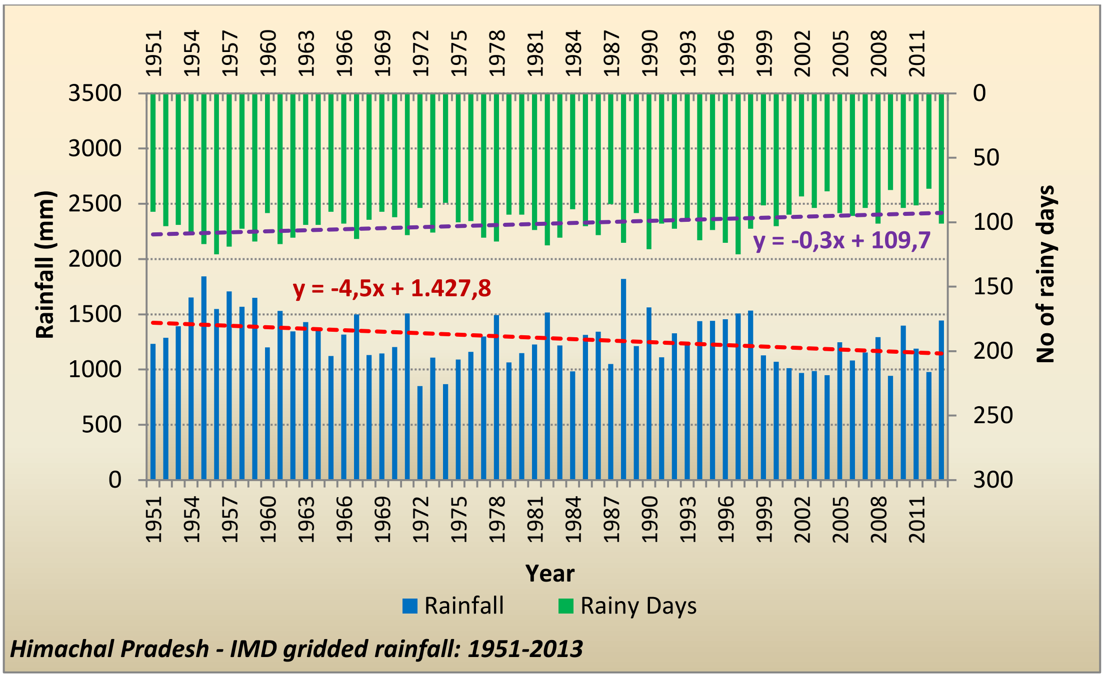



**Figure 5: Observed annual rainfall and number of rainy days for Himachal Pradesh**
Source: GIZ and INRM (2017)

## Observed and Projected Climatic Change

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

- Mean annual maximum temperature for RCP4.5 scenario is projected to increase by about 1.4 degrees Celsius by mid-century and by 2.5 degrees Celsius by end-century. For RCP 8.5 scenario it is projected to increase by about 1.6 degrees Celsius by mid-century and 5.0 degrees Celsius by end-century for the State of Himachal Pradesh.
- Mean annual minimum temperature for RCP4.5 scenario is projected to increase by about 1.4 degrees Celsius by mid-century and by 2.7 degrees Celsius by end-century. For RCP 8.5 scenario it is projected to increase by about 1.8 degrees Celsius by mid-century and 5.1 degrees Celsius by end-century.
- Mean annual rainfall for RCP4.5 scenario is projected to decrease marginally by about 5.9 per cent towards mid-century and increase by about 13.8 per cent towards end-century. For RCP 8.5 scenario rainfall is projected to increase by about 14 per cent towards both mid-century and end-century.

## Water sector, including water in agriculture

The state is richly endowed with a hilly terrain having an enormous volume of water from the catchment areas of Satluj, Beas, Ravi and Chenab rivers. These rivers form part of the Indus system. As such, the state has enormous potential of water resources in the form of glaciers and rivers but ground water resource is limited (GOHP, 2014). Only one-third of its cultivated area is irrigated because of physiographic constraints. It is ironical that this water rich state is also not free from drought at times (GOHP, 2014). Water storage in Himachal Pradesh is estimated at around 14,000 million m3.

**Surface Water Resources**

Most of the surface water resources of Himachal Pradesh flow from perennial rivers which originate from glaciers. The flow in these rivers is further augmented by run-off from the catchment areas.

90 per cent of Himachal's drainage forms part of the Indus river system. The rivers that actually have their origin in the state and flow through it are the Chenab, the Beas, and the Ravi. The Satluj has its origin in Tibet and flows through Himachal Pradesh forming the largest river catchment area in the state. The Yamuna river crosses only the south-eastern border but has some catchment area in Himachal Pradesh (GOHP, 2014).

There are a number of lakes in Himachal Pradesh, such as Manimahesh and Khajiar lakes in Chamba district, Chandratal and Surajtal lakes in Lahaul and Spiti district, Rawalsar, Prashel and Kamrunag lakes in Mandi district (GOHP, 2014).

Himachal Pradesh also has man made water bodies such as reservoirs for specific purposes, such as irrigation, hydro power generation, flood control etc. The two major storages located on the borders of the state are the:

- The Govindsagar Reservoir (Bhakra Dam) in the Satluj River with 6,900 million m3 live storage, was completed in 1963. The project, located on the border with Punjab, is a major source of hydropower and irrigation.
- Pong Dam located on the border with Punjab in the Beas River with 7,300 million m3 live storage is primarily used for irrigation in Rajasthan, Haryana and Punjab and also for hydropower
- The Pandoh Dam, a hydroelectric dam on the river Beas upstream of Mandi, has live storage of 18 million m3. Most of the hydroelectric dams however, only have storage capacity to meet the basic requirements of a few hours. (ADB, 2010)

**Groundwater Resources**

The groundwater resource occurs mainly in unconsolidated sediments of intermontane valleys and in the sub-montane tract. Kangra, Una, Hamirpur, Bilaspur, Mandi, Solan and Sirmaur districts, particularly their valley areas depend upon groundwater. The exploitation is done through open wells, tube wells, infiltration galleries and wells (GOHP, 2014).

Estimates by the Central Groundwater Board indicate that in all five valleys, groundwater extraction remain below the maximum sustainable levels. Under climate change conditions, the projection is that the annual rainfall will fall in more intensive storms resulting in increased runoff and lower levels of infiltration to support groundwater recharge. Groundwater in the valleys gets recharge from both the rivers and rainfall. (ADB, 2010)

**Snow and Glacier**

Various studies and estimates of the state of the glaciers have been prepared. Covering an area of 4160 $km_2$, these high frozen reservoirs release their water at the top of the watersheds. The glaciers plus the seasonal snow cover serve as the perennial sources of rivers that wind their way through grazing, agricultural, and forest lands, and are used as renewable sources of irrigation, drinking water, energy, and industry for Himachal Pradesh.

There are about total of around 791 glaciers in Himachal Pradesh (334 glaciers in the Satluj basin and 457 glaciers in the Chenab basin) (Kulkarni et. al, 2007). Studies done on global warming impact on Himalayas show that, with a temperature increase of 2-4 degrees, there will be snow and glacier field loss, which will affect the flow in river system, the flow in lower elevation. The glacier fields may reduce by more than 50% due to rise in temperature, increased melting rate, monsoon, extreme events may further increase the issues of sedimentation, intense erosion, destabilization of slopes and the increase in events of glacial lake outburst floods (GLOFs) etc. (Kulkarni et. al, 2007).

**Agriculture sector in Himachal Pradesh**

Due to its hilly terrain, the economy of the state is predominantly mixed farming, agro-pastoral, silvipastoral and agro-horticultural. Most of the group based farming systems, engaging a majority of the farmers, are found in the valleys of Yamuna, Satluj, Beas, Ravi, Chandera Bhaga and their tributaries. Agriculture accounts for over 30 per cent of the state's net domestic product and provides employment to about 71 per cent of its residents (GOHP, 2014).

Agriculture in the state suffers from certain limitations. Most of the farming is rainfed as only about one lakh hectares of its net sown area has assured irrigation. Operational land-holdings are small and scattered. Fruit cultivation is thriving on old plantations whose bearing is low. Farm mechanisation is scanty. Awareness level of farmers is low and technologies are out of date (GOHP, 2014). While there is plenty of water in the hills yet water use for irrigation is limited to over 1.05 lakh hectares out of nearly 6 lakh hectare of cultivated land.

**Climate Impacts and Vulnerability Assessment of the Water and Agriculture Sector in Himachal Pradesh**

For Himachal Pradesh, the very high levels of hydroelectric and other infrastructure development in rivers and lack of long-term records make estimates of trends difficult (ADB, 2010).

The linkages between trends in climate and trends in glacier extent (length, area, volume, and melt volumes) are of key concern to the future water resources of Himachal Pradesh as well as of downstream states (ADB, 2010). The consensus is that glaciers around the world are shrinking primarily because of global warming; the precise rate of melt is still not well re searched. Nineteen glaciers in the Baspa basin were monitored over a period 1962 to 2001. The investigation showed that all the glaciers were receding and overall, 19 per cent deglaciation was observed in the period (ADB, 2010).

## 2.2 Existing policy framework

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

**Table 3: National level policies and their implication for the TNA**

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

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

## 2.3 Relevant state-level policies

**Table 4: State level policies and their implication for the TNA**

| Year | Policy | Water | Agriculture | Implications for TNA (specific technologies) | Funding options under this policy |
|---|---|---|---|---|---|
| 2010 | Mandatory rainwater harvesting | ✓ | | Rainwater harvesting has been mandatory at all levels in the state, (can be made effective through with soak pits) | No specific funding options |
| 2005 - 2006 | Horticulture Technology Mission | | ✓ | High value crops and technology dissemination in the fields to raise productivity , Apple replantation scheme can also improve irrigation | Rs 321 crore supported by Japan International Co-operation Agency |

| | | | | | |
|---|---|---|---|---|---|
| | | | | issues | |
| 2001 | Organic Farming policy | | ✓ | Increase productivity, production and profitability of crops can also improve irrigation issues | No specific funding options |
| 2005 | Watershed development Programme | ✓ | | Improving productive potentials of watersheds, through soil moisture conservation, RWH, contour trenching | US$ 8.45 million supported by World Bank |
| 2013 | State Water Policy | ✓ | | Still under revision , integrated water resource management,<br>Basin level management, maintenance of water quality | No specific funding options |

# 3. Deriving a longlist of CCA technology options

As a next step of the TNA process, an overview of technologies for adaptation was developed and provided to the stakeholders based on the vulnerabilities identified. Technologies were categorized in terms of the vulnerability element it addresses. 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. 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 5: 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**: Increased frequency of heavy precipitation, extreme rainfall intensity | The main losses that occur through Increased flood flows, Increased runoff and higher levels of sediment loading. Reduced groundwater recharge leading to damage to crops and increased soil erosion causing severe economic loss for farmers. | • Runoff control structures for storm water management | Reduce exposure, reduce sensitivity | W1 |
| | | • Early warning systems for floods | Reduce exposure, reduce sensitivity | W2 |
| | | • Multipurpose dams | Reduce exposure, increase adaptive capacity | WA6 |
| | | • Slow-forming terraces | Reduce sensitivity, increase adaptive capacity | WA7 |
| **Drought**: Increased likelihood of water shortages/ drought, | Reduced dry season flows, Drying up of some minor tributaries and springs, Major impact on rainfed cropping. Some impact on | • Source water protection | Reduce exposure, Increase adaptive capacity | W6 |

| CC Impact | Description of CCA Gap | Possible Solutions/ technologies | Element of Vulnerability Addressed | Technology Code |
|---|---|---|---|---|
| Reduced levels of precipitation as snow | irrigated cropping, Potable water schemes in snow-fed rivers and streams would have reduced flow | • Decentralized community level water recycling/ reuse | Increase adaptive capacity | W5 |
| | | • Snow management and harvesting | Increase adaptive capacity | W7 |
| | | • Fog harvesting | Increase adaptive capacity | W4 |
| | | • Rooftop rainwater harvesting (both house hold level and community building) | Increase adaptive capacity | W3 |
| | | • Water security plans through Water User Associations/ VWSC | Increase adaptive capacity | WA1 |
| | | • Water Conveying Systems: surface, drip, sprinkler and low cost hybrid systems | Increase adaptive capacity | WA2 |
| | | • Capacity building for farmers on agronomical practices (collective farming and crop rotation) | Increase adaptive capacity | WA5 |
| **Variability**: Increased variability in rainfall patterns, Earlier snow melt | Erratic river flow patterns, Major impact on non-irrigated crops. Increased spring flows, Increased winter season runoff.<br>Loss of some perennial sources of potable water and irrigation. | • Snow management and harvesting | Increase adaptive capacity | W7 |
| | | • Rooftop rainwater harvesting (both house hold level and community building) | Increase adaptive capacity | W3 |

| CC Impact | Description of CCA Gap | Possible Solutions/ technologies | Element of Vulnerability Addressed | Technology Code |
|---|---|---|---|---|
| | | • Spring Shed Management | Increase adaptive capacity, Reduce sensitivity | WA3 |
| | | • Multipurpose dams | Reduce exposure, increase adaptive capacity | WA6 |
| **Increased Temperature**: Loss of glacier volumes as well impact on crops | Initially increased dry season flows. Over the longer term, likely reduced dry season flows-time frame uncertain.<br>Long term reduced dry season flows to neighbouring states, Increased river and lake temperatures. | • Climate Resilient Varieties: higher temperature growing apples | Reduce exposure, Increase adaptive capacity | WA8 |
| | | • Anti-Hail Nets | Increase adaptive capacity | WA4 |
| | | • Early warning systems for floods | Reduce exposure, reduce sensitivity | W2 |
| | | • Capacity building for farmers on agronomical practices (collective farming and crop rotation) | Increase adaptive capacity | WA5 |

# 4. Prioritising: Shortlist of CCA technology options

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

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

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

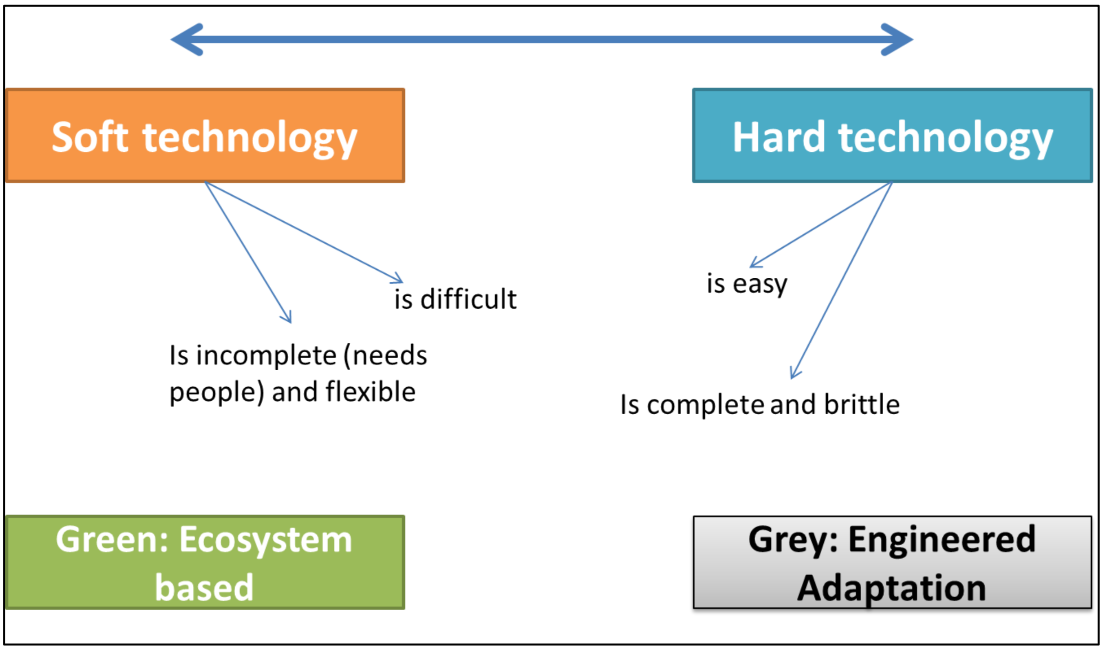



**Figure 6: Types of Technologies**

Source: DA adopted from Hobson (2011)

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

**Table 6: Longlist of Technology Solutions**

| Water | Code | Type |
|---|---|---|
| Runoff control structures for storm water management | W1 | Hard |
| Early warning systems for floods/ flash flood guidance systems | W2 | Hard/ Soft |
| Rooftop rainwater harvesting (both house hold level and community building) | W3 | Hard |
| Fog harvesting | W4 | Hard |
| Decentralized community level water recycling/ reuse | W5 | Hard/ Soft |
| Source water protection | W6 | Soft |
| Snow management and harvesting | W7 | Hard |
| **Water in Agriculture Sector** | **Code** | |
| Water security plans through Water User Associations/ VWSC | WA1 | Soft |
| Water Conveying Systems: surface, drip, sprinkler and low cost hybrid systems | WA2 | Hard |
| Spring Shed Development and Management | WA3 | Hard |
| Anti-Hail Nets | WA4 | Hard |
| Capacity building for farmers on agronomical practices (collective farming and crop rotation) | WA5 | Hard/Soft |
| Multipurpose dams | WA6 | Hard |
| Slow-forming terraces | WA7 | Hard |
| Climate Resilient Varieties: higher temperature growing apples | WA8 | Hard |

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

***Runoff control structures for storm water management:*** Runoff control structures temporarily store rainfall. When a heavy rainfall event occurs, the volume of runoff into rivers increases dramatically, increasing the danger of flood damage. A water storage design can release the rainwater to the river over a longer period of time. Runoff control structures are designed to capture runoff during peak flows, and can function as temporary storage sites. These structures are typically built with a discharge component to slowly release water into the nearby waterway to avoid it overflowing from the storage basin.

***Early warning systems for flash floods (Cloud burst):*** 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. Floods due to cloud burst are very quick formation 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).

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

***Fog harvesting:*** Fog harvesting provides an alternative source of freshwater through a technique used to capture water from wind - driven fog. Fog harvesting systems are typically installed in areas where the presence of fog is naturally high, typically coastal and mountainous regions. The systems are usually constructed in the form of a mesh net, stabilized between two posts that are spread out at an angle perpendicular to the prevailing wind carrying the fog. As the wind passes through the mesh, drops of freshwater form and drip into an underlying gutter, from which pipes lead the water into a storage tank. (UN Environment – DHI, CTCN, UNEP DTU, 2017)

***Decentralized community level water recycling/ reuse:*** Water recycling and reuse is an example of an Environmentally Sound Technology because it protects the environment, results in less pollution, utilizes resources in a more sustainable manner, allows its waste and products to be recycled, and handles residual wastes in a more acceptable manner than the technologies for which it substitutes (UNEP and GEC, 2004).

***Source water protection:*** Source water protection is a management approach used to protect public drinking water sources against contamination and overuse. This may include both surface water (rivers, lakes or streams) and underground aquifers. Source water protection entails management and policy measures that restrict overuse and pollution of water at its source, and may include regulations (e.g. water allocation quotas, water quality compliance regulations), compensation schemes (e.g. payments to industrial or agricultural users to reduce use of pollutants or extraction volumes, payments for ecosystem services schemes) or conservation measures in the upstream watershed. Plans are often designed in close collaboration with local communities, for example through education and awareness programs or new local governance structures.

***Snow management and harvesting:*** Snow harvesting involves using a snow fence to capture drifting snow and preserve it for water harvesting, in regions where seasonal snow occurs and additional water during summer months would be beneficial. Snow fences are, and have been, used to manage the distribution of snow for the purposes of supplementing water supply in Afghanistan, Canada etc (Thompson et.al, 2009).

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

***Water security plans through Water User Associations/ VWSC:*** A Water User Association (WUA) or Village Water and Sanitation Committee (VWSC) is an organisation for water management made up of a group of small and large-scale water users, such as irrigators, who pool their financial, technical, material, and human resources for operation and maintenance of a local water system, such as a river or water basin. Water Secuirty Plans developed by these groups can play a key role in integrated approaches to water management that seek to establish a decentralised, participatory, multi-sectoral and multi-disciplinary governance structure (UN Environment – DHI, CTCN, UNEP DTU, 2017).

***Water Conveying Systems: surface, drip, sprinkler and low cost hybrid systems:*** Effective irrigation can reduce water efficiency as well as reduce $CO_2$ emissions. Suffice as to say that all types of irrigation, such as flood, sprinkler, surface and sub-surface drip, can all enhance crop yields with subsequent increases in crop residues and enhanced carbon sequestration. Drip irrigation is based on the constant application of a specific and focused quantity of water to soil crops while the sprinkler system focuses on pressurised irrigation that consists of applying water to the soil surface using mechanical and hydraulic devices that simulate natural rainfall. Both systems uses pipes, valves and small drippers or emitters transporting water from the sources (i.e. wells, tanks and or reservoirs) to the crops (UN Environment – DHI, CTCN, UNEP DTU, 2017).

***Spring Shed Development and Management:*** Research of the hydrogeology in the Himalayan sub region demonstrated that aquifer recharge does not necessarily follow a ridge-to-valley approach, but a valley-to-valley pattern. This suggests that investments in recharge without understanding the recharge-discharge areas could be misguided and are unlikely to deliver a full return on investment. Accordingly, springshed development and management involves the assessment of the geologic controls on springs, the recharge potential of springs through springshed development measures (at the micro level), the maintenance and protection of springs, and the effective monitoring of spring discharge and water quality (Dhawan, 2015).

***Anti-Hail Nets:*** Originally used by apple growers to cover their orchards with netting to protect against hail. However, newer types can help in physical protection from intense solar radiation, excessive winds, untimely precipitation, and destructive pests and pathogens. It is already being implemented in Himachal Pradesh, but not at large scale.

***Capacity building for farmers on agronomical practices (collective farming and crop rotation):*** These are agronomical practices that increase capacities and therefore climate resilience of farmers during drought. 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 (ClimateTechWiki, n.d.). Crop rotation consists in sequentially producing plant species in a given location by alternating crops every year, every two years or every three years. This diversified production system prevents the build-up of pests and diseases as well as the exhaustion of the soil that usually occur with production of a single crop (or crops of a single family) in successive agricultural cycles (UN Environment – DHI, CTCN, UNEP DTU, 2017).

***Multipurpose dams:*** Multipurpose dams combine two or more functions of traditional single-purpose dams into one hydro infrastructure project. A multipurpose dam may combine storing and supplying water for irrigation, industry and human consumption with other uses such as flood control, power generation, navigation, run-off storage and water discharge regulation.

***Slow-forming terraces:*** Slow-forming terraces are constructed from a combination of infiltration ditches, hedgerows and earth or stone walls. This technology decreases superficial water run-off, increasing water infiltration and intercepting the soil sediment (UNESCO-ROSTLAC, 1997). Slow-forming terraces are called as such because they take between three and five years, and possibly even ten years, to fully develop (ClimateTechWiki, n.d.).

***Climate Resilient Varieties: higher temperature growing apples:*** Breeding for improved performance under environmental stresses involves activities which accumulate favourable alleles (different forms of a gene) which contribute to stress tolerance through biotechnology or selective breeding. Biotechnological contributions to crop adaptation to climate change give us the prospect of making more dramatic changes to crop responses to stress than is possible with conventional breeding and making them more rapidly.

## 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 Himachal Pradesh, some of them are already in place whereas others are good practices from different states or countries that could be beneficial for Himachal Pradesh, 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 7: 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 | 0: very low → 10: very high |

| | | | |
|---|---|---|---|
| | | Panchayati Raj Institutions, Urban Local Bodies, Water Users Associations) | |
| Environmental Benefits | D1 | Contribution of the technology to protect and sustain aquatic ecology. Protecting the diversity of the rivers and ponds where water technology adaptation takes place. | 0: very low → 10: very high0: very low → 10: very high |
| | D2 | Recycling /Reuse of water and/or substitute to domestic water supply | 0: very low → 10: very high |
| Economic Benefits | E1 | Involve and encourage corporate sector / industries to take up, support and promote technology as part of CSR to ensure the financial sustainability of the technology and its use. | 0: very low → 10: very high |
| | E2 | Improving economic performance in that sector through increased productivity etc. farmer income and ability to reinvest | 0: very low → 10: very high |
| Technological Benefits | F1 | Local experience exists, technology can be operated by local operators without needing external support, does not conflict with existing processes, easier technology diffusion and farmer acceptance. | 0: very low → 10: very high |
| | F2 | Technology helps in increasing beneficial output per unit of water i.e. looking at engineering and agronomic aspects in conjunction, increasing water use efficiency | 0: very low → 10: very high |
| Cost | G1 | Low cost of set-up including the costs of importation and installation. | 0: very low → 10: very high |
| | G2 | Low cost for maintenance/ operation and other running costs of the technology over time. | 0: very low → 10: very high |

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

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

**Table 8: 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 | **18** |
| 2 | Social Benefits: Contribution to social development priorities | **20** |

| | | |
|---|---|---|
| 3 | Institutional Benefits: Implementation availability through national and state level coherence | **9** |
| 4 | Environmental Benefits: Contribution to environmental conservation priorities | **14** |
| 5 | Economic Benefits: Potential of leveraging funds from private sources as well as improving incomes | **14** |
| 6 | Technological Benefits: Potential for higher acceptability of technology | **12** |
| 7 | Cost: Potential benefits through lower costs of operation and maintenance | **13** |
| **Total** | | **100%** |

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

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

**Table 9: Multi Criteria Matrix for identified CCA technologies**

| Code | Climate Benefits | | Social Benefits | | | Institutional Benefits | | | Environmental | | Economic | | Technological | | Cost | | Total scores | Total Weighted Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Criteria Weight (total 100 %) | A1 | A2 | B1 | B2 | B3 | C1 | C2 | C3 | D1 | D2 | E1 | E2 | F1 | F2 | G1 | G2 | | |
| | 18.00% | | 20.00% | | | 9.00% | | | 14.00% | | 14.00% | | 12.00% | | 13.00% | | | |
| **Water Sector** | | | | | | | | | | | | | | | | | | |
| W1 | 8 | 2 | 4 | 5 | 6 | 8 | 7 | 8 | 5 | 7 | 6 | 7 | 7 | 7 | 3 | 3 | 5.8 | 5.6 |
| W2 | 8 | 2 | 8 | 8 | 7 | 7 | 8 | 8 | 8 | 3 | 5 | 8 | 8 | 6 | 6 | 8 | 6.8 | 6.4 |
| W3 | 8 | 1 | 7 | 7 | 7 | 9 | 7 | 9 | 4 | 6 | 4 | 7 | 10 | 7 | 5 | 5 | 6.4 | 6.1 |
| W4 | 7 | 5 | 7 | 6 | 7 | 6 | 7 | 6 | 6 | 7 | 7 | 6 | 8 | 8 | 5 | 5 | 6.4 | 6.4 |
| W5 | 8 | 1 | 8 | 8 | 8 | 7 | 7 | 7 | 8 | 10 | 6 | 5 | 7 | 9 | 6 | 6 | 6.9 | 6.8 |
| W6 | 7 | 4 | 8 | 7 | 7 | 7 | 6 | 7 | 9 | 5 | 4 | 7 | 8 | 7 | 7 | 6 | 6.6 | 6.6 |
| W7 | 7 | 5 | 7 | 6 | 8 | 9 | 7 | 7 | 7 | 6 | 4 | 7 | 6 | 7 | 5 | 5 | 6.4 | 6.3 |
| **Water in Agriculture Sector** | | | | | | | | | | | | | | | | | | |
| WA1 | 7 | 4 | 7 | 7 | 7 | 7 | 4 | 7 | 7 | 7 | 6 | 7 | 5 | 6 | 9 | 7 | 6.5 | 6.5 |
| WA2 | 8 | 8 | 6 | 5 | 6 | 8 | 8 | 8 | 7 | 7 | 6 | 6 | 8 | 7 | 9 | 10 | 7.3 | 6.8 |
| WA3 | 8 | 3 | 7 | 7 | 7 | 8 | 8 | 9 | 8 | 6 | 5 | 5 | 5 | 7 | 8 | 7 | 6.8 | 6.6 |
| WA4 | 7 | 2 | 7 | 7 | 8 | 9 | 9 | 7 | 6 | 2 | 7 | 6 | 7 | 8 | 10 | 3 | 6.6 | 6.3 |
| WA5 | 7 | 6 | 3 | 7 | 6 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 9 | 6.5 | 6.4 |
| WA6 | 7 | 6 | 7 | 7 | 7 | 7 | 6 | 8 | 2 | 4 | 4 | 4 | 3 | 7 | 7 | 8 | 5.9 | 5.7 |
| WA7 | 7 | 2 | 8 | 7 | 7 | 7 | 8 | 7 | 8 | 6 | 6 | 4 | 4 | 7 | 9 | 7 | 6.5 | 6.3 |
| WA8 | 9 | 3 | 8 | 7 | 7 | 9 | 9 | 9 | 7 | 3 | 6 | 9 | 8 | 8 | 6 | 6 | 6.9 | 6.5 |

## 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 et. al (2015) particularly technologies identification and prioritization of technologies with the use of the criteria and scoring and decision on the priority technologies through stakeholders consultation.

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

**Table 10: List of prioritised technologies**

| Technology | Code | Total Cumulative scores (out of 10) | Total Weighted Score (out of 10) |
|---|---|---|---|
| **Shortlist of Technologies for Water Sector:** | | | |
| Early warning systems /Flash flood guidance systems (including cloud burst) | W2 | 6.8 | 6.4 |
| Decentralized community level water recycling/ reuse | W5 | 6.9 | 6.8 |
| Source water (watershed) protection | W6 | 6.6 | 6.6 |
| **Shortlist of Technologies for Water in Agriculture Sector:** | | | |
| Water Conveying Systems: surface, drip, sprinkler and low cost hybrid systems | WA2 | 7.3 | 6.8 |
| Springshed Development and Management | WA3 | 6.8 | 6.6 |
| Climate Resilient Varieties: higher temperature growing apples | WA8 | 6.9 | 6.5 |

## 4.4 Prioritised technologies

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

### 4.4.1. Prioritised technologies for Water Sector

### Option 1: W2: Early warning systems for floods/ flash flood guidance systems (cloud burst)

| | | |
|---|---|---|
| Technology | Early warning systems / Flash flood guidance systems (including cloud burst) | |
| 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. Floods due to cloud burst are very quick formation 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). | |
| Climate related criteria | | Score |
| A1: CCA Efficiency | Increases resilience through early preparedness, response and recovery. | 8 |
| A2: GHG reduction | Does not contribute much to climate change mitigation, through GHG emission reduction | 2 |
| 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 | 7 |

| | | |
|---|---|---|
| **Institutional Benefits** | | |
| C1: refers to existing plans | Is usually under the purview of the HP State Disaster Management Authority, 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 SDMA | 8 |
| C3: coherent with policies | Is covered under the Disaster Management Plan 2015 of HP state | 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 damage to surrounding ecosystems. | 8 |
| 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 | 5 |
| E2: productivity | Helps improve farmer incomes through avoiding major losses during disasters, | 8 |
| **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. | 8 |
| 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 | 8 |

## Option 2: W5: Decentralized community level water recycling/ reuse

| | | |
|---|---|---|
| Technology | Decentralized community level water recycling/ reuse | |
| Sector | Water | |
| Subsector | Alternative water sources | |
| **Technology characteristics** | | |
| Introduction | Water recycling and reuse is an example of an Environmentally Sound Technology because it protects the environment, results in less pollution, utilizes resources in a more sustainable manner, allows its waste and products to be recycled, and handles residual wastes in a more acceptable manner than the technologies for which it substitutes (UNEP and GEC, 2004). Further, Climate proofed drinking water treatment systems and piped household connection supply provides clean and safe water even in times of extreme weather events which contaminate household level water sources like shallow tubewells or water reservoirs. | |
| **Climate related criteria** | | **Score** |
| A1: CCA Efficiency | Water recycling and reuse is an important adaptation response to climate change as the increasingly unpredictable weather patterns and their effects are likely to have negative consequences on freshwater resource quantity and quality | 8 |
| A2: GHG reduction | Does not contribute much to climate change mitigation, through GHG emission reduction | 1 |
| **Social criteria** | | |
| B1: Health | It helps improve water availability and addresses WASH needs thereby improving health parameters with reduced human morbidity | 8 |
| B2: Inequity | Small scale and simple techniques are possible at the household level, for example directly reusing household waste water for flushing toilets and can help address sanitation issues for women and adoloscent girls. | 8 |
| B3: sustainable development | Increases water availability for potentially water stressed or arid areas thereby addressing water scarcity | 8 |
| **Institutional Benefits** | | |
| C1: refers to existing plans | As per the National Water Mission and National Water Policy the state recommends water recycling of waste water | 7 |
| C2: clear responsibility | The responsibility mainly lies between the Public Works and Rural Development Department. There is still some level of cooperation required with community level institutions. | 7 |
| C3: coherent with policies | The HP sustainable development programme includes water recycle and reuse as an initiative | 7 |

| Environmental Benefits | | |
|---|---|---|
| D1: Ecology / biodiversity | Retains wastewater for reuse, instead of it being discharged into the environment and potentially polluting ecosystems | 8 |
| D2: Recycle, Reuse, Substitute | The technology core focus is on recycling/ reuse of water to substitute for domestic water use. | 10 |
| **Economic Benefits** | | |
| E1: private sector participation | There is a possibility of corporate CSR to flow into this technology as there have already been some examples of water purification systems and filters being distributed to communities. | 6 |
| E2: productivity | Provides an easily accessible water source to economic sectors such as industry and agriculture, promoting economic development and food production | 5 |
| **Technological Benefits** | | |
| F1: experience and acceptance | Public may be against coming into contact with reused "waste" water. There might be sensitization and awareness sessions required. | 7 |
| F2: water efficiency | Technology provides high level of beneficial output per unit use of water | 9 |
| **Cost** | | |
| G1: investment | As a community owned decentralized water treatment system, costs may be limited to purchase and distribution of treatment systems | 6 |
| G2: O&M | Post-treatment water quality testing, system monitoring and maintenance are very important and form the major costs for maintenance once the technology is installed. | 6 |

### Option 3: W6: Source water protection

| | | |
|---|---|---|
| Technology | Source water protection | |
| Sector | Water | |
| Subsector | Water pollution | |
| **Technology characteristics** | | |
| Introduction | Source water protection is a management approach used to protect public drinking water sources against contamination and overuse. This may include both surface water (rivers, lakes or streams) and underground aquifers. Source water protection entails management and policy measures that restrict overuse and pollution of water at its source, and may include regulations (e.g. water allocation quotas, water quality compliance regulations), compensation schemes (e.g. payments to industrial or agricultural users to reduce use of pollutants or extraction volumes, payments for ecosystem services schemes) or conservation measures in the upstream watershed. Plans are often designed in close collaboration with local communities, for example through education and awareness programs or new local governance structures. | |
| **Climate related criteria** | | **Score** |
| A1: CCA Efficiency | Helps protect drinking water sources against contamination and overuse; including surface and groundwater sources. Addressing both quality and quantity | 7 |
| A2: GHG reduction | There isn't much GHG emission reduction except through reduced use of RO systems or other energy intensive water purification units | 4 |
| **Social criteria** | | |
| B1: Health | Provides benefits to all community members, both upstream and downstream; in terms of potable drinking water thereby improving health parameters. | 8 |
| B2: Inequity | Source protection plans are developed in close collaboration with communities and can address gender and equity issues, for water distribution. | 7 |
| B3: sustainable development | Creates livelihood opportunities as it has a participatory approach, strengthening communities near the watershed | 7 |
| **Institutional Benefits** | | |
| C1: refers to existing plans | Has been implemented through DoA, HPFD, DoH through Joint Forest Management and Participatory Watershed Development. Has support from existing work as IWDP | 7 |
| C2: clear responsibility | Mostly focussed under the Department of Agriculture and Department for Horticulture | 6 |

| | | |
|---|---|---|
| C3: coherent with policies | It requires collaboration with communities and government officials closely, further there maybe frequent interaction when compensation to upstream users is involved | 7 |
| Environmental Benefits | | |
| D1: Ecology / biodiversity | Benefits biodiversity, protecting upstream habitats, Improves water quality throughout the watershed. Contributes to sediment control and reduces erosion. | 9 |
| D2: Recycle, Reuse, Substitute | It doesn't directly recycle or substitute for domestic water however, provides a sustainable supply of clean water and reduces or avoids water treatment costs. | 5 |
| Economic Benefits | | |
| E1: private sector participation | Private sector investment may be improved if tourism interests are involved. | 4 |
| E2: productivity | Supply of clean water and reduces or avoids water treatment costs. Further in case of Himachal Pradesh clean water streams help improve livelihood income opportunities (tourism) | 7 |
| Technological Benefits | | |
| F1: experience and acceptance | Is easily adopted by communities as source protection plans are often designed in close collaboration with them | 8 |
| F2: water efficiency | Provides increased amount of potable water for use, increases efficiency | 7 |
| Cost | | |
| G1: investment | Implementation costs can be high (compensation to upstream users for reduced or avoided land and water use). Also required extended awareness and sensitization programmes. | 7 |
| G2: O&M | Maintenance through communities (water user associations). Additionally, to ensure the rules are being followed (for example no illegal logging), water quality and upstream land use should be regularly monitored. | 6 |

### 4.4.2. Prioritised technologies for Water Sector

#### Option 1: WA 2: Water Conveying Systems: Surface, drip, sprinkler and low cost hybrid systems

| | | |
|---|---|---|
| Technology | Water Conveying Systems: Surface, drip, sprinkler and low cost hybrid systems | |
| Sector | Agriculture/ Water | |
| Subsector | Water Efficiency and Demand Management | |
| **Technology characteristics** | | |
| Introduction | Effective irrigation can reduce water efficiency as well as reduce $CO_2$ emissions. Suffice as to say that all types of irrigation, such as flood, sprinkler, surface and sub-surface drip, can all enhance crop yields with subsequent increases in crop residues and enhanced carbon sequestration. Drip irrigation is based on the constant application of a specific and focused quantity of water to soil crops while the sprinkler system focuses on pressurised irrigation that consists of applying water to the soil surface using mechanical and hydraulic devices that simulate natural rainfall. Both systems uses pipes, valves and small drippers or emitters transporting water from the sources (i.e. wells, tanks and or reservoirs) to the crops (UN Environment – DHI, CTCN, UNEP DTU, 2017). | |
| **Climate related criteria** | | **Score** |
| A1: CCA Efficiency | It increases adaptive capacity. Particularly in areas subject to climate change impacts such as seasonal droughts, improved irrigation systems reduce demand for water and reduces water evaporation losses (as evaporation increases at higher temperatures). | 8 |
| A2: GHG reduction | In some cases if there is sufficient difference in height between the water source and the field, distribution may be gravity-based rather than pump-based (UN Environment – DHI, CTCN, UNEP DTU, 2017). Thereby reducing GHG emissions. | 8 |
| **Social criteria** | | |
| B1: Health | Improved irrigation system technologies can be implemented via a water user association to improve economic benefits and reduce initial investment costs. Improved irrigation system contributes to efficient water use, reduces requirements for fertilisers and increases soil productivity. This could further address increased per capita food availability. | 6 |
| B2: Inequity | This technology does not directly reduce inequity between social classes, gender, ethnic groups etc. but by improving incomes does help improve financial status. | 5 |

| | | |
|---|---|---|
| B3: sustainable development | With improving water efficiency, improved irrigation system is suitable in areas with permanent or seasonal water scarcity | 6 |
| Institutional Benefits | | |
| C1: refers to existing plans | Government support is available for drip irrigation through the Ministry of Agriculture and currently it is focussed under the National Mission on Sustainable Agriculture (NMSA). | 8 |
| C2: clear responsibility | It falls under one ministry/ department of agriculture and therefore allows for a high level of convergence. | 8 |
| C3: coherent with policies | It is currently under the Pradhan Mantri Krishi Sinchayee Yojana and has financial assistance available. It is also one of the flagship programmes of the government. | 8 |
| Environmental Benefits | | |
| D1: Ecology / biodiversity | The only environmental/ ecosystemic benefit is efficient water use. It also further does not create adverse ecosystem impacts in which it is used. | 7 |
| D2: Recycle, Reuse, Substitute | These maybe used to convey recycled water, however they do not possess a system of reuse otherwise. It however reduces usage thereby allowing water to be used for other purposes. | 7 |
| Economic Benefits | | |
| E1: private sector participation | In terms of private investment, companies are usually focused on large land extension projects and do not cater for small and medium-sized farmers. | 6 |
| E2: productivity | Studies have shown that help increases farmers' incomes in some applications producers' incomes rise by as much as 35% (ClimateTechWiki, n.d.) | 6 |
| Technological Benefits | | |
| F1: experience and acceptance | Farmers prefer as it gives immediate water conservation impacts. However, it easy easily implementable/ upscalable once a clear understanding of the technical characteristics of the system and of the crop's water requirements are given. | 8 |
| F2: water efficiency | The technology's core idea is water efficiency and therefore has a very good output per unit of water. | 7 |
| Cost | | |
| G1: investment | The main costs involved are the materials for the distribution network, including the pump, the filtering and fertilizing systems and the drip line. The cost of labour for installation is also considerable. Further training in system operation and maintenance are assumed. | 9 |
| G2: O&M | At the start capacity building costs are involved for maintenance as over time drip tape or tubing must be carefully maintained in order to avoid leaking or plugging and emitters must be regularly cleaned to avoid blockage from chemical deposits. | 10 |

## Option 2: WA 3: Spring-shed Development and Management

| | | |
|---|---|---|
| Technology | Spring-shed Development and Management | |
| Sector | Agriculture/ water | |
| Subsector | Water conservation | |
| **Technology characteristics** | | |
| Introduction | Research of the hydrogeology in the Himalayan sub region demonstrated that aquifer recharge does not necessarily follow a ridge-to-valley approach, but a valley-to-valley pattern. This suggests that investments in recharge without understanding the recharge-discharge areas could be misguided and are unlikely to deliver a full return on investment. Accordingly, springshed development and management involves the assessment of the geologic controls on springs, the recharge potential of springs through springshed development measures (at the micro level), the maintenance and protection of springs, and the effective monitoring of spring discharge and water quality (Dhawan, 2015). | |
| **Climate related criteria** | | **Score** |
| A1: CCA Efficiency | Augments water storage, recharges aquifers for the dry season, builds adaptive capacity using mountainous ecosystem as a water tower | 8 |
| A2: GHG reduction | Does not add to GHG emissions and may reduce emissions by less use of pumps in some cases | 3 |
| **Social criteria** | | |
| B1: Health | Increases freshwater supply for drinking through stream regeneration therefore improves health parameters | 7 |
| B2: Inequity | While it doesn't contribute much to water distribution it provides for equal protection to all social classes/ ethnic groups | 7 |
| B3: sustainable development | Reports have indicated that an average of 15% increase in crop yield and 25% increase in the cultivation of irrigated crops such as paddy, tomato and vegetables has been seen in Sikkim where this approach was implemented.[2] | 7 |
| **Institutional Benefits** | | |
| C1: refers to existing plans | There as been implemented already in pockets in Himachal Pradesh, under the Participatory Ground Water Management Programme, CPWD Programme. PSI in Himachal Pradesh has successfully worked on springs in the Sirmour district (NITI Aayog, 2017) | 8 |

[2] Indian Institute of Science's assessment report (2013)

| | | |
|---|---|---|
| C2: clear responsibility | The governance of springs is as complex as managing ground water anywhere else in the country. Springshed management involves the institutions presiding over the functions of catchment management or creating water distribution systems. The broader resource management, which entails catchment protection, recharge interventions, soil and water conservation, and plantation, is usually split between the government departments for forest and for rural development (Dhawan, 2015). | 8 |
| C3: coherent with policies | Is already part of the Mid-Himalayan Watershed Development Project taken up by DoA and the Department of Rural Development (ADB, 2010) | 9 |
| Environmental Benefits | | |
| D1: Ecology / biodiversity | Has helped in recharging lakes, reviving springs, reforestation, thereby overall ecosystem health | 8 |
| D2: Recycle, Reuse, Substitute | Springshed may not possess a system of reuse directly. It however reduces usage of existing water sources thereby allowing water to be used for other purposes. | 6 |
| Economic Benefits | | |
| E1: private sector participation | There is no direct private investment but there is some interest in the sector for being involved in the management of springs. | 5 |
| E2: productivity | Increased irrigation due to more available water/ recharged springs provides improved crop yield and production leading to improves incomes | 5 |
| Technological Benefits | | |
| F1: experience and acceptance | Has been a successful application in Sikkim, requires training and sensitization of communities for higher uptake. There is training required in para-hydrogeology. This also provides other employment opportunities | 5 |
| F2: water efficiency | It makes use of water which is usually lost due to the runoff and it provides improved output during water scarcity times per unit of water. | 7 |
| Cost | | |
| G1: investment | Costs are involved in terms of training, studies for identifying recharge areas of various springs and streams, and building the structures. Departments will also have to develop protocols for reporting by the communities | 8 |
| G2: O&M | Maintenance is in the form of capacity building of communities to undertake such activities in the long-term and also become equipped in the operation and maintenance of springs. However, a system of Operation and Maintenance (O&M) fund to provide capital for future upkeep and management of the system can help in protection of the spring | 7 |

### Option 3: WA 8: Climate Resilient Varieties: higher temperature growing apples

| | | |
|---|---|---|
| Technology | Climate Resilient Varieties: higher temperature growing apples | |
| Sector | Agriculture | |
| Subsector | Increasing crop resilience and productivity | |
| **Technology characteristics** | | |
| Introduction | Breeding for improved performance under environmental stresses involves activities which accumulate favourable alleles (different forms of a gene) which contribute to stress tolerance through biotechnology or selective breeding. Biotechnological contributions to crop adaptation to climate change give us the prospect of making more dramatic changes to crop responses to stress than is possible with conventional breeding and making them more rapidly. | |
| **Climate related criteria** | | **Score** |
| A1: CCA Efficiency | Less water using, higher temperature tolerance increase adaptive capacity of crops and add to increased resilience | 9 |
| A2: GHG reduction | With higher temperature and drought tolerant crops there will be less irrigation thereby reducing GHG emissions | 3 |
| **Social criteria** | | |
| B1: Health | Can provide better health benefits in terms of less pesticide use, Helps maintaining food and fibre production in a degrading environment | 8 |
| B2: Inequity | Does not really help in equitable water distribution but allows for less use of water for irrigation thereby saving water for other purposes. | 7 |
| B3: sustainable development | Help to increase incomes through better crop during periods of climate stress contributing to sustainable development | 7 |
| **Institutional Benefits** | | |
| C1: refers to existing plans | Finds synergies under the Mission for Sustaining the Agriculture & Horticulture, further supported by DoH | 9 |
| C2: clear responsibility | Mostly taken care of by the DoH, has one department strongly focussed on climate resilient varieties | 9 |
| C3: coherent with policies | This is also supported through the National Mission on Agriculture and involves community participation | 9 |
| **Environmental Benefits** | | |
| D1: Ecology / biodiversity | Excessive uses of inputs such as fertilizers and pesticides, frequent cultivation, and lack of proper erosion control systems are constant threats to the environment. As input use, particularly fertilizers and pesticides, can be controlled in crop diversification, it will be environmentally friendly and provide products of high quality free of pesticide residues for human consumption. | 7 |

| | | |
|---|---|---|
| D2: Recycle, Reuse, Substitute | There is not much scope of water reuse/recycle as it is an agriculture based technology, | 3 |
| Economic Benefits | | |
| E1: private sector participation | There can be private investment leveraged for buying products from farmers at higher price and seeds support | 6 |
| E2: productivity | Enables farmers to grow surplus products for sale at market and thus obtain increased income | 9 |
| Technological Benefits | | |
| F1: experience and acceptance | The main barrier to introducing new and improved crop varieties through farmer experimentation is the misconception that hybrid species have low productivity. | 8 |
| F2: water efficiency | These maybe drought tolerant or less water requiring crop varieties leading to improved outputs per unit of water. | 8 |
| Cost | | |
| G1: investment | Costs of farmer experimentation are generally low, but results may only have local applicability. Capital investment will relate to the purchase of new seed varieties (if not available 'wild' locally) and labour time. Where farmers are implementing a project initiated by an external agency, capital costs for training, technical experts and field staff, on farm trial equipment (an experimental plot may be established), and site visits may also be required. | 6 |
| G2: O&M | Only preliminary feasibility and market research costs need to be considered in the financial requirements. Infrastructure (such as transport and storage) and marketing costs should also be considered at the start. Further profits from crop production could yield the maintenance costs in terms of buying new seeds etc. | 6 |

# 5. Case study for Himachal Pradesh: Spring-shed development and management for water security

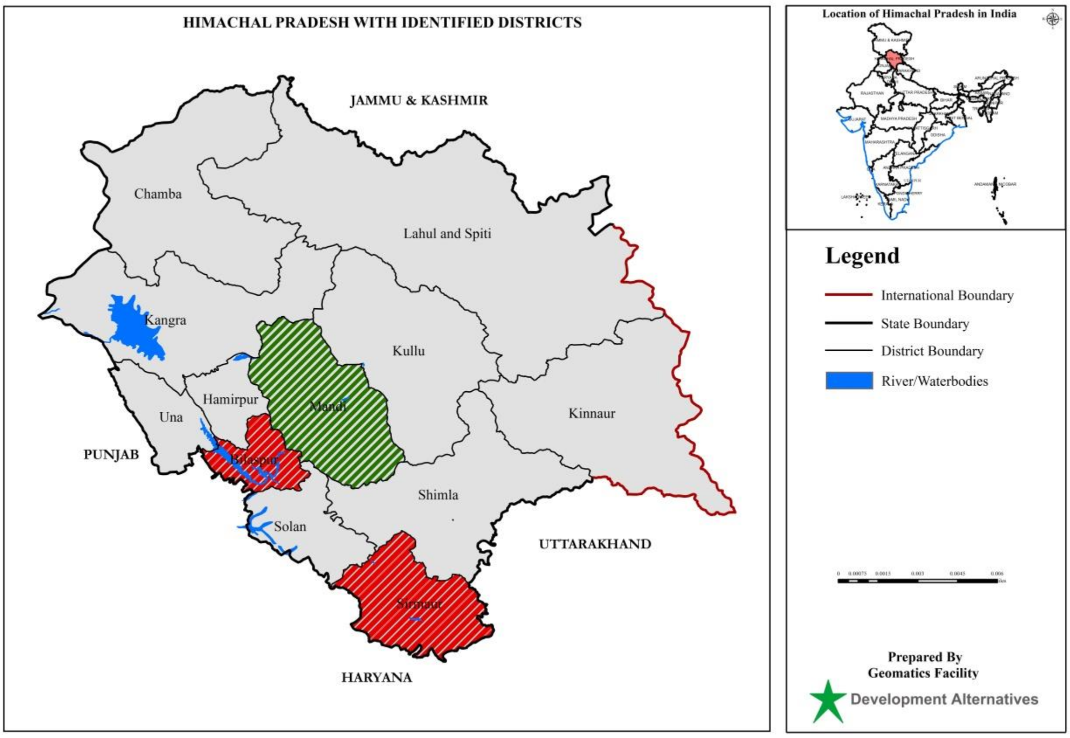



**Figure 7: Suggested District for Project (Mandi) and Existing Springshed Project Districts (Bilaspur and Sirmaur)**

Source: DA (2018)

Mountain springs are the primary source of water for the rural households in the Himalayan region. For many people, springs are the sole source of water (ADB, 2010). In the State many rural water schemes are sourced from springs or small rivers located strategically close to and with adequate elevation to supply settlements by gravity (ADB, 2010). There is increasing evidence that springs are drying up or their discharge is reducing throughout the Himalayan region (NITI, 2017). Increased drought and reduced dry season flows will likely put many smaller river and spring sources at risk of inadequate flow or drying up.

A survey in Sikkim found that the water discharge has declined in half of all springs in the state – a dangerous sign that aquifers are depleting in a state which is almost entirely dependent on springs for drinking water. Similar effects are being observed in nearly all the mountainous regions of India. Besides, water quality is also deteriorating under changing land use and improper sanitation (NITI, 2017).

**Springshed Development and Management:** Research of the hydrogeology in the Himalayan sub region demonstrated that aquifer recharge does not necessarily follow a ridge-to-valley approach, but a valley-to-valley pattern. This suggests that investments in recharge without understanding the recharge-discharge areas could be misguided and are unlikely to deliver a full return on investment. Accordingly, springshed development and management involves the assessment of the geologic controls on springs, the recharge potential of springs through springshed development measures (at the micro level), the maintenance and protection of springs, and the effective monitoring of spring discharge and water quality (Dhawan, 2015). The methodology has been able to successfully integrate natural science with social sciences, hydrogeology with engineering and research with implementation while ensuring the common thread of community involvement and skill developing throughout.

In another Himalayan state, Sikkim, they have found a way to manage these springs. The first systematic initiative was undertaken through the Dhara Vikas Programme by the Rural Management and Development Department (RM&DD), Government of Sikkim.

**Springshed Development in the Bilaspur and Sirmaur District**

People's Science Institute from Dehradun has used the concept of Participatory Groundwater Management (PGWM) to manage spring water in the Thanakasoga – Luhali Panchayat area through a comprehensive springshed management approach. Improved spring discharge, especially during the lean season through systematic recharge measures based on hydrogeological mapping has been the most significant impact. Protection and conservation of the natural recharge area for the aquifers feeding this spring system has also led to improved quality of spring water over a three-year period. Demand management protocols have also been developed in close co-ordination with the local communities.

In 2001-02, PSI initiated the "Resolving the Himalayan Dilemma" programme under the initiative "*Himmothan Pariyojana*" supported by Sir Ratan Tata Trust. The objective was to provide training and development support to 15 voluntary organisations in the states of Uttarakhand and Himachal Pradesh for undertaking participatory natural resources management projects on a watershed basis, each in an area of about 500 ha over a period of four years. Between 2002 and 2006, eleven watershed development projects were undertaken by PSI with local partner organizations (POs) to help the communities to meet their basic needs (water, food, fodder, fuel wood and employment) through participatory processes. In the 11 watersheds, spring-shed development activities were undertaken creating water sanctuaries. The spring-shed development activities included engineering measures (digging of staggered contour trenches, nala treatment, brush wood check dams, loose boulder check dams, construction, gabions/retaining walls/spurs, diversion drains) and vegetative measures (fuelwood, fodder and fruit trees plantations, grassland development, and live hedge rows).

**Expected Results**:

- Can help in reviving natural spring source, reforestation, thereby overall ecosystem health
- Increases irrigation & drinking water.
- Creation of Village spring atlas
- Provides improved crop yield and production leading to improves incomes
- Training and sensitization of communities for higher uptake.

**Synergies :** There has been implemented already in pockets in Himachal Pradesh, under the Participatory Ground Water Management Programme, CPWD Programme. PSI in Himachal Pradesh has successfully worked on springs in the Sirmour district (NITI Aayog, 2017). Further it is already part of the Mid-Himalayan Watershed Development Project taken up by DoA and the Department of Rural Development (ADB, 2010).

This can be led by the DEST, IPH, Rural Development and District Administration. However, the governance of springs is as complex as managing ground water anywhere else in the country. Springshed management involves the institutions presiding over the functions of catchment management or creating water distribution systems. The broader resource management, which entails catchment protection, recharge interventions, soil and water conservation, and plantation, is usually split between the government departments for forest and for rural development (Dhawan, 2015).

**Project Concept:**

A project on developing and mangaging springshed can be Mandi District, however, there have been successful examples in Sirmaur and Bilaspur districts. Following are the few steps that may be followed in order to develop an intervention:

- Use of Global Positioning System (GPS), GIS to identify spring shed areas
- Capacity building of communities to sensitize about spring shed management
- Laying of contour trenches.
- Digging of trenches and laying of pipes for the recharge of natural springs

# 6. Bibliography

ADB (2010). Climate change adaptation in Himachal Pradesh: Sustainable strategies for water resources. Mandaluyong City, Philippines: Asian Development Bank, 2010.

ClimateTechWiki website (no date). Retrieved from http://www.climatetechwiki.org/content/

CRGGS (2015). Climate Resilient Green Growth Strategy for Himachal Pradesh (Summary for Policymakers). Implemented by The Energy and Resources Institute (TERI) in collaboration with Global Green Growth Institute (GGGI).

Dhawan, H. (2015). *Improving the Practice and Policy of Springshed Management in India*. Daegu and Gyeongbuk Republic of Korea: Dhawan, 7th World Water Forum 2015.

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

Government of Himachal Pradesh – GOHP (2012). State Action Plan on Climate Change. Shimla.

Government of Himachal Pradesh - GOHP (2014). Himachal Pradesh Development Plan.

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

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

Kulkarni, A, M. Bahuguna, I, Rathore, B, Singh, S, Randhawa, S., Sood, R and Dhar, S. (2007). Glacial retreat in Himalayas using Indian Remote Sensing Satellite data. Current science. 92. 69-74.

Thompson, K. J., Chalmers A. S., Henry, K. S. and Hardy, J. S. (2009), Snow Harvesting: A Potential Water Source for Afghanistan, U.S. Army Corps of Engineers, Washington.

NITI Aayog (2017). *Inventory And Revival Of Springs In Himalayas For Water Security*. Delhi: Ministry of Science & Technology, Government of India.

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.

UN Environment – 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.

UNEP and GEC (2004). Water and Wastewater Reuse: An Environmentally Sound Approach for Sustainable Urban Water Management.

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

UNESCO-ROSTLAC (1997) at ClimateTechWiki website, undated. Retrieved from https://www.climatetechwiki.org/content/slow-forming-terraces