Final Report

Shimla Climate Change Adaptation Partnership Project

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URBAN CLIMATE CHANGE RESEARCH NETWORK

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CONTENTS

LIST OF FIGURES

LIST TABLES

Executive Summary

This report presents key observations and findings of Shimla Climate Adaptation Partnership Project implemented by International City/County Management Association (ICMA) in association with CityLinks Program and Urban Climate Change Research Network (UCCRN) during 2015-2016. The works carried out under the program and the outcomes of the study are based on three visits to Shimla during May 2015 - August 2016. The first trip consisted in 'Outlining the Work Plan', and identifying and prioritizing the key climate change challenges and vulnerability sectors. The main purpose of the first trip was to advance a city to city exchange program between the cities of Shimla, Himachal Pradesh, India and Boulder, Colorado, USA on climate adaptation and resilience, by identifying key climate change adaptation challenges and ascertaining a set of key issues for technical exchange between the two cities. During this trip water was identified as the most vulnerable sector to climate change impact in Shimla. It was ascertained that the partnership program should focus on assessing the impact of climate change on water availability, distribution, utilization and community access; and to suggest measures for improving the availability, distribution and efficiency of water resources in the city keeping in view the past, as well as future trends in climate change. The second visit to Shimla was the 'Technical Assistance Trip' which involved comprehensive field-visits to different water supply projects and their catchment areas, assessment of water distribution system and mechanism, status of water supply, collection of data and information from diverse sources, ground observations, interaction with community and their political representatives, meetings with officials of key government departments, and making presentations of the preliminary key findings in the stakeholders workshop. The third and final trip to Shimla provided the opportunity of in-depth discussion with policy planners at the local and State Government levels, and finalization of the final outcomes and recommendations with various stakeholders.

The city of Shimla was settled by the British during colonial period, and was declared the Summer Capital of the British India in 1864. It is a rapidly urbanizing town located in the tectonically alive and high seismic risk zone in the Lesser Himalayan ranges of the State of Himachal Pradesh in India. Shimla evolved from a small hill settlement to one of the largest towns situated in the Himalayan mountains of India. Besides being the capital of the State of Himachal Pradesh, Shimla is one of the most popular and heavily visited hill stations located in the Himalayan mountains. During the recent years, Shimla experienced rapid but mostly unplanned urban growth which is increasing the susceptibility of intensively modified and densely populated fragile slopes to the active processes of mass movement and slope failure.

Shimla is highly exposed to rainfall variability and increase in temperature which may affect the ecosystem services, particularly the availability, supply and quality of freshwater; and increase the vulnerability of urban systems to climate change induced natural risks, specifically high intensity rainfall, flash-floods, slope failures landslides, droughts causing loss of life, and devastation of property, urban services, infrastructure, livelihood and health of people, particularly that of marginalized and poor households. Shimla's water supply comes from different streams and rivers located outside the boundaries of the town. It was observed that the water availability in streams and springs is declining due to rapid land use intensifications and deforestation in catchment areas of springs and streams, and changes in precipitation pattern. All the streams originating and flowing across the town are highly contaminated due to sewage and waste pollution. Additionally, the observed future climatic changes in Shimla are likely to exacerbate the problem of water availability and supply to the fast growing population. Shimla may need to address several challenges ahead under rapidly changing

climatic conditions, including integrating climate models to future scenarios for ensuring adequate water supply, reducing vulnerability to climate change induced natural disasters, sustainable tourism, and adapting to increasing pressures of urbanization.

Shimla Climate Adaptation Partnership Program has been established by the International City/County Management Association (ICMA) and CityLinks. The program partners international cities from developing countries with resource cities in developed countries. In the current partnership programmes, Shimla in India is involved as the partner city from a developing country and Boulder, USA is participating as a resource city, whereas the UCCRN is serving as the CityLinks' key science knowledge provider. During a 15- month period, climate experts and urban policy planners from both cities participated on three exchange trips to share and exchange the technical knowledge, and develop a concrete climate action plan for the partner city.

The Scope of the Work

The present report focuses on the following aspects based on intensive field surveys, comprehensive review of available literature, information, observations and discussions held with various stakeholders:

- Observation of past climate changes trends and future projections based on historical monitoring of climatic data and interpretation of future trends.

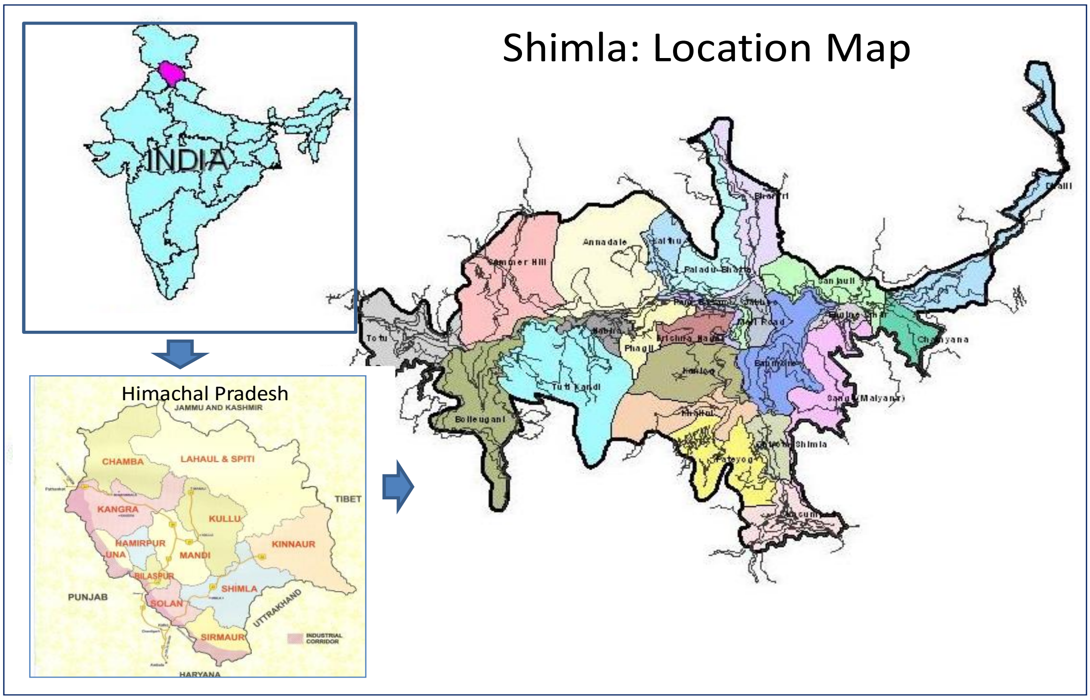
- An appraisal of urban ecosystems and urban ecosystem services, as well as their responses to climate change.

- Comprehensive assessment of impacts of climate change on the status and availability of water resources.

- Identification of appropriate measures for adaptive management of water resources under possible impacts of climate change.

Location and Geo-Environmental Settings

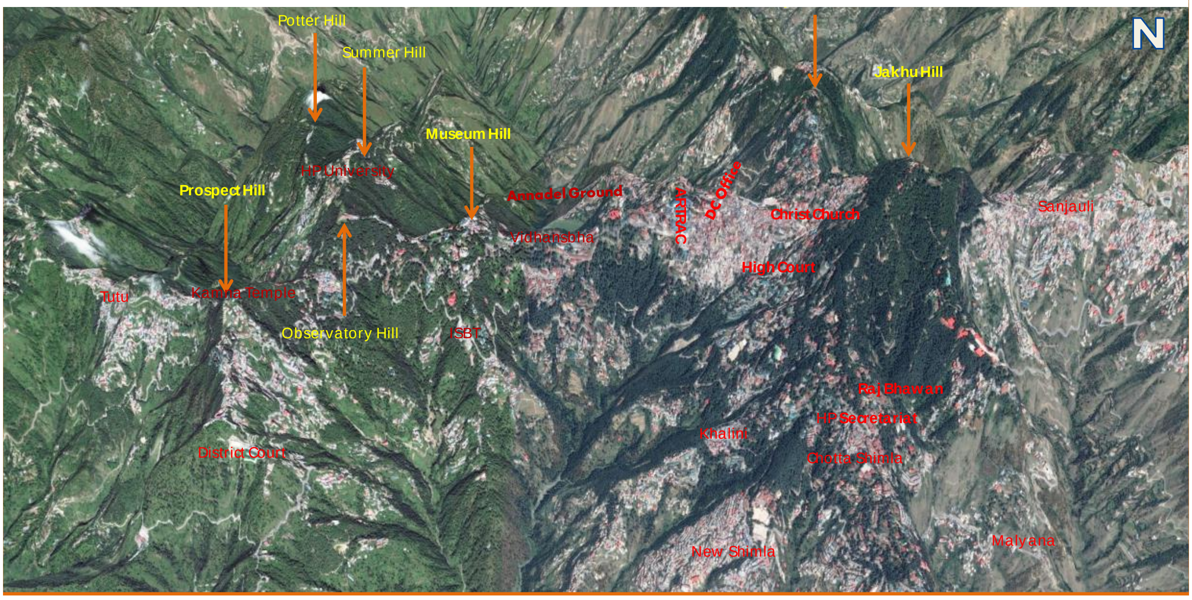
Shimla was discovered by the British in 1819, and evolved from a small hill settlement to one of the largest towns situated in the Himalayan mountains of India. In 1985, the Planning Commission of India delineated areas with an average slope of 30% and above, as hilly and mountainous regions. As per this criterion, Shimla town is classified as a hilly town. Shimla was mostly settled by the British during colonial period, and was declared the Summer Capital of the British India in 1864. The city now houses the capital of the State of Himachal Pradesh, and is one of the most popular and heavily visited hill stations located in the Himalayan mountains. Situated between $31^0$4' and $31^0$10' north latitude and $77^0$5' and $77^0$15'east longitude, Shimla city is extended over a geographical area of 31.60 km^2 in the north-western Himalaya with a mean elevation of 2397.59 m (7866.10 ft) (2073 - 2454m) above mean sea level. The city stretches nearly 9.2 km from east to west on a ridge and it has seven spurs in the densely populated Lesser Himalayan Ranges (Figures 1 and 2). The Jakhu hill is the highest point in Shimla with an altitude of 2454m (8051 ft) (Department of Environment, Science and Technology Government of Himachal Pradesh, 2012). Situated in the close proximity of Main Boundary Thrust (MBT) - a tectonic juncture between the Lesser Himalayan range in the north and Siwalik mountains in the south - Shimla constitutes a tectonically alive domain. Besides MBT, the town is criss-crossed by several other faults which make the geology of the town highly complex. The important geomorphological features include tectonic scarps, landslide scars and debris cones. The drainage network of the city is greatly influenced by geology and structural formation. The average slope in different areas of the city ranges between 1° and above 55° (Shimla Municipal Corporation, 2012). The city of Shimla, draped in evergreen glades of pine, deodar, oak and rhododendron, and experiences pleasant summers, and cold and snowy winters. Furthermore, the entire city is highly vulnerable to earthquakes as it falls under Zone - IV (the Highest Risk Zone) of seismic risk according to the earthquake hazard zoning of India (Shimla Municipal Corporation, 2012). Geographically, Shimla is situated on a critical water-divide between the Ganges and the Indus Rivers Systems which form some of the largest trans-boundary drainage basins of the planet. Shimla constitutes headwater of a large numbers of perennial as well seasonal springs and streams which flow across the slopes of the town and large streams downstream.



Source: Author

Figure 1

Shimla Urban Landscape:
An Overview of Seven Hills of Shimla



Source: Himachal Pradesh State Council for Science and Technology and Environment

Figure 2

Demographic Pattern and Trends

The population of Shimla Municipal Corporation was 171640 persons in 2011 with a population density of as much as 4197 persons/km^2 (Figure 3). The Shimla Municipal Corporation is constituted by 25 wards, and ward-wise families, males, females and total population as per 2011 census of India has been presented in Table 1. The Table shows that Chota ShimlaWard - the new fast growing part of the city - has the highest population with 15399 persons; whereas Jakhu Ward which has very dense forest cover has the lowest population with 3505 persons. The population of the city increased from merely 13960 in 1902 to as many as 171640 persons in 2011 (Table 2). The decadal increase in population is almost constant varying from 31.5% to 35.54%. The growth of population in Shimla has been recorded as 9.94% as from 2011 census (Census of India, 2011) (Table 3). During the past few decades, the city's population has grown much faster than the average population growth of the State of Himachal Pradesh. Shimla’s changing socio-economic conditions and better amenities are now the major pull factors for rural population migrating from rural areas to the city. The increasing trends of rural-urban migration are likely to have severe adverse impact on the natural ecosystem and on the overall development of Shimla City. Being the capital of the state, the city houses several central and state government offices and a number of academic and research institutions. Nearly 47% of the working population of Shimla is employed in government sector, whereas the tourism sector provided employment to only 10% of the human resource in the city in 2011. A large proportion of the remaining working population is engaged in handicrafts and small scale industries producing tourist souvenirs and a range of horticultural products. Out of the total households, 37% live in their own houses, whereas 63 % live in rented accommodation (Shimla Municipal Corporation, 2012).

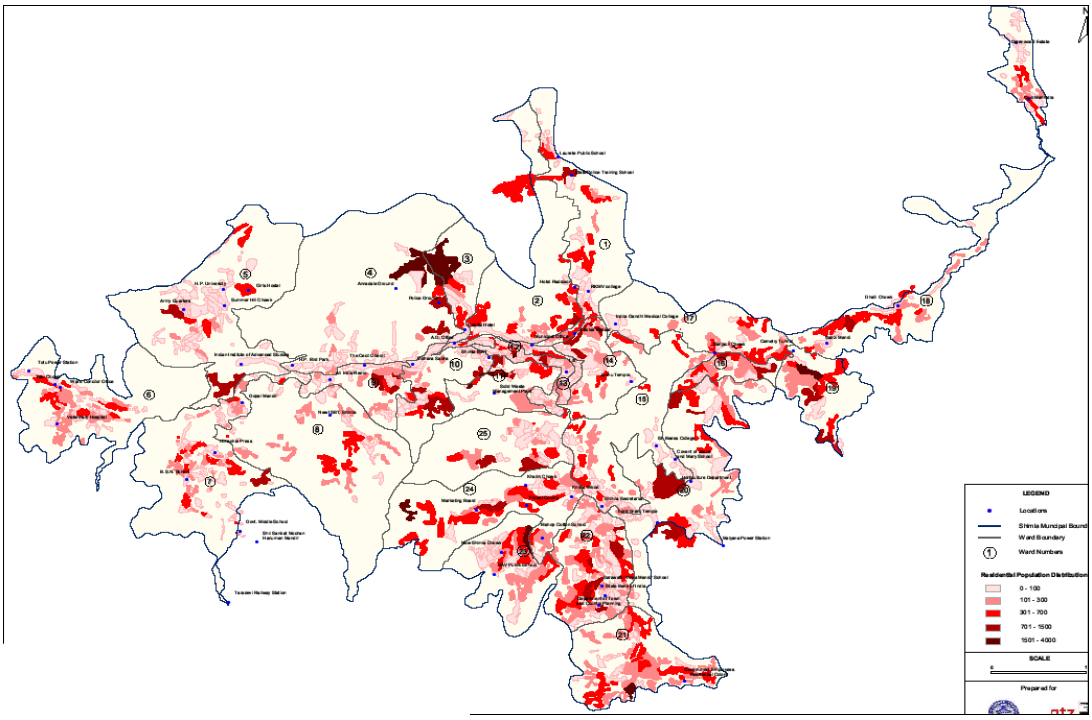
Since Shimla has been a tourist destination ever since it was discovered in the mid-nineteenth century, the town also hosts a large floating population -particularly during the peak tourist season from April to June- people mostly work as petty vendors, coolies, horsemen, and waiters in hotels and restaurants. In 1971, the total floating population of the town was 23459 persons which increased to 76000 persons in 2011. It has been estimated that Shimla would likely accommodate a floating population of 100000 persons in 2021 (Shimla Municipal Corporation, 2012). The increasing trends of floating population -particularly the poor-, are creating several kinds of environmental problems related specially with housing, sanitation, garbage disposal and water supply, increasing the vulnerability of the town to climate change. The city has developed into a congested built-up area through modifying fragile slopes for construction, haphazard development, traffic congestion, encroachment on road and public land that affected the natural setting as well as ecosystems of the city.

Table 1: Ward-wise Population Patterns in Shimla (Census of India, 2011)

S. No.	Name of Ward	No. of Families	Total Population	Male	Female	Children (Below 6 Years)
1	Bharari	1058	4113	2174	1939	276
2	Ruldhu Bhatta	1768	6839	3797	3042	563
3	Kaithu	1093	4298	2361	1937	277
4	Annadale	1300	4962	2682	2280	434
5	Summer Hill	1194	5391	2478	2913	387
6	Totu	2792	9208	5118	4090	804
7	Boileaugunj	2243	8205	4543	3662	690
8	Tutikandi Badai	1428	5361	3068	2293	460
9	Nabha	1324	4665	2510	2155	370
10	Phagli	1180	4518	2622	1896	356
11	Krishna Nagar	1671	7190	4246	2944	675
12	Ram Bazar Ganj	888	3734	2199	1535	227
13	Lower Bazar	866	3936	2199	1535	227
14	Jakhu	953	3505	1856	1649	210
15	Benmore	958	3988	1983	2005	218
16	Engine Ghar	1441	5196	2724	2472	433
17	Sanjuli Chowk	1777	6526	3685	2841	645
18	Dhalli	2004	7327	3952	3375	645
19	Chamyana	2986	9627	5098	4529	783
20	Maliyana	2834	9884	5331	4553	855
21	Kasumpti	2587	9185	5092	4093	768
22	Chot Shimla	4432	15399	8424	6975	1230
23	Pateog	3472	12029	6572	5457	1069
24	Khalini	2414	8456	4931	3525	671
25	Kanlog	1643	6036	3137	2899	447

Source: Shimla Municipcal Corporation

Shimla: Population Density



Source: UNDP 2015

Figure 3

Table 2: Year-wise Population in Shimla (1902 - 2011)

Year	Population
1902	13960
1911	19405
1921	27213
1931	18144
1941	18348
1951	46150
1961	42597
1971	55326
1981	70604
1991	82504
2001	156127
2011	171640

Source: Shimla Municpal Corporation

Table 3: Decadal Growth of Population in Shimla (1971 - 2011)

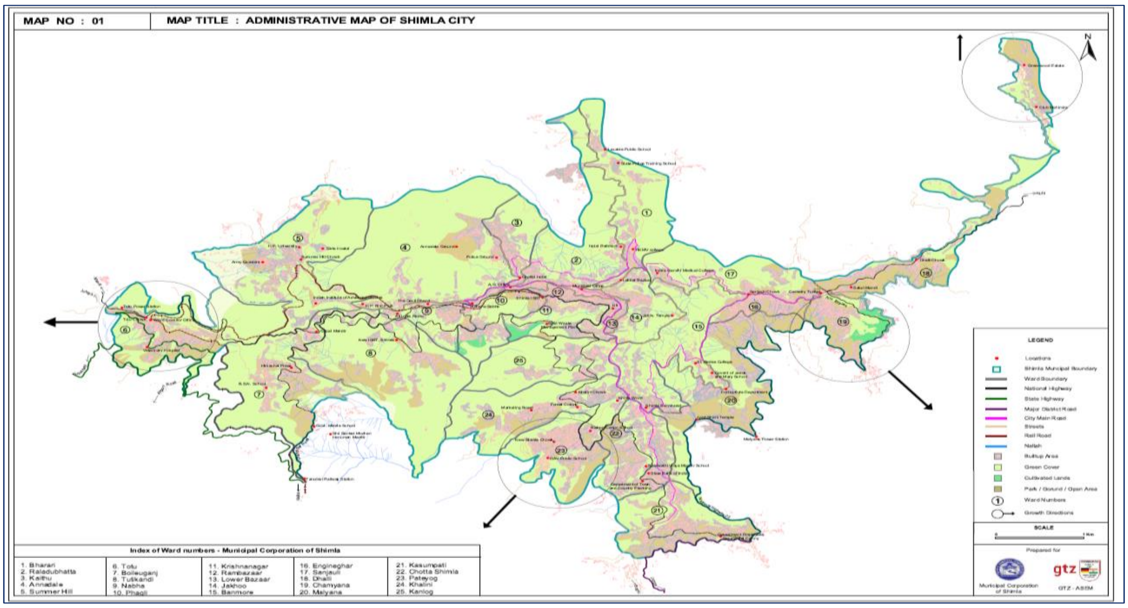
Year	Persons	Decadal Growth in %
1971	72870	-
1981	95851	31.5
1991	129827	35.54
2001	156127	20.25
2011	171640	9.94

Source: Shimla Municpal Corporation and Census of India 2011

Structure and Governance of Shimla Municipal Corporation

Shimla city consists of the Shimla Municipal Corporation (SMC) and Shimla Planning Area (SPA). The SPA is constituted by Dhalli, Tutu and New Shimla urban agglomerations. Shimla Planning Area was delineated by the Town and Country Planning (TCP) Department of Himachal Pradesh for the preparation of Development Plan (CDP) for fast growing Shimla City and adjoining peri-urban areas. With the passing of the Himachal Pradesh Municipal Corporation Act, 1994 the Government of Himachal Pradesh divided up the Shimla Municipal Corporation Area into 21 wards with a total area of 9.55 km^2, and in 2001 the number of municipal wards have been increased from 21 to 25 (Figure 4). The SPA comprises the core urban area of Shimla, its peri-urban fringe and parts of the adjoining rapidly urbanizing rural hinterland. Shimla Municipal Corporation is governed through the Elected Body, comprised by elected councillors and directly elected Mayor and Deputy Mayor. The Administrative Body of the Corporation is headed by Commissioner and Deputy Commissioner, and is responsible for strategic and operational planning and management of Corporation. The elected body of Shimla Municipal Corporation has 27 councillors out of which 25 are directly elected and 2 are nominated by the Government of Himachal Pradesh. Each of the 25 municipal corporation wards is represented by one elected councillor. As per rule, 33% wards of the Corporation must be represented by women councillors. The tenure of the councillors, Mayor and Deputy Mayor is for five years.

Shimla Municipal Corporation: Administrative Wards



Source: UNDP 2015

Figure 4

Land Use Pattern

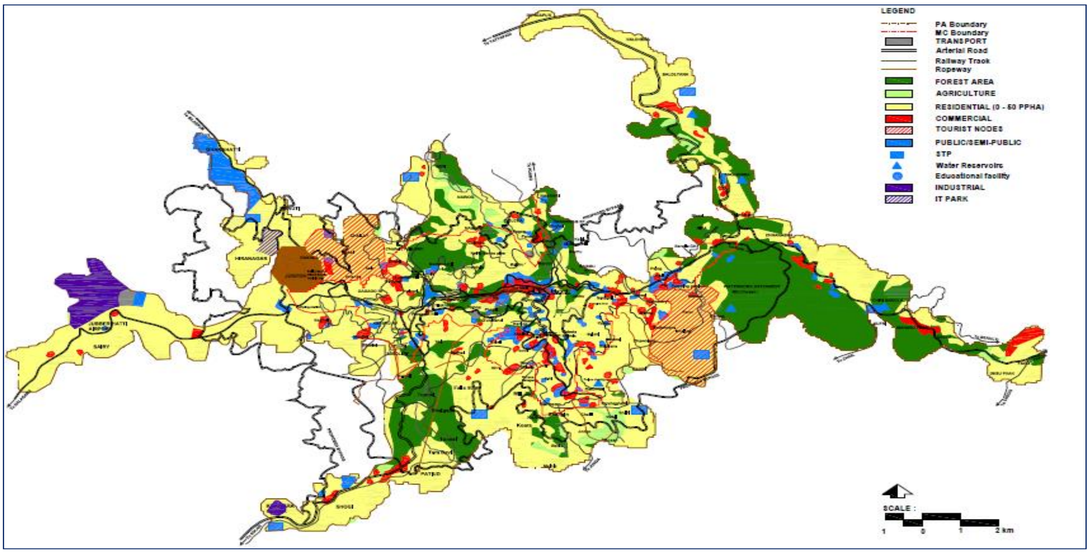
The total geographical area of Shimla Planning Area (SPA) is 9950 ha, which includes Shimla Municipal Corporation with its added areas of Dhalli, Tutu, New Shimla and Kasumpti. According to Town and Country Planning Department, Government of Himachal Pradesh, out of the total geographical area of the city, 6080.15 ha -which accounts for 61.12% of total Shimla Planning Area (SPA)- is under forest. Conforming to climatic conditions and altitude, the natural vegetation around Shimla is generally dense and comprises many species of temperate evergreen types. However, during recent decades the forest and biodiversity around Shimla has degraded and depleted steadily ad significantly, mainly due to increasing anthropogenic impacts and land use intensifications in the town. An area of 963.13 ha - amounting 9.07%- is under residential use; 219.34 ha or 2.20% is under water-bodies; 138.78 ha or 1.39% is under public and semi-public uses; 25.22 ha or 0.25% is commercial; 21.70 ha or 0.22% is under tourist activities and infrastructure. As much as 2174.75 ha, which accounts for 21.85% of the total geographical area of Shimla Planning Area (SPA) is under agriculture (Table 4 and Figure 5). The agriculture is mainly practiced in the peri-urban areas which have been included as part of Shimla Planning Area (SPA).

Table 4: Land Utilization Pattern of Shimla City (2013)

S. No	Land Use Categories	Area (in ha)	% of Total Area
1	Residential	963.13	9.07
2	Commercial	25.22	0.25
3	Industrial	9.00	0.07
4	Tourism	21.70	0.22
5	Public and Semi Public	138.78	1.39
6	Park and other spaces	6.00	0.06
7	Traffic and Transportation	371.73	3.75
8	Agriculture	2174.75	21.85
9	Forest	6080.15	61.12
10	Water bodies and Barren land	219.34	2.20
11	Total	9950.00	100%

Source: Shimla Municpal Corporation

Shimla: Land Use Pattern



Source: UNDP 2015

Figure 5

Climatic Trends

In India, climatic data, trend analysis and projections at city level are rarely available. In view of this constraint, the past trends in temperature and precipitation patterns and various climatic parameters have been analyzed based on the Regional Assessment Report published by the Indian Network for Climate Change Assessment (INCCA), reports published by India Meteorological Department (IMD), and State Strategy and Action Plan on Climate Change, Himachal Pradesh (HPSSAPCC). These sources provided the assessment of past trends, as well as preliminary future trends of the key climatological parameters for the north-western Himalayan region in which Shimla is located, and in some cases for Shimla City specifically. In order to analyse the past trends in climate, a comprehensive assessment of temperature, snowfall and rainfall for more than 100 years as well as for the recent past was used.

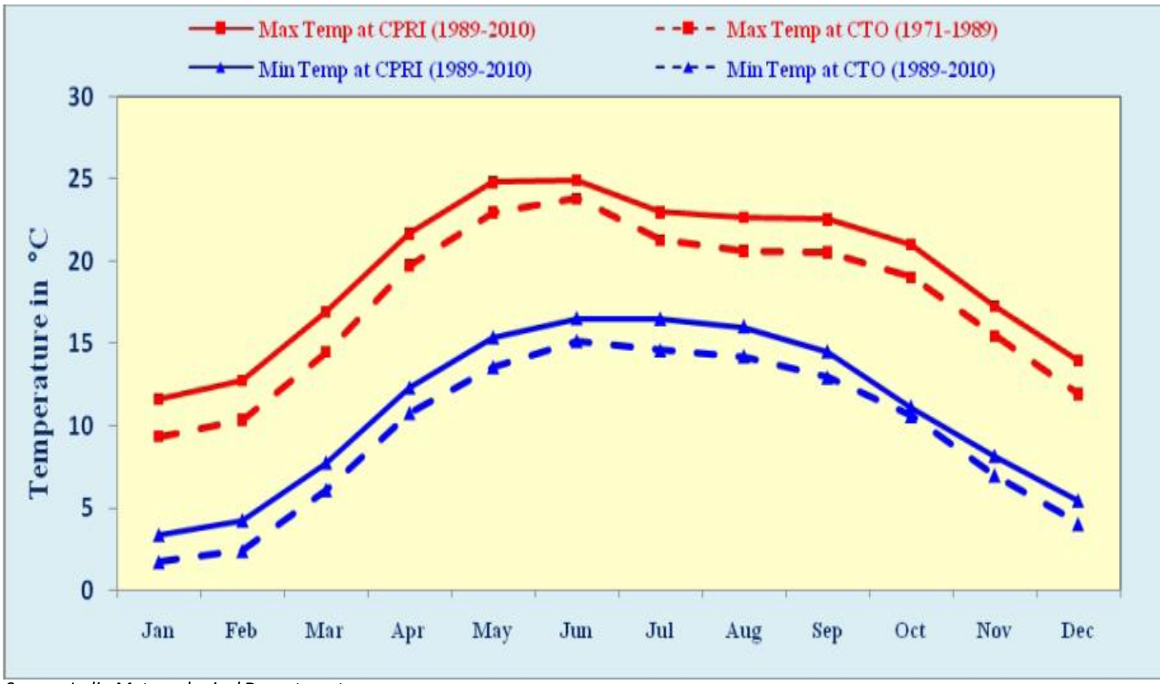
According to Koppen's climatic classification, Shimla falls under 'Subtropical Highland Climate'. It enjoys cold-humid climatic conditions primarily governed by the summer monsoon. The climate of Shimla is predominantly cool during winters and moderately warm during summer. Temperatures typically range from - 6°C to 31°C over the year. The average temperature during summer is between 19°C and 28°C and between -1°C and 10°C in winter. Monthly precipitation ranges from 15 mm in November to as much as 434 mm in August. It is typically around 45 mm per month during winter and spring and around 175 mm in June, upon the arrival of the monsoon. The average total annual precipitation is 1575 mm, which is much less than what most of other hill stations receive, but still greatly heavier than the adjoining plains. Historically, Shimla received frequent snowfall during winter (November to February). However, the pattern of snowfall has changed during recent decades.

Temperature trends have been analyzed through the interpretation of the climatic data obtained from India Meteorological Department (IMD) for the years 1969-88 and 2008-14. The monthly minimum temperature distribution in Shimla shows that the minimum temperature is decreasing over the period of 20 years, whereas the maximum temperature is increasing. The maximum daily temperature for the period 1969-88 shows a gradually increasing trend with a few exceptions in the months of August and October. The highest temperatures are observed during the months of April to June, which is also seen in the monthly maximum temperature distribution for the years 2008-14. It is also observed that maximum monthly temperature has increased during the recent years. As observed from the monthly minimum daily temperature variations for the years 1969-88 and 2008-14, the temperature in the city drops below zero in the months of January, February and December with the lowest temperature observed in the month of February (Figures 6 and 7).

However, the minimum temperature for the duration 2008-14 indicates sharp change in the above mentioned trend. For example, the temperature drops sub-zero only during the months of January and February. This observation substantiates the overall increase in temperature observed in Shimla. During the period 1969-2014, the lowest and highest minimum temperatures are observed during December to March. During most of the years, the lowest minimum temperatures recorded are around 0-4 C^0 during December, -5 C^0 to -1 C^0 during January, -4 C^0 to 0 C^0 in February and -2 C^0 to 2 C^0 in the month of March when western disturbances influence the weather conditions all across the northern parts of India (UNDP, 2015).

Extreme temperature days were analysed for the city of Shimla for the three distinct yearly seasons, pre-monsoon (summer) spanning February to May, monsoon (rainy season) from June to September and post-monsoon (autumn and winter months) from October to January. This analysis was carried out based on standard deviation. The maximum temperature never raised above 10 C^0 more than average maximum temperature in Shimla. However, during the winter months, lowest temperature fell 10 C^0 below average the minimum temperature a few times during both observation periods (1969-88 and 2008-14). Extreme temperature was also estimated for the city employing standard deviation method for pre-monsoon, monsoon and post-monsoon seasons. It was observed that during 1969-88 period, around 8-10 days in each month the temperature was more than one standard deviation difference from the average maximum temperature during the pre-monsoon. Whereas, during the 2008-14, this number increased considerably in all four months. The average maximum temperature also rose by 2^0-3^0 in the later years (UNDP, 2015).

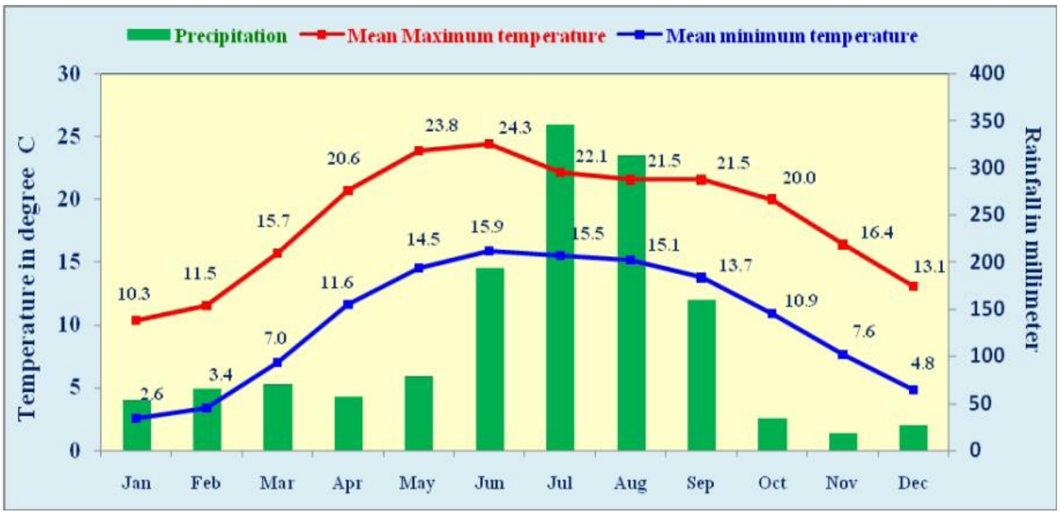
Average Maximum and Minimum Temperature in Shimla



Source: India Meteorological Department

Figure 6

Monthly Average Maximum and Minimum Temperatures and Rainfallin Shimla



Source: India *Meteorological* Department

Figure 7

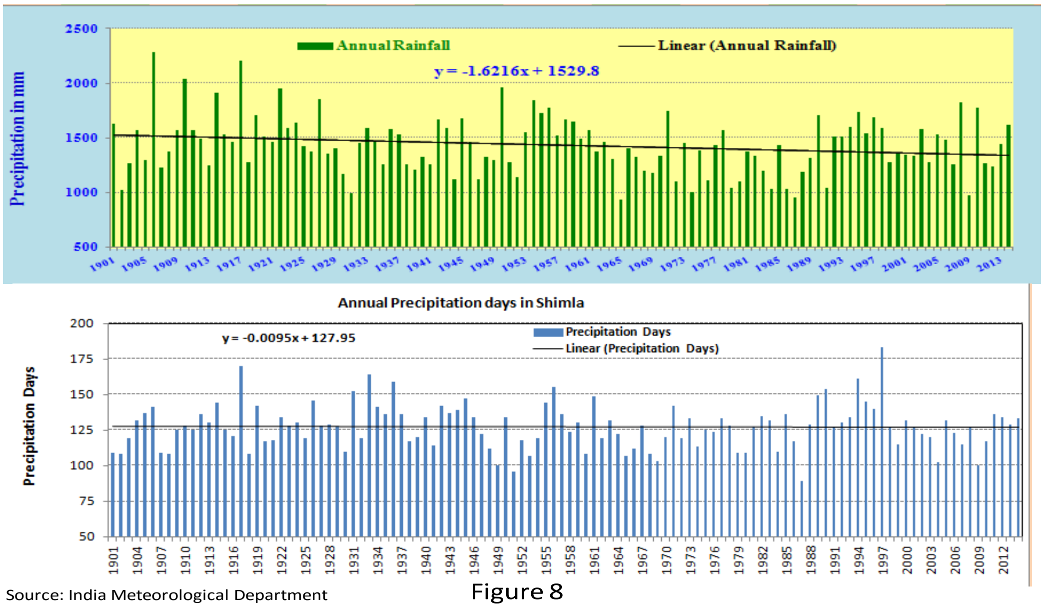
During monsoon months, the number of days with more than one standard deviation than the average maximum temperature have increased by almost 90% between the 1969-88 period and 2008-14 period. At the same time, the days with more than two standard deviation difference from average maximum temperature has also increased considerably. The maximum number of hot days was recorded during June and July in the later period. A slight increase was observed in the average maximum temperature during June and July in the later years; it remained steady during August and September all through the years. During the post-monsoonal winter months, the average maximum temperature in the Shimla has remained almost steady during the period of observation. Although there is a significant increase in the number of days where the temperature rose by one standard deviation difference from average maximum temperature, the overall increase in the temperature has not been more than 1°C in the city. The later winter months of December and January, show the maximum variation in average maximum temperature during the years. During the pre-monsoon summer season, the number of cold days was found to be more during 1969-88 as compared to the period 2008-14 (UNDP, 2015).

Average minimum temperature is greatly fluctuating between 1969-88 and 2008-14. An overall increase in temperature was observed from the analysis. During the rainy season, a distinct increase in temperature was recorded. Throughout the monsoon months, the number of days with temperature less than one standard deviation than the average minimum temperature was much greater during 1969-88 compared to 2008-14. It was analysed that the days with more than two standard deviation difference from average minimum temperature have also decreased considerably during 2008-14. It was also observed that average minimum temperature fluctuated significantly through the years. The average minimum temperature recorded high fluctuation during the post-monsoon months, and an increase of about 1 °C was recorded during the season. The winter months of December and January registered more number of days with temperature lower than one and two standard deviations than the average minimum temperature during 1969-88, whereas the number of such cold days were considerably lower during the later period of 2008-14 (UNDP, 2015). The interpretation of the trends in temperature clearly indicate an overall increase in the ambient temperatures.

Rainfall Analysis

As in other parts of western Himalaya, rainfall in the Shimla increases from the middle of June with frequent pre-monsoon showers and with the on-set of south-west monsoon at the end of the month. Shimla receives nearly 85% of its annual rainfall during four months from June to September. Normally, July and August are the months of highest rainfall, and monsoon retreats from western Himalaya towards the end of September. The rainfall decreases drastically after September with November being the month of lowest precipitation; but, it again starts increasing from December on. A slight decreasing trend has been observed for long term accumulated yearly rainfall in Shimla (Figure 8). The interpretation of available rainfall data clearly indicated that the rainfall variability has been very significant in Shimla during the recent years. It was observed that the days of extreme high rainfall were few, with four significant extreme events in 1971-72, 1974 and 1984 (UNDP, 2015). Another important phenomenon about the observed rainfall variability over the town is that the monsoon onset has been shifting from the end of May in the 1960's to almost the beginning of July in the 1980's. This indicated that the monsoon is arriving late and retreating early. Thus, the total amount of precipitation in Shimla during one monsoonal cycle has been decreasing steadily over the years. In the recent years, the same trend of the onset of monsoon shifting towards post-monsoon season has been observed. Extreme rainfall and rainy days were analysed for Shimla for pre-monsoon, monsoon and post-monsoon seasons using standard deviation data. The analysis indicated a steady increase in average rainfall in pre and post monsoon months. In general, Shimla has shown an increase in the rainfall during pre-monsoon season and during the months of June and July; but a significant decrease during peak monsoon months of August and September (UNDP, 2015).

Trends in Annual Rainfall and Rainy Days in Shimla (1901-2014)



Source: India Meteorological Department

Figure 8

Snowfall Analysis

Shimla generally experiences snowfall from the middle of December to the middle of March. The city recorded an average snowfall of 7, 38, 39 and 7 cm respectively in the months of December, January, February and March during the period of 1990- 2008**.** However, recent data indicated that the amount of snowfall has decreased drastically during the month of March with the notable exception of the year 2014. Nevertheless, the month of January continues to receive the maximum amount of snowfall over the years (2008-14). The distribution of snowy days over Shimla showed distinct inter-year variability during 2008-14, with significant decreasing trends in monthly snowfall days between 1971 and 2008 (Figures 9 and 10). Average monthly snowfall was analyzed using snowfall data of 20 winter seasons (i.e. from 1990-91 to 2010-2011) for Shimla. Monthly highest snowfall was observed to be 205 cm in December 1990, 109 cm during January 1993, 113 cm during February 2007 and 63 cm in the March 1998 (UNDP, 2015). Percentage distribution of the snowfall with respect to the total precipitation during the month of December, January, February and March is 7%, 42%, 43% and 7% respectively (Figures 11 and 12). The trend observed in the seasonal snowfall days from 1971 to 2010 show a significant decrease. This decrease in the snowfall days is probably due to rise in temperature.

Climate Change Vulnerability

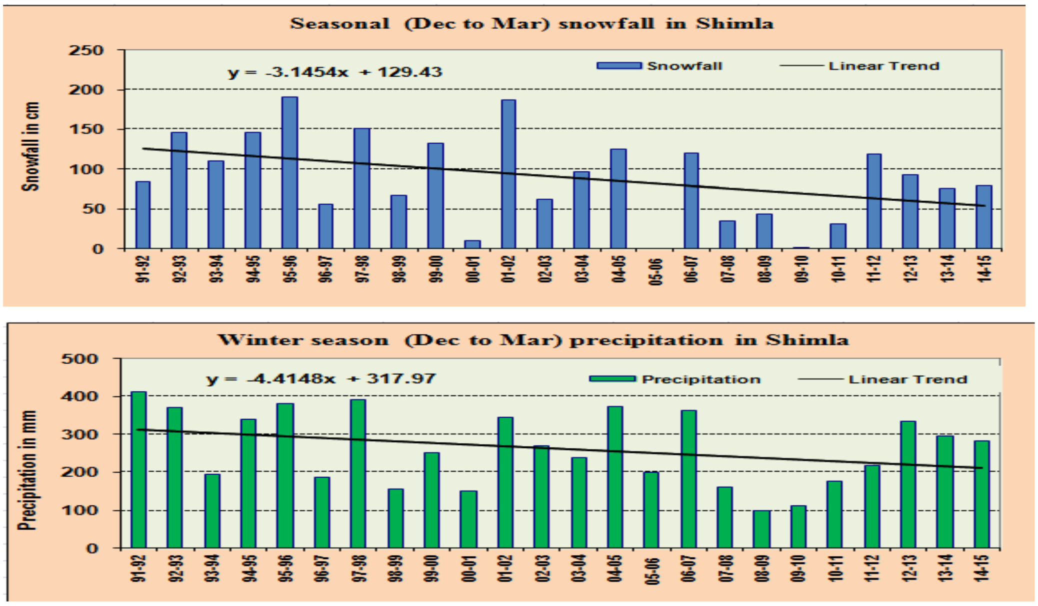
A scoping exercise was carried out based on the survey of available literature, assessment and status reports, action plans; series of discussion and meetings held with various stakeholders; and field observations. The exercise revealed that the city is highly exposed to rainfall variability and increase in temperature. The important observations of the scoping exercise are as follows:

- The analysis of the past trends revealed that annual, winter and monsoon precipitation has shown significant decline. There has been about 40% reduction in rainfall during 1987-2009. Approximately 17% decrease in rainfall was observed from 1996 onwards. The decreasing trend of seasonal snowfall has been observed since 1990 and was lowest in 2009.

Past trend of temperature over last 100 years indicated that there has been an increase at a rate of 0.86°C/100 years in temperature in the region. However, during 1970 to 2000 the temperature has increased at a rate of 0.46°C/10 years, which is quite alarming.

- Although the climate projections are currently not available for Shimla, the regional projections indicate changes in rainfall patterns with increased variability and decline in precipitation in south-eastern parts of Himachal Pradesh, in which Shimla is located. This is likely to cause frequent droughts in the region, including Shimla and its surrounding areas. It is being anticipated that the North Western Himalayan region including Himachal Pradesh may experience 1.7°C to 2.2°C increase in the mean annual temperature by 2030.
- The overall warming rate of Shimla was higher during the period 1991-2002 as compared to earlier decades. Furthermore, 17% decrease in rainfall in Shimla was observed from 1996 onwards. Both the amount and frequency of snowfall has been observed to be decreasing in Shimla.
- These changes in the key climatic phenomena may affect the ecosystem services, particularly the availability, supply and quality of freshwater; and increase the vulnerability of urban systems to climate change induced natural risks, specifically high intensity rainfall, flash-floods, slope failures landslides, droughts causing devastation of life, property, urban services, infrastructure, livelihood and health of people, particularly that of marginalized and poor households.

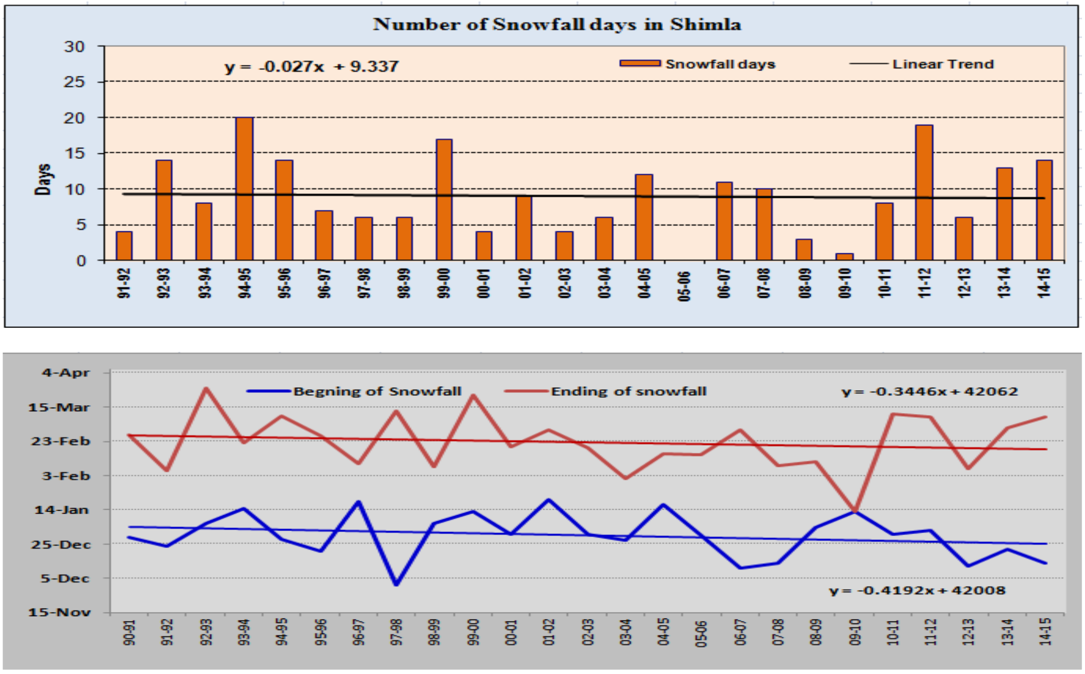
Trends in Snowfall and Total Precipitation in Shimla



Source: India Meteorological Department

Figure 9

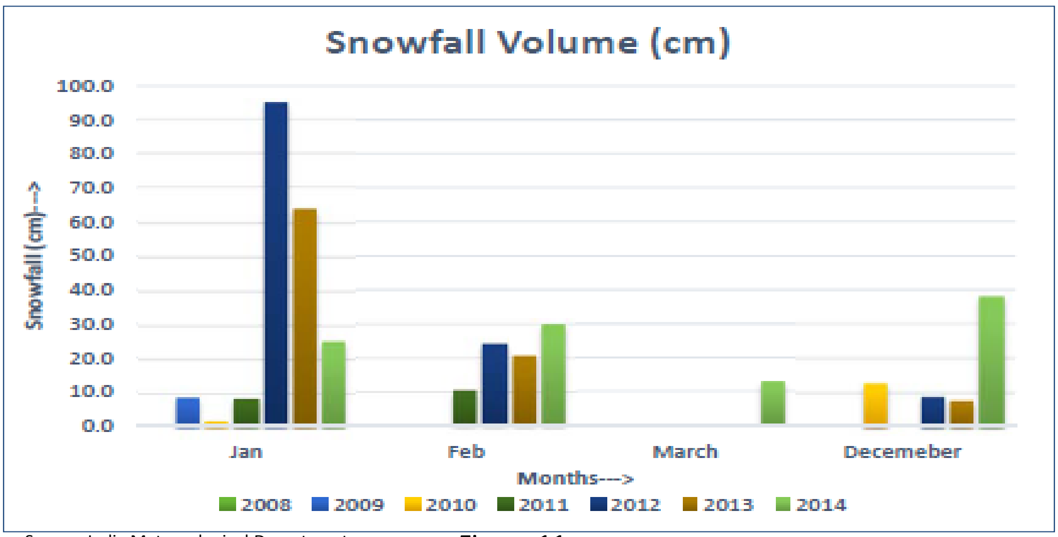
Trends in Snowfall Days and Snowfall Season



Source: India Meteorological Department

Figure 10

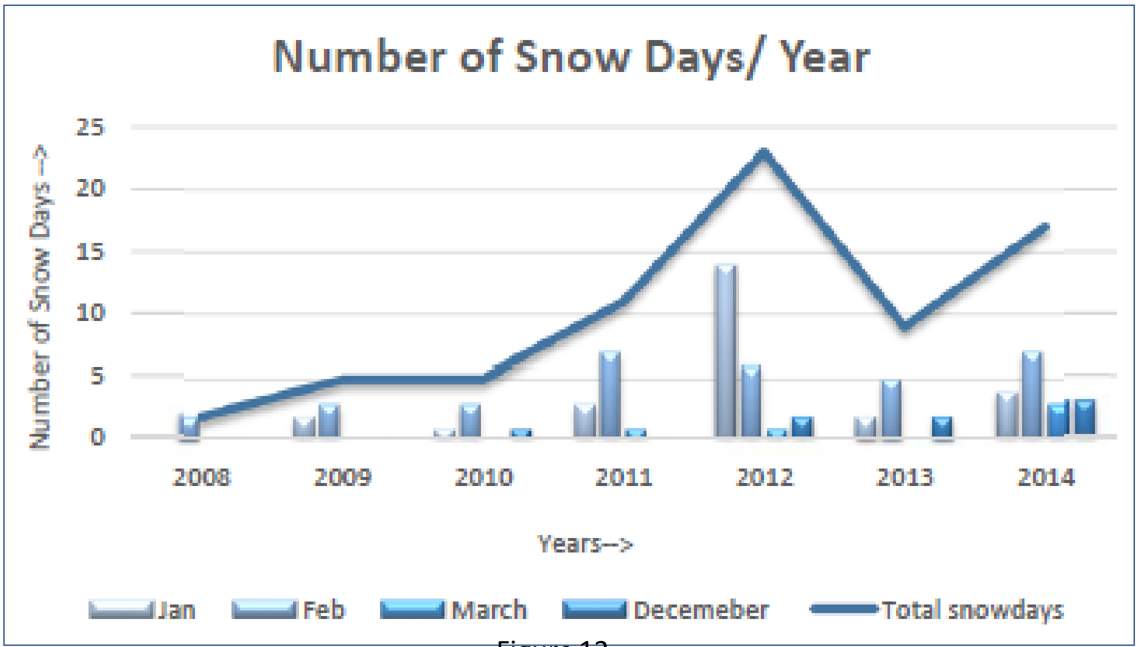
Snow Volume in Shimla (2008 - 2014)



Source: India Meteorological Department

Figure 11

Snow Days in Shimla (2008 – 2014)



Source: India Meteorological Department

Figure 12

Climate Projections

The Urban Climate Change Research Network (UCCRN) -based on a combination of 33 global climate models (GCM) simulations, and 2 representative concentration pathways (RCP) greenhouse gas emission scenarios- developed projections of temperature and precipitation for Shimla, and a total of 66 possible outcomes for each climate variable were obtained (UCCRN, 2015). GCMs are physics-based mathematical representations of the Earth's climate system over time that can be used to estimate how sensitive the climate system is to changes in atmospheric concentrations of greenhouse gases and aerosols. Although it is not possible to predict the temperature or precipitation for a particular day, month or year, GCMs are valuable tools for projecting the likely range of changes over multi-decadal time periods.

The GCMs run for the Shimla projections were the ones used to create global projections for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC, 2007, 2013 and 2014). They are downscaled from the bias-corrected and spatially disaggregated (BCSD) dataset, with 0.5-degree resolution that is derived from the Coupled Model Inter-comparison Project Phase 5 (CMIP5)[i] multi-model data set. RCPs represent the amount of radiative forcing caused by greenhouse gases and other important agents such as aerosols. Each RCP is consistent with a trajectory of greenhouse gas emissions, aerosols, and land use changes developed for the climate modelling community as a basis for long-term and near-term climate modelling experiments (Moss et al., 2010). The RCP scenarios used were the RCP 4.5 and RCP 8.5, which respectively represent the low and high future emissions trajectory scenarios, and serve as inputs to the GCMs that guide the projected intensity of future climate changes.

Downscaled projections were developed for two climate variables – temperature and precipitation – to provide guidance on how the climate in Shimla may change over the coming century. The projections are expressed relative to the 1971 to 2000 baseline period for temperature and precipitation. The projections are provided for three future time-slices (2020s, 2050s, and 2080s) that are centered on a given decade. For both variables, 30-year time-slices are used; (i.e., the 2050s time-slice refers to the period from 2040 to 2069). The climate projections indicated that in Shimla, temperatures are projected to increase between 2.1°C and 3.2°C by the 2050s, while projected changes in precipitation range from a decrease of 2% to an increase of 18% (Table 5). Table 5 shows a range of projections for four distribution points of the projected outcomes in each of the three time slices for temperature and precipitation relative to the 1971-2000 baseline period (UCCRN, 2015).

Table 5: Temperature and Precipitation Projections for Shimla, Over the Coming Century

Climatic Parameters	2020s	2050s	2080s
Temperature	+1.0 (1.1 to 1.5) 1.9°C	+1.8 (2.1 to 3.2) 3.8 °C	+2.3 (2.8 to + 4.7) 6.0 °C
Precipitation	- 6% (- 2% to +11%) +15 %	-6% (-2% to +18%) +27%	-7% (+1% to +27%) +38%

Source: UCCRN

Expected Climatic Trends:

In general, the following trends in climate are expected:

- Rapid local and regional warming trend
- Changes in the onset of the rainy season
- Changes in the intensity and duration of rainstorms
- Changes in snow pack and water falling as snow

Urban Ecosystem Services under Climate Change

All urban settlements are dependent on the ecosystems beyond the city limits, but cities also benefit from internal urban ecosystems (Bolund and Hunhammar, 1999). In order to receive ecosystem services, the urban population depends on the large hinterlands needed to provide input and take care of output from the city. It was estimated that the cities claimed ecosystem support areas much larger than the area of the cities themselves (Folke et al., 1997). The aim of this section of the report is to analyze the ecosystem services generated by ecosystems within the urban area of Shimla. Ecosystem services are referred to as the benefits human population derives directly or indirectly from ecosystem functions (Costanza et al. 1997). Costanza et. al. identified 17 major categories of ecosystem services, and a number of these services are not consumed by humans directly, but they are essential to sustain the ecosystems themselves, such as pollination of plants and nutrient cycling. Further, ecosystem services can be available on the local or global scale according to the scope of the problem they are connected to and the possibility of transferring the service from where it is produced to the location where humans make use of it (Bolund and Hunhammar, 1999).

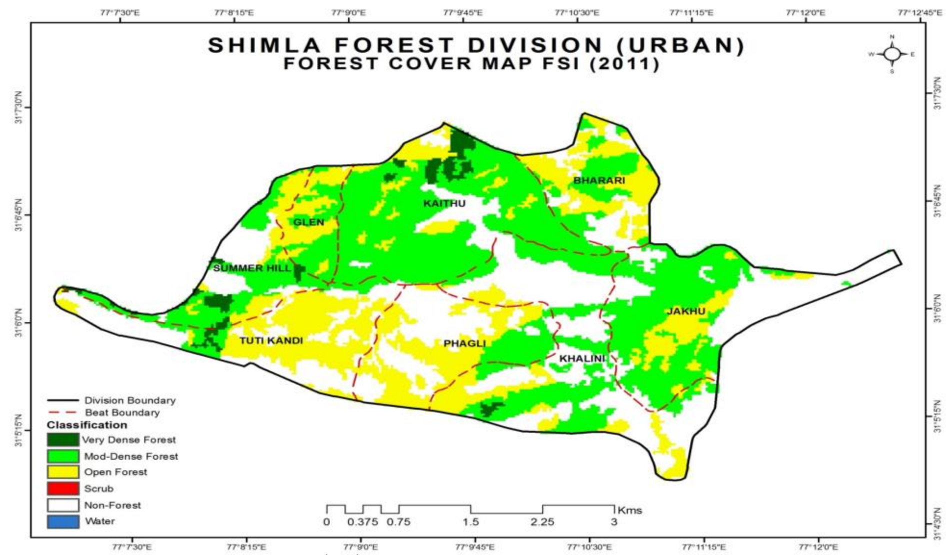
The following four different urban ecosystems have been identified in Shimla city through ground observation and mapping; and consultation with forest and other government agencies:

(i) Forests; (ii) streams and natural springs; (iii) lawns and parks; and (iv) wetlands. These ecosystems generate a variety of environmental services for the urban population of Shimla. Natural forests are the most visible and prominent ecosystem of Shimla city (Figure 13). In fact, Shimla is known for its urban forests. Out of the 17 classes of ecosystem services listed by Costanza et al. (1997), six are considered to have a major importance for Shimla urban area (Table 6). These ecosystem services include: (i) air purification; (ii) micro-climate regulation; (iii) drainage regulation and groundwater recharge; (iv) landslides and erosion control; and (v) recreational and cultural services. It was observed that each ecosystem generates a number of different services simultaneously. The natural urban ecosystems increase the quality of-life of urban citizens in a number of ways (Table 6). A large number of problems are generated locally, and the most appropriate way to deal with these local urban problems is through local solutions (Bolund and Hunhammar, 1999). In this respect, the urban ecosystems are most critical for the functioning of urban complexes.

Table 6: Shimla Urban Ecosystem Services (Modified after Bolund and Hunhammar,1999)

Ecosystems	Ecosystem Services				
	Air Purification	Micro Climate Regulation	Drainage Regulation and Groundwater Recharge	Landslides and Erosion Control	Recreational and Cultural Services
Natural Forests	×	×	×	×	×
Streams and		×	×	×	×
Wetlands			×	×	×
Park and Lawns	×	×	×	×	×

Forest Cover Map of Shimla City



Source: Forest Department, H. P.. Shimla

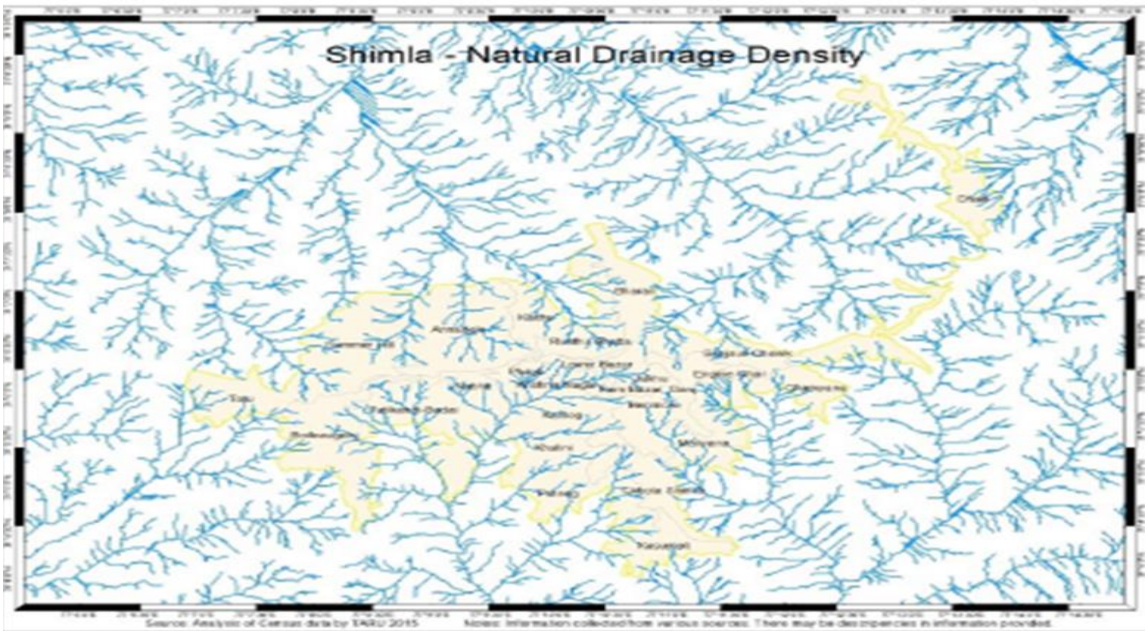
Figure 13

Impact of Climate Change on Ecosystem Services

The observations of rainfall and precipitation clearly indicate that Shimla is experiencing rapid climatic change which is visible in prolonged meteorological droughts, rise in mean annual temperature, increasing variability in precipitation pattern, and increasing frequency of high intensity rainfall. These change in climatic conditions are changing the composition of forest species, loss of biodiversity, drying of vegetation, and fungal infection in plants. These disturbances are ascribed to increasing temperatures, destruction of habitats, accelerated erosion and slope failure. Besides, the sprawling urban growth around Shimla and rapid expansion of built areas and infrastructure, and resultant land use changes are depleting and degrading urban natural ecosystems and also damaging local flora and fauna. In view of soil conditions and pressure of existing terrestrial development, tree cover has been affected largely in Shimla. Survival rate of plantations is very poor. Uprooting and falling of trees during normal rain has become a very common phenomenon. As a result, ecosystem services have now become less efficient, exhibit lower levels of functioning, deliver fewer services, become less reliable (more unpredictable, more variable), and less resilient to environmental changes. If the city keeps losing species, eventually ecosystems would collapse and climate change is one of its manifestations.

Water Availability and Supply

The city of Shimla is situated mainly on spurs and ridges (Figure 2), and these constitute the headwater of a large number of streams and springs that feed to larger streams and rivers in the downstream areas. As most of the cities located on the ridges at the Himalaya, Shimla depends for its supply of freshwater on perennial streams and natural springs. The important streams from where the town draws its freshwater are located into deep valleys far away from the city, but as mentioned above they are fed by a large number of streams and natural springs which originate from the forested slopes of Shimla and flow across the city before finally joining to main-streams (Figure 14). Surface water from streams and rivulets is lifted and stored in tanks and small reservoirs at different locations, relatively at higher elevations in the city, and from where the water is distributed across the town through gravity.



Source: UNDP, 2015

Figure 14

Water supply system of Shimla was established in 1875 by the British to serve a population of only 16000, with 4.45 Million Litre Day (MLD) capacity. Shimla receives its water supply from 6 sources which are located outside the city, mainly in the rural areas (Table 7). Table 7 shows that water from only one source - Dhalli Catchment Wildlife Sanctuary - is collected through gravity, whereas from the other 5 sources water is lifted through pumping as they all are located in the deep valleys. Water from all above-mentioned sources is treated, filtered and stored for distribution in six large reservoirs at different locations of the city. However, it was observed during field surveys that all these water-reservoirs are located in geologically fragile sites and surrounded by densely populated zones that may pose serious risk during landslide and earthquake disasters and disrupt water supply to major parts of the town. The detailed account of different water sources of Shimla is presented below:

Dhalli Catchment

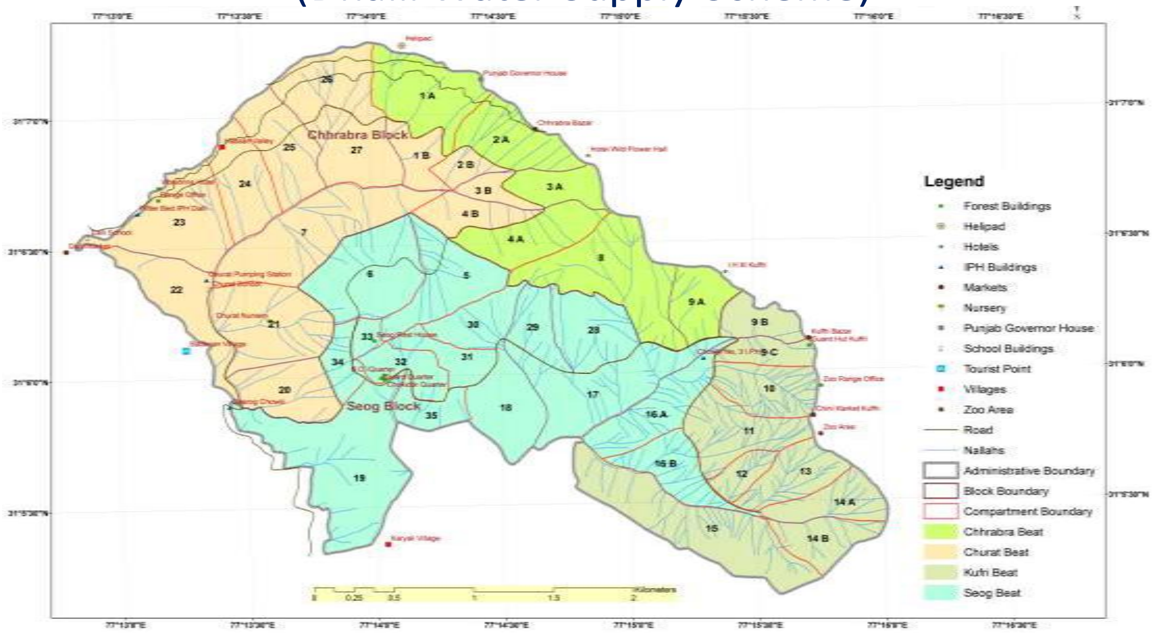
Dhalli Catchment is located very close to the city of Shimla where water was collected from 9 perennial natural springs originating from forested slopes through gravity (Figure 15). An average of 0.45 MLD water is received from Dhalli Catchment. Keeping in view its ecological importance and richness of flora and fauna, the catchment area was notified as 'Shimla Water Catchment Wildlife Sanctuary' in 1999. However, most of the water sources in the catchment have now dried or have become seasonal, mainly due to climate change and depletion of forest cover in the watershed. It was also observed that water discharge of the springs is also declining.

Table 7: Water Schemes and Water Supply Status of Shimla

Source Name / River Name	Transmission Type	Year of Start	Installed Capacity (MLD)	Quantity of Water Produced (MLD)	Supply to SMC (MLD)	
					Non Lean Period	Lean Period
Dhalli Catchment	Gravity	1875	4.54	1.80	0.23	0.20
Cherot/Agroti Nallah	Pumping	1889	4.80	3.86	3.50	2.48
Chair Nallah	Pumping	1914	2.50	3.00	1.20	0.55
Nauti Khad (Gumma)	Pumping	1924& 1982	24.06	19.75	14.25	14.14
Ashwani Khad	Pumping	1992	10.80	10.80	7.60	4.96
Giri Rivir	Pumping	2008	20.00	20.00	15.00	12.00
Total			71.24	66.38	44.28	36.63

Source: Shimla Municpal Corporation

Shimla Water Catchment Wildlife Sanctuary
(Dhalli Water Supply Scheme)



Source: Forest Department, H. P.. Shimla

Figure 15

Cherot and Jagroti

These are two streams which together provide an average of 3.50 MLD of water to Shimla. Part of this water is distributed in the adjoining area of Dhalli Ward, and the part of the water goes Sanjauli reservoir through gravity.

Chair Nllah

Chair Nallah - a small rivulet - generates, an average of 1.70 MLD water which is pumped from Chair source to storage tank at Lambidhar, and from there the water is distributed to Kufri under Shimla Planning Area (SPA).

Gumma at Nauti Khad (1)

This is the main source of water supply to Shimla, which provides approximately 16.75 MLD of water to the city. The water is pumped from Gumma, and received at Carignano reservoir from where it is gravitated to the Sanjuli reservoir, and from Sanjauli this water is further gravitated to the Ridge reservoir in the middle of the city and also to Mans field reservoir. In addition to this, some of the sectoral tanks are also fed through feeder line from Sanjuli reservoir. These sectoral tanks are Engine Ghar, North Oak, Bharari, Advanced Study Centre, Sandal Chakkar and Totu.

Gumma at Nauti Khad (2)

This scheme provides about 4.54 MLD of water which is pumped and received at Carignano reservoir from where it is gravitated to the Sanjuli reservoir. From Sanjauli, this water is further gravitated to the Ridge reservoir and also to Mans field reservoir. In addition to this, some of the sectoral tanks are also fed through feeder line from Sanjuli reservoir. These setoral tanks are Engine Ghar, North Oak, Bharari, Advanced Study Centre, Sandal Chakkar and Totu.

Ashwani Khad

The Ashwani Khad Water Supply Scheme constitutes one of the major water supply projects for Shimla city. From this source, about 7.60 MLD of water is pumped through two stages and received at Kasumpti reservoir from where part of the water is distributed in the adjoining area. The remaining water is again pumped from this reservoir to Mans field tank, and from Mans field tank the water is distributed in the adjoining area. However, this scheme has been shut down since February 2016 due severe contamination and resultant reported severe health risks.

River Giri

River Giri produces about 20.00 MLD of water which is pumped into Dhalli Treatment Plant and distributed in the adjoining area of Dhalli Ward.

Currently, the authorities responsible for water supply in Shimla are the Irrigation and Public Health (I and PH) Department and the Shimla Municipal Corporation (SMC). The I and PH looks after bulk supply and treatment of water while the SMC is mainly responsible for the distribution and pumping, metering and billing of potable water to domestic as well as commercial users. It was observed that the water supply infrastructure is very old and is not capable of supporting the growing water-demand of current as well as future population. Moreover, the current water losses are very high leading to inefficient utilization and distribution of water. Household level supply is being provided through a total of 41060 water taps connections. The entire population of the city is provided with water through taps with per capita water supply of 110 lpcd/135 lpcd. About 63% of the water connections are private while the rest account for public stand-posts. Only 70% of the population of Shimla is served with private water taps. Water is supplied for around 60 to 90 minutes every day in the non-lean period and for around 60 minutes on alternate days during lean period. Out of the total water connections in Shimla city as many as 76% are for domestic water supply, 19% are commercial, 3% for street hydrant and construction activities, and 2% water connections are in government buildings, religious establishments and institutions (Table 8). Inadequate water sources in near vicinity, erratic water supply particularly during summer, heavy subsidy on water supply (i.e. 90%), old and leaking distribution system, poor maintenance of available infrastructure, shortage of manpower, water theft, inefficient metering system and illegal connections result in heavy losses of water during transmission and distribution.

Table 8: Current Status of Water Utilization

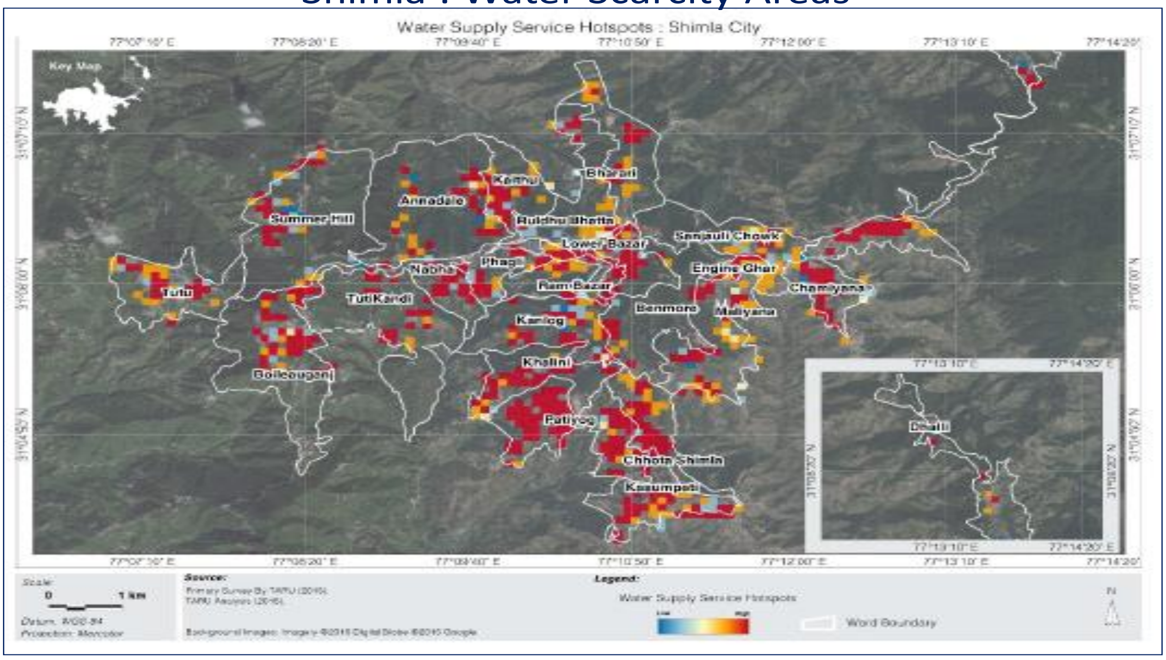
Sl. No.	Water Utilization Category	No. of Connections
1.	Domestic	76
2.	Commercial	19
3.	Street Hydrants /Construction connection	3
4.	Government Buildings/ Institutions/ Religious Organizations	2
5.	Total	100

Source: Shimla Municpal Corporation

As per the discussion held with the officials of MCS and I and PH Department, 90% population of Shimla has access to safe drinking water either through private connection or public outlets. The authorities also claim that currently there is no scarcity of water in the town. However, they are very much aware of the increasing demand of water in view of the current trends of urban growth and the resultant increase both in resident as well as floating population in the town. In view of this, one large drinking water project outside Shimla Planning Area (SPA) has been planned which is currently under the process of administrative clearance. The authorities are currently planning to ensure 24 hours uninterrupted water supply to all inhabitants and extension of water supply pipelines to currently uncovered areas of the city.

It was observed that in general water crisis prevails in many pockets of the. Depletion of yield of sources during lean period cause further increase in demand and supply gap resulting in much hardships and miseries to the inhabitants of the city. Although the I and PH is producing 66.38 million liters of water per day from 6 water supply schemes, it was observed during field visits and discussion with communities that existing water supply and infrastructure is not capable of supporting the water requirement of existing urban population. A large number of city inhabitants feel that the water supply in city is very erratic and unreliable. The areas where people are facing scarcity of water have been shown in Figure 16. The relationship between population and rainfall was found inverse, and the availability of water per capita per day decreasing with increase in number of family members. The City Development Plan (CDP) proposed under Jawaharlal Nehru National Urban Renewal Mission (JNNURM) identifies water supply and sanitation as major priorities to be tackled in order to lessen the growing gap between demand and supply of water. In order to provide adequate quantum of portable water to the inhabitants of the city, the CDP has envisioned a water supply at the rate of 135 lpcd (person/litre/day). The plan has estimated total quantity of water required till the end of planning year of 2047 as 71.11 Million Litre Day (MLD). Further, the plan reiterates availability of about 30 MLD of water, which falls too short of present requirement of the city causing severe water crisis.

Shimla : Water Scarcity Areas



Source: UNDP, 2015

Figure 16

Land Use Change and Depletion of Water Resources

Land use changes are now being considered as one of the major driving force, transforming the natural landscape and affecting ecosystem services (Jandl et al., 2009; Ives, 1989; Haigh, 2002;

Grover et al., 2015). Further, it is anticipated that anthropogenic interventions and resultant land use changes will become increasingly dominant in 21st century. Urban growth often results in intensive and rapid land use changes with consequent degradation and disruption of critical ecosystem services (Buytaert et al, 2011). These changes in ecosystem structure and function, particularly in headwaters, are causing great loss of biodiversity and disruption of hydrological processes in the mountains (Tiwari, 2000, 2007, 2008 and 2010; Borsdorf et al., 2010). Studies indicated that the rapid urbanization and resultant land use intensifications have disrupted the hydrological regimes of Himalayan headwaters (Tiwari and Joshi 2012a, 2012b; Tiwari 2008; Ives, 1989). The studies carried out in other parts of middle Himalaya revealed that the amount of surface runoff from urban areas is much higher compared to the amount of runoff from other categories of land, particularly, forests and horticulture (Tiwari, 1995, 2000, 2008; Rawat 2009). The large-scale depletion of forest resources in Himalayan headwaters is causing great damage to the underground water resources by reducing the groundwater recharge and resultant decline in water generating capacity of land to springs and streams in the region (Tiwari and Joshi, 2005; Haigh and Rawat, 1990). Therefore, a large proportion of the rainfall is lost through surface run-off without replenishing the groundwater reserves in urbanized landscape, a large number of springs that support a variety of life sustaining activities are drying up fast in the region (Rai and Sharma, 1995, 1998; Rai et al., 1998; Tambe et al., 2012; Valdiya and Bartarya, 1991; Tiwari and Joshi, 2012a).

In Shimla, it was observed that due to phenomenal increase in built up area and roads and other infrastructure the overland flow has increased considerably, reducing groundwater recharge through infiltration and percolation (Tiwari and Joshi, 2007, 2009, 2011 and 2015). As in other Himalayan non-glacial fed watersheds, streams and rivers are fed by groundwater storage, viz., aquifer emanating water through natural springs. However, the natural springs in Shimla headwaters as well as in the surrounding watersheds are drying, and as a result; the streams are also drying fast in the headwater regions. This substantiates the finding that water resources in Shimla headwater and in adjoining catchments are diminishing and depleting fast owing to the rapid land use changes and resultant reductions in groundwater recharge (Tiwari and Joshi 2012a; Valdiya and Bartarya, 1991; Tiwari 1995, 2000; Bisht and Tiwari 1996). As in other Himalayan headwaters, these hydrological imbalances are clearly discernible in Shimla in the following forms:

- The long-term decreasing trend of stream discharge
- Diminishing discharge and drying up of springs
- Human impacts on surface run-off flow systems and channel network capacity

Contamination and pollution of water sources is challenging problem related with water security in Shimla. It was investigated during field surveys that most of the streams originating and flowing across the town are highly contaminated due to sewage and waste pollution. All these streams, finally drain into and feed larger streams down-slopes which constitute principal sources of water supply to Shimla city. As mentioned in the preceding sections, one of the major water supply projects of Shimla was shut down in February 2016 due to very high level of contamination and resultant serious health risks.

Climate Change and Water Availability

The identified possible climatic changes in Shimla are likely to exacerbate the water security problem in future. The observed changes in the climatic conditions and future climate projections may transform the hydrological regimes of mountain headwaters including Shimla and disrupt hydrological system all across the catchments (ICIMOD, 2009, 2010 and 2012).

Consequently, regime of water resources in Shimla is likely to change rapidly, with respect to discharge, volumes and availability (Tiwari 2000 and 2008; Tiwari and Joshi, 2012a, 2005; Bandyopadhyay et al., 2002). The rainfall variability, particularly the incidences of high intensity rainfall and frequent and long meteorological droughts are likely to cause further depletion of water resources, and reduce the availability of freshwater in the streams and springs. This can disrupt/damage water supply infrastructure as well as the sewage system of the town. Increased temperatures will lead to increased demand for water, putting additional stress on the water supply system. This would reduce the availability of community access to water, and consequently adversely affect quality of sanitation, hygiene and citizen's health in the city. Damaged water supply system infrastructure would impact sewage and transportation system, and in turn cause traffic congestion and further contamination of the water sources. Besides, climate change induced slope failure and landslides are likely to disrupt natural drainage and water supply infrastructure impacting both the availability and supply of water.

Additionally, it was observed during field surveys that a large proportion of population, particularly slum-dwellers and floating population, depends on natural springs of the city for the fulfilment of their water needs. However, due to rapid urban growth and phenomenal magnitude of construction activities in the catchment areas, changes in temperature and precipitation pattern, and resultant depletion of the streams and springs, the availability of and access to water, particularly to poor and marginalized sections of urban population is being adversely affected. Climate change is likely to intensify the magnitude of anthropogenic stress on water resources of the town and affect the quantity, quality as well as equity of water (ICLEI, 2013).

These findings have been clearly substantiated by the observations made in Himachal Pradesh State Strategy and Action Plan on Climate Change (HPSSAPCC) and ICLEI (2013). The Action Plan observed that climate change induced weather extremes such as unprecedented drought, frequent floods, cloud-bursts, erratic and changing pattern of rain and snowfall, higher temperature and milder and late winters have affected the critical ecosystem services in general, and the water in particular. Over the years, the water availability in all towns of the State has declined, and majority of them are facing scarcity of water during most of the time of the year. The traditional water sources are either on the verge of extinction or have dried. Any change in the behaviour of water resources will have adverse impact on the overall economy and development of the State.

Climate Change Adaptation Measures Priorities, Efforts and Gaps

Urbanization in Shimla has largely been unplanned, resulting in the lack of civic amenities in proportion to population density. Unplanned and unsystematic urban growth together with rapid urban expansion and increasing inflow of tourists have made severe environmental impacts on the urban ecosystem of the city, particularly in view of climate change. Shimla despite being a capital city, has grown in a completely unplanned manner causing immense pressure on the limited urban infrastructure and services resulting into degradation of the urban environmental conditions and increasing vulnerability of large population to emerging threats of climate change. Major environmental concerns associated with such unplanned urban development are emerging risks of climate change induced geo-hydrological hazards, disruption of ecosystem services, particularly freshwater; destruction of forest and critical habitats, loss of bio-diversity, air-pollution and climate change. Despite realizing the increasing vulnerability of urban areas to climate change induced risks, no specific climate change adaptation plan has so far been evolved for any cities of Himachal Pradesh including Shimla by the State Government and other agency.

However, Shimla is covered by the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) of Government of India, and under which a range of urban development interventions, including the development solid-waste management, wastewater treatment and city sanitation plans are underway in the town. Nevertheless, no detailed climate vulnerability risk assessment framework is currently available for such a sensitive and high mountain city. However, keeping in view the phenomenal changes taking place in climatic parameters and their possible adverse impacts on human life, community livelihood capital, infrastructure and basic urban services; the Government of Himachal Pradesh has evolved State Strategy and Action Plan on Climate Change (HPSSAPCC). The Action Plan recommended certain measures towards collating available data and information of impacts of climate change on cities, their systems, infrastructure, and people towards improving scientific knowledge and evidence base and understanding of climate change and its impacts.
Moreover, in pursuance of the National Action Plan on Climate Change (NAPCC), the Government of Himachal Pradesh took several important measures to address the climate change adaptation and mitigation issues. These include hosting of 'Himalayan Chief Ministers' Conclave' on 'Indian Himalaya: Glaciers, Climate Change and Livelihoods' in Shimla in October 2009; and evolving joint 'Integrated Climate Change Mitigation And Adaptation Programme' for Himalaya called 'Shimla Declaration on Climate Change and Himalayan Development'. Besides, a state-of-art State Centre on Climate Change was established under the aegis of the State Council for Science Technology and Environment, Department of Environment, Science and Technology, Himachal Pradesh so that State's initiatives could be dovetailed with the national priorities and programmes on climate change.

The Himachal Pradesh State Strategy and Action Plan on Climate Change underlines the need of taking necessary steps to improve understanding of climate change and its effects; education and awareness; and developing and strengthening the partnership and cooperation with a range of institutions and stakeholders. It also emphasizes the initiation of processes for developing the necessary coordination mechanisms, sectoral policy initiatives and institutional arrangements to build the capacity of urban ecosystems to be resilient to the risks and impacts of climate change through implementing adaptation measures and contributing to mitigation of greenhouse gas emissions. The plan further emphasizes the need of developing and deploying a range of awareness and capacity building programmes for municipal officials for promoting appropriate measures towards climate resilience, as well as similar programmes for building awareness on climate change and its impacts for the urban populations. The strategy underlines the urgent need of converging such efforts with other sectoral initiatives such as health, education, housing and water supply, and fostering inter and intra departmental coordination.

Acknowledging the vulnerability of the Himalayan mountain ecosystem to impending impacts of climate change, the Swiss Agency for Development and Cooperation (SDC) is currently implementing 'Indian Himalaya Climate Change Adaptation Programme' (IHCAP) with specific focus on the Himachal Pradesh for the last five years. A series of capacity building programmes have been organized under the project for the officials of urban local bodies across the State.

During the recent years two comprehensive plans: (i) The City Development Plan for Municipal Corporation of Shimla, and (ii) Shimla City Development Plan were respectively prepared by Infrastructure Development Corporation, and the Town and Country Planning

Department of Himachal Pradesh. However, it is surprising to note that the climate change impacts and adaptation needs of the city have not been considered in both of these important policy documents.

The ICLEI (2013) South Asia has prepared a climate change vulnerability and risk assessment report titled 'Climate Resilience Strategy for Shimla'. The strategy has identified two climatic hazards – increase of temperature, and increase in precipitation impacting the city. The report has clearly indicated that Shimla is likely to face water shortage due to the impact of climate change (ICLEI, 2013).

However, there exists a large gap in the knowledge and information about the urban climate change impact and adaptation in the State, which is clearly reflected in the complete absence of studies on urban climate vulnerability and risk assessment and incorporation of climate change adaptation component in ongoing urban development programmes across the State.

The Way Forward

Shimla is not only one of the largest towns both in terms of population and geographical area located in Indian Himalaya, but is also highly vulnerable to the impacts of climate change. During the recent decades, sincere efforts have been made to improve the environmental governance of the town and conservation of its ecosystem services. However, the environmental conditions of the town continued to deteriorate. Shimla situated in tectonically active domain and in the zone of maximum precipitation is characterized by relief differences of the highest order is highly vulnerable to the processes of environmental changes. The rapid urbanization is increasing the susceptibility of intensively modified and densely populated fragile slopes to the active processes of mass movement, landslides, and hydrological disruptions disturbing water availability and its supply. Moreover, the rapidly changing climatic conditions, particularly the climate change induced hydrological extremes are posing severe threats to the sustainability of fast growing urban ecosystem by depleting the water resources and increasing the frequency, intensity and severity of geo-hydrological hazards in the town and its surrounding region. The climate change is likely to disrupt the hydrological regime, and the availability and supply of water to the town which is already under stress of increasing urbanization (UN, 2012). The city development plan and also the state disaster risk reduction framework and climate change adaptation plan did not make any provision for addressing the emerging risks of climate change, particularly the scarcity of freshwater for growing urban population and reducing the risks of geo-hydrological disasters. In view of this, the following recommendations are made:

City Climate Change Impact Assessment and Adaptation Plan

A comprehensive climate change vulnerability and risk assessment and mapping of the town should be carried taking into account all the critical parameters of exposure, sensitivity and adaptive capacity of urban ecosystem. An integrated climate change adaptation governance plan need to be formulated incorporating the above-mentioned points involving a range of institutions and stakeholders (e.g., government line departments, private enterprises, civil society and non-governmental organizations, community based organizations and academic and research institutions). The planning should be so framed that it would not only integrate the existing system of water supply but would also envisage a strategic plan consistent with future overall development of the city. The planning should also be streamlined to fit into the regional development plans, long-term sector plan, land use plan and other open space planning. The planning scenario may also include the supporting activities like health, education, staff training and infrastructural improvements.

Comprehensive Urban Land Use Policy

A comprehensive urban land use policy should be evolved and implemented in Shimla and its peri-urban zone taking into account conservation, developmental, climate change adaptation, and sustainable development needs and priorities; and demand and availability of water resources.

Community Based Water Conservation Plan

A participatory framework for the conservation of water resources particularly through reducing anthropogenic intervention in the headwater recharge zone of the natural springs and streams should be evolved.

Risk Zone Mapping

A detailed and large-scale risk zone mapping of the town should be carried out analyzing the parameters of geology, structure, litho-logy, geomorphology, demography, economy and livelihood, infrastructure and services.

Improvement of Water Pumping, Storage, Distributions and Maintenance System:

It was investigated that out of the total water stored in different reservoirs in the city, nearly 30-45% water is lost in transmission, conveyance and distribution. This massive loss of precious resource is mainly due to the old water lifting and distribution system, lack of maintenance and personnel. In view of this, replacement and strengthening of pumping machineries, storage and distribution system by laying new feeder lines will not only reduce the water loss, but also improve the efficiency of distributions system and enhance community access to water.

Catchment Area Development

Despite being the water tower of the world, Himalaya is heading towards severe water poverty primarily due to population growth, speedy urbanization and resultant land use changes; and rapidly changing climatic conditions. The middle Himalayan mountains in which most of the fast growing cities such as Shimla, are located, is the most densely populated and rapidly urbanizing mountain area of the world. The burgeoning population living in sprawling cities and densely populated rural settlements in middle Himalayan mountains is completely dependent on rain-fed streams, rivers and natural springs for their water supply. As observed and discussed in the preceding sections, the desertification caused by the disappearance of both, the surface and groundwater is critically serious as it may collapse the both natural and human systems in the mountains. The most appropriate way to rejuvenate and conserve the water sources is to develop the 'Spring Sanctuaries' in the catchment areas. A spring sanctuary is in fact a recharge zone or a headwater which recharges water into the ground storage or aquifer that constitutes the source of natural springs, streams and rivers (Tambe et al., 2012; Rawat, 2009; Negi and Joshi, 2002 and 2004; Negi et al., 2001). The rocks-pores, joints, fractures and faults of spring sanctuary are filled with water and the upper limit of the saturated rocks is known as ground water table (Rawat, 2009). The following measures are suggested for the development of spring sanctuaries in Shimla headwater regions and in adjoining catchments from water supply that comes to the city (Rawat, 2009):

Mechanical Development Measures: The mechanical treatment measures increase (i) soil moisture storage, (ii) control run-off, and (iii) improve infiltration capacity of soils and recharge of groundwater through enhanced percolation. The mechanical measures mainly include: (i) ***Infiltration Trench*** which is small (0.5 - 1.0 m in height) and is constructed along the slope at a spacing of 10 m at an average slope condition of 20^0. The main purpose of infiltration trench is to arrest the overland flow or excess hill slope run-off during rainfall and thus to facilitate groundwater recharge; (ii) ***Bio-percolation Check Dam*** is a small (0.5 - 1.0 m in height) check dam constructed by coir-netted pine needle or other dried tree-leaves or dead wood logs across tiny temporary stream of the first order. The Bio-percolation Check Dam stops the water-flow of tiny streamlets during rainfall for short periods and thus contributes towards recharging groundwater; (iii) ***Stone Check Dam*** (1.0 - 1.5 m in height) is a barrier of dry stones across a second order seasonal drain. This stops water flowing off the channel during high intensity rainfall for few minutes and recharges groundwater into the aquifer; (iv) ***Wire Carte Check Dam*** is an obstruction of stones (1.5 - 2.0 m in height), filled into wire-net along a third order stream. This barrier holds the torrential water flow during high intensity rain for short duration and allows the water to recharge the groundwater pool; and (v) ***Minor Check Dam*** is a 2-3 m in height concrete impediment normally built across perennial streams. These type of permanent structures recharge groundwater throughout the year.

Biological Development Measures: The biological measures improve the hydrological responses of the spring sanctuary through (i) bringing the land under protective vegetal cover, particularly planting broad leaved species, indigenous, shrubs, herbs and grasses; and (ii) developing water holding surface using fresh litter, partially decomposed and composed litter. The biological measure of spring sanctuary development includes: (i) improvement of the forest through afforestation and reforestation, particularly through community forestry programs; rehabilitation of degraded and wasteland through development forests, grassland and horticulture.

Conservation of Traditional Water Sources:
In Shimla, there are large number of springs particularly in the lower parts of the city. These springs not only contribute to the discharge of streams, but some of them also constitute the sources of important streams of the town. The natural springs of the town traditionally constituted the significant sources of freshwater for the large number of inhabitants living nearby the springs. The local people had also evolved participatory governance framework for the conservation, maintenance and protection of their water sources. Even today, when most of the city population is covered by piped water supply, a large number of families, particularly the poor and slum dwellers and seasonal laborers, depend on these depleting springs for the supply of freshwater. As stated in the preceding sections, most of these springs have dried or become seasonal and their water is contaminated. In view of ensuring water security to growing population amidst conflicting and competing water demand under climate change, it is highly imperative to replenish, rejuvenate and conserve these traditional water sources through community participation and involvement.

Improvement in Water Literacy: The information obtained during field-visits indicated that most of the residents of the city were aware of the impact of climate change on the availability and supply of water in the town. A fairly large number of city dwellers were found very much aware of the importance of rainwater harvesting, and some of the families have developed rainwater harvesting structures in their houses. However, it was observed that the level of water literacy needs to be improved in urban population. Despite rainwater harvesting in private houses being mandatory by law, only 10% families have implemented rain water harvesting measures in their houses. This underlines the need of community movement for improving water literacy among the inhabitants of the city. Educational institutions including colleges and universities, students in association, youth clubs, women's association, electronic and print media, and NGOs should be involved in improving community awareness level.

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