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THEME: WATER

Subtheme: Water security, Water Planning and Management

# Water security in the mid - elevation Himalayan watershed, East district with focus in the State of Sikkim

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## ABSTRACT

*Water being a critical resource, it is essential to ensure that there is enough of it to meet the demand of people for various purposes. But scarcity and misuse of water pose a serious threat to food security, human health and development. Competition for water is already prevalent in the mid-elevation Himalayan watershed of India due to high population growth and land transformation for urbanization. Water shortage has always been a problem for hamlets situated at mid to higher elevation, away from the main streams/spring in many mountainous regions of India. Moreover, water and overall environmental security in the rainfed mid-altitude watersheds of the Himalayan region are highly vulnerable to seasonal changes in the water regime. During a drought period, when the upper springs dry up, these habitations experience serious water shortages. Similarly reducing discharge in the springs and drying up of hilltop lakes is a growing issue in Sikkim. Thus, there is clearly a need for water conservation and water management programme that target various water needs of the hill people. Considering this watershed development approach has been adopted in the country for proper management of natural resources by Planning Commission, and other funding agencies. However, these watershed development projects have focused on intensifying land uses using water as one of the freely available environmental goods. The services provided by the watershed hydrology have largely been neglected. The distribution of rainfall is not uniform but varies seasonally, regionally and temporally, in terms of form, amount, duration and intensity. Variations in rainfall from year to year or even from one season to the other season, becomes critical for agricultural operations. Rainstorms generate runoff, and its occurrence and quantity are dependent on the characteristics of the rainfall event. Rainfall runoff is an important component contributing significantly to the hydrological cycle. Keeping in view, the present paper attempts to discuss the water demand and water scarcity problem of the state of Sikkim in particular due to ever increasing population and urbanization and also deals with population projection, water availability and water demand forecast studies under different scenarios in the mid - elevation Himalayan watershed of east district of Sikkim besides exploring the relationship between rainfall-runoff and sediment load estimation. The paper also highlights some water resources, changing rainfall pattern, conservation and management measures in the state of Sikkim for resolving the water security issues in the future.*

**Key words:** Mid- elevation Himalayan, water availability, and water demand, water scarcity, rainfall-runoff, watershed development

# 1. INTRODUCTION

Water being a critical resource, next in importance only to air, is essential to ensure that there is enough of it to meet the demand of people for drinking and household consumption, irrigation and other use (Anonymous, 2002). From time immemorial, perennial rivers were the major sources of water, and the people, who were far away from river sources practices utilization of ground water and stored rainwater for their sustenance (Avasthe *et al.,* 2013). Water security from household to global levels means that an individual or community has access to enough safe water at affordable cost for basic and other economic needs while, at the same time, ensure the health of the natural environment. It encompasses the concept of holistic water governance, strikes a balance between water conservation and use. India has more than 18 percent of the world's population, but has only 4 percent of world's renewable water resources with 2.4 percent of world's land area (Gupta, 2013). There is a widespread consensus that six decades after independence, India's water situation is characterized by scarcity and lack of coordinated planning (Narasimhan, 2005). With scanty population, the water resource appears to be abundance. However, with the increase of urbanization and multiple uses of water, this resource becomes scarce and need therefore arises for its proper assessment of its utilization, efficient management and the requirement of additional water sources is strongly felt (Kumar and Rawat, 1996). In a report published in November 2009, the 2030 Water Resources Group has estimated that the world's water availability will lag demand by 40% by 2030, and that in India availability will lag demand by 50% by that time (Water Resources Group, 2030; Narasimhan, 2010). Agriculture is the main user of water and food security of a nation is directly dependent/linked to water security (Biyani, 2008). The knowledge already exists to at least double the yields in rain-fed agriculture, but the water poses a particular challenge and large water investments focussing on water management are lacking (Sharma, 2011). More than half of humanity relies on freshwater from mountain regions (Liniger *et al.,* 1998) and the term **'water tower'** has been widely adopted to express the importance of mountains in providing freshwater for downstream areas (Liniger *et al.,* 1998). Indian Himalayan Region occupies 18% of the geographical area of India with 6% resident population (Krishna and Kundu, 2002). The Himalayan mountain system is both fragile and dynamic, and is one of the principal sources of fresh water in the Indian sub-continent (Saravanan, 2000). The Eastern Himalayan Region is the second largest hydrologic region in the world (Ahmad *et al.,* 2001). The mid elevation hills are one of the most fragile and vulnerable areas in the Himalayan region. This zone is characterized by high rainfall and high rates of specific runoff during monsoon and little rainfall during the long dry season, as well as by high population densities and intensive human activities (Alford, 1992). The water resources in the Indian Himalayas are estimated to be about 1, 20,700 million cubic metres in average annual flow (CSE, 1991). This water has the potential to generate 28,150 megawatts of electricity and to contribute about 2,46,000 million cubic metres of water for irrigation (Valdiya, 1997). However, the complexity of the region makes the utilization of water potential questionable. Only 15% of the rain water is able to percolate down through the ground of treeless slopes to recharge the springs, the remaining 85% flows as surface runoff and causes floods (Valdiya, 1997). Most of the rains become subsurface flows and only 0.3 to 1.3% of rainfall flows as surface water. The non-forested area has more surface flow but with less magnitude (CSE, 1991).

The distribution of rainfall is not uniform but varies seasonally, regionally and temporally, in terms of form (such as rain, snow, and hail), amount, duration and intensity (Kale *et al., 2001*). Variations in rainfall from year to year or even from one season to the other season, becomes critical for agricultural operations (Chakraborty and Mandal, 2008). Rainstorms generate runoff, and its occurrence and quantity are dependent on the characteristics of the rainfall event, i.e. the intensity, duration and distribution. Apart from these rainfall characteristics, there are number of catchment specific factors, which have a direct effect on the occurrence and volume of runoff. This includes soil type, vegetation cover, slope and catchment type (Pradhan *et al.,* 2010). In the fragile mountain ecosystems of Himalaya, the current trends reflect exploitation at rates much higher than those at which these resources get replenished (Anonymous, 1992). Competition for water is already prevalent in the mid-elevation Himalayan watershed of India due to high population growth and land transformation for urbanization. As long as water demand remains small compared to its availability, all users can coexist without conflicts and as such the problems of water allocation does not arise (Babel *et al.,* 2005). But with the increase in demand the conflicts between users intensify and increase in frequency and its impacts on water resources become noticeable. Despite the fact that the Himalayas are the largest storehouse of fresh water at lower altitudes, for the bulk of people inhabiting these mountains, water is extremely scarce all year round. They receive either too much during the few months of monsoon or too little for the rest of the year (Chalise, 1996). Scarcity of this valuable resource is posing a serious threat to food security, human health and development (Pisani, 1995). Water scarcity is a relative concept and can occur at any level of supply or demand. Water scarcity often has its roots in water shortage and in the event of high population growth, economic development coupled with wide climate variability the problems of water scarcity are most acute (FAO, 2007). In many localities people face various magnitudes of water scarcities, even for drinking (Negi *et al.,* 1988). Water and overall environmental security in the rainfed mid-altitude watersheds of the Himalayan region are highly vulnerable to seasonal changes in the water regime. Understanding the characteristics of the seasons and the flows of the seasons from one to the next as they have been in past decades provides a major step toward understanding and coping with changes in seasonality of sources.

The topographical and the geographical location of Sikkim is unique in the sense that the hydro-metrological situation has made it one of the highest rainfall zones in the country and has a dense network of drainage channels. The state, as such, is very rich in water resources. But this has never before been fully tapped or utilized or conserved properly. As a result, the need for better and sustainable water use facilities in the state is being felt increasingly. The state has immense potentialities for the development of tourism in the state and has seen the temporal increase of tourists mainly for religious and recreation/trekking purposes (Rai and Rai, 1994). Today the number of tourists visiting Sikkim has reached 3.5 lakhs per annum (Joshi and Dhyani, 2009). Most of the tourists stay at Gangtok. Consequently, this place becomes over crowded during the peak season (Rai and Rai, 1994). This adds to the water scarcity problem even more. In recent years, some places in Sikkim faced a drought like situation or moisture stress during winter. Keeping all these points in view, the present paper attempts to discuss the population projection studies, water availability, water demand under different scenarios in the mid – Himalayan watershed in East Sikkim. In addition, it also finds out the relationship between rainfall-runoff and sediment load. Finally, it also attempts to highlight the water resources, changing rainfall pattern, water security and scarcity issues, identifies regions vulnerable to water availability, presents water utilisation by different sectors and suggests some management measures and strategies to address climate change concerns to deal with water scarcity issue and ensure water security in the state of Sikkim.

## 2. MATERIALS AND METHODS

### A. Study Area

The present study was conducted in the mid elevation Himalayan watershed which varies from 932m to 3172m. It extends from $27^0$15’ to $27^0$20’ N and $88^0$37’30” to $88^0$42’30” E, embracing an area of 35.42 sq. km which is about 0.49% of the total geographical area of Sikkim state. It lies entirely in the mountainous zone. The watershed is the catchment of the river “Taktsom Chu”. It drains finally in the Ranikhola (river) at Jalipool (2 kms away from Ranipool). Taktsom Chu is a tributary of Ranikhola, lies in Teesta Basin. Ranikhola merges with river Teesta at Singtam about 30 kms away from Gangtok. The Taktsom Chu watershed is situated at the south-eastern part of the state in the East district, Sikkim (Fig. 1). The watershed is covered by three revenue blocks i.e. Naitam, Assam and Lingzey blocks with a population of 4,065 (Census, 2001). The Naitam part of the watershed is very steep while the Assam Lingzey part of the watershed is moderately steep. The shape of the watershed is elongated.

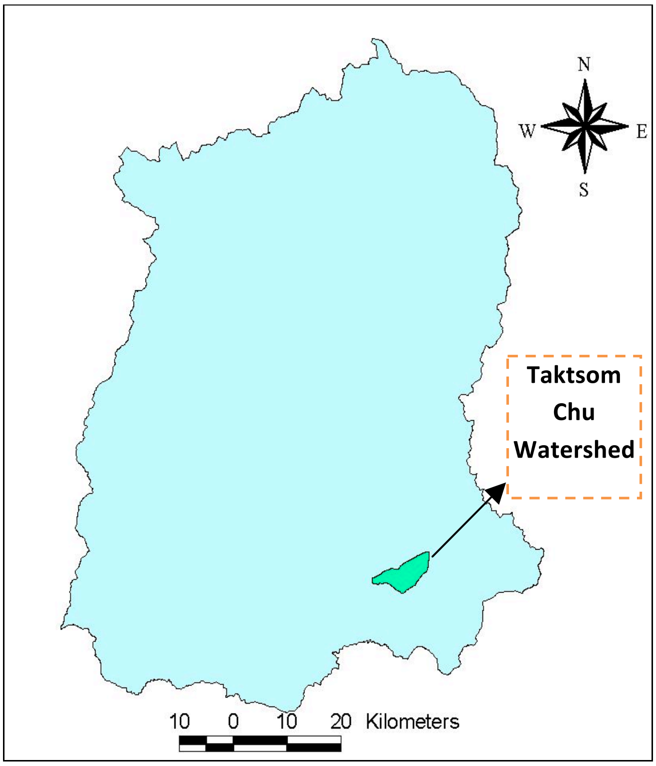


Fig. 1: Location of Taktsom Chu watershed, East District, Sikkim

Sikkim is situated in the eastern Himalayas spread below the *Mount Khangchendzonga* (8534 m), the third highest mountain in the world. The state is spread between $27^0$ 00’46” to 15’ to $27^0$ 07’48”N latitude and $88^0$00’58” to $88^0$55’25” E longitude, with an area of 7096 sq km and measuring approx. 112 km from the north to south and 90 mm from east to west; the elevation ranges from 300m to over 8540 m above sea level. It has a human population of 6,10,577 as per Census, 2011, which constitutes 0.05 only of India’s total population. The state is bounded in the north by the Tibetan plateau, by China (Tibet) on the north-east, by Pangolakha range of Bhutan on the south-east, by Darjeeling district of West Bengal on the south and Singalila range and Khangchendzonga on the west and north-west. Sikkim is drained by large number of perennial rivers, which merge into two prominent rivers, the Teesta and the Rangit. River Rangit is a tributary of Teesta and joints at Melli, the boundary between Sikkim and West Bengal. The state of Sikkim has been administratively divided into four districts viz. North Sikkim, South Sikkim, East Sikkim and West Sikkim using water divides of major and minor tributaries of Teesta River as criteria. Human population of Sikkim comprises mainly of Nepali, Bhutia and Lepcha. Majority of the residents depend on agriculture and related activities for their livelihood. Maize, large cardamom, rice and wheat are the principal crops grown in the state.

## B. Methodology

Plate 1: Estimation of Runoff at SOP site at Bala khola, Assam Lingzey, East Sikkim

N : 27$^0$17'23.4", E : 088$^0$38'38.8" ; Elev. 1180m

The Indian state of Sikkim is mainly located in the watershed of the Teesta River. The state of Sikkim was focused with respect to the various quantitative aspects of water. The study is based on regular field survey and investigation. The ancillary information on the water scarcity and demand was developed after the review of newspapers, published researched articles on them and through google search. With the manual rain gauge installed in Gairigaon, Assam Lingzey daily rainfall record was measured and recorded. The daily runoff was also estimated at the Silt Observation Post (SOP) site, Bala khola, a tributary of Taktsom Chu in Gairigaon (Plate 1). The Velocity – Area method was used for runoff measurement. The velocity in the stream was measured by float methods. Water sample was collected daily using narrow mouthed polyethylene bottles using standard methods (Ostrem, 1975). The collected water samples will be taken for analysis in the laboratory. The sediments will be filtered out from the samples using pre-weighted Whatman No. 42 (ashless filter paper, 125 mm diameter). Oven dry method was used for sediment load estimation. Image registration was done in Leica Geosystem, ERDAS imagine using geographic Lat/Long projection. The layout of the maps was prepared with the help of ARC GIS Arcmap.

## 3. RESULTS AND DISCUSSIONS

The results and discussions of the present paper are presented in two sections (1) Taktsom Chu watershed, East Sikkim and (2) Sikkim.

## (1) Taktsom Chu watershed, East Sikkim

### A. Rainfall and runoff relationship

. Rainfall is the main source of water in all the habitats, above and below the surface of the earth and in the atmosphere (Gupta *et al.,* 1972). The rainfall - runoff process is a complex, dynamic and nonlinear process, which is affected by many and often interrelated, physical factors (Veerana *et al.,* 2009). The runoff studies are essential for efficient utilization of available water resources. Runoff is generated by rainstorms and its occurrence and quantity are dependent on the characteristics of the rainfall event, i.e. intensity, duration and distribution besides soil types, vegetation, slope and catchment size. Mountain catchments are specific by fast response of runoff to precipitation events. This phenomenon is explained by low retention capacity of high mountain areas. Fig. 2 shows rainfall pattern in the watershed from 2008 - 2012. The year 2009 was driest of all with only 2468.9 mm of rainfall as compared to 3695.11 mm, 3665.9 mm and 3636.5 mm in the year 2008, 2010 and 2011 respectively.

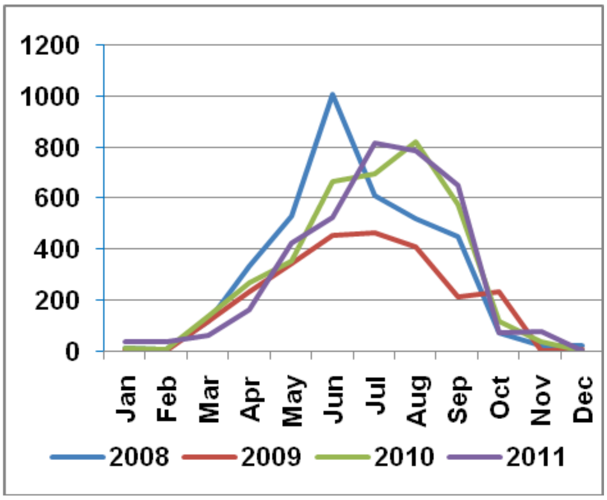


Fig. 2: Monthly Rainfall (mm) pattern different years (2008-2011)

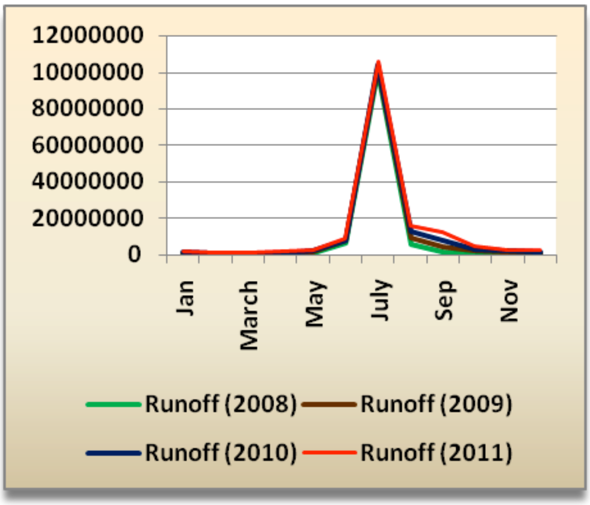


Fig. 3: Monthly Runoff ($M^3$) of different years (2008-2011)

On analysis of the runoff of the studied period, it was revealed that in all the months the flow pattern remained almost the same except in the months from August to October where the runoff showed in increasing trend in all the years (Fig. 3). The source of the stream was the number of groundwater springs at the upper reaches. This established the fact that in the year 2009, although the watershed received far less rainfall (2468.9 mm) as compared to other years which was more than 3600 mm each yet sustained an increased runoff.

## B. Relationship between Runoff and Sediment load/yield

The information on sources of sediment yield within a catchment can be used as perspective on the rate of soil erosion occurring within that catchment (Jain and Kothyari, 2000). The magnitude of surface erosion and sediment yield is found to vary spatially in a catchment due to the variation in rainfall and catchment heterogeneity (Jain *et al,* 2010). 80% of the sediments delivered to the world's oceans each year come from Asian rivers and amongst these the Himalayan rivers are the major contributors (Stoddart, 1969). There has been considerable increase in the sediment yield of developing countries as a result of deforestation and intensification of land use. Himalaya contributes sediment in the range of 500 – 1000 t $km^{-2}$ $yr^{-1}$ (Milliman and Meade, 1983). The Ganga and Brahmaputra rivers in India, carry away the world's maximum total suspended sediment yield of 1128 tonnes/$km^2$/yr as against the global average suspended sediment yield of approximately 150 – 175 t/$km^2$/yr (Tiwari, 2000).

Fig. 4 - 7 shows relationship between discharge and sediment load from the year 2008 and 2011 respectively.

The value of Coefficient of Determination ($R^2$) of 0.4125 between runoff and sediment load for the year 2009-2010 indicates that 41% of variation in sediment load can be explained by volume of runoff and remaining 0.59% of variation cannot be explained by runoff. There is high relationship between runoff and sediment load with a Correlation Coefficient (r) value of 0.70. The value of Coefficient of Determination ($R^2$) of 0.37 between runoff and sediment load from Jan. 2010 to July 2011 indicated that 37% of variation in sediment load can be explained by volume of runoff and remaining 63% of variation in sediment yield cannot be explained by runoff. The relationship between runoff and sediment showed a strong correlation coefficient of 0.61($P > 0.01$) from Jan. 2010 to July 2011. This implied a sediment source within the stream channel, rather than erosion from slopes, contributing sediment to this channel. There was a high relationship between runoff and sediment load with a Correlation Coefficient (r) value of 0.70($P > 0.01$) in the year 2009-2010. Similar, findings were reported in the Srikot Gad and Dugar Gad catchment in the Garhwal Himalaya (Joshi *et al.,* 1996).

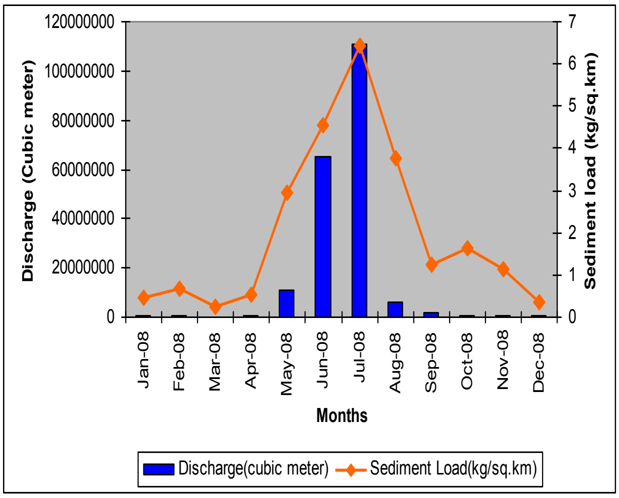


Fig. 4: Relationship between discharge (runoff) and sediment load for the year 2008

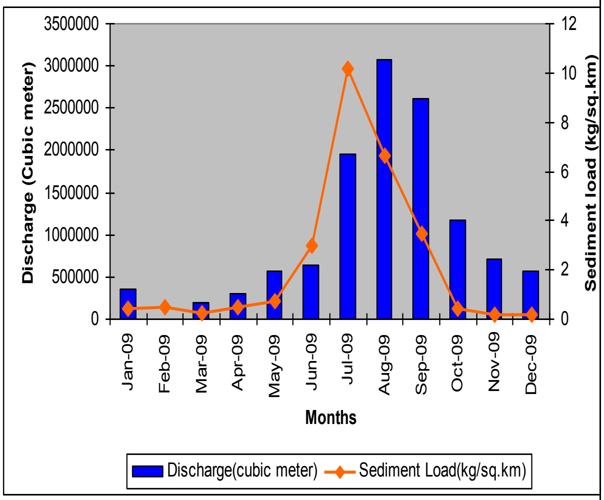


Fig.5: Relationship between discharge (runoff) and sediment load for the year 2009

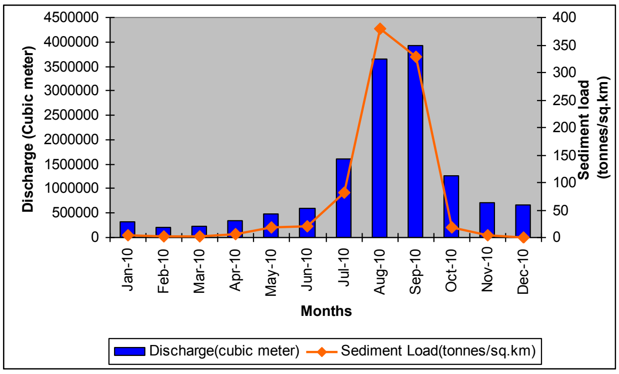


Fig. 6: Relationship between discharge (runoff) and sediment load for the year 2010

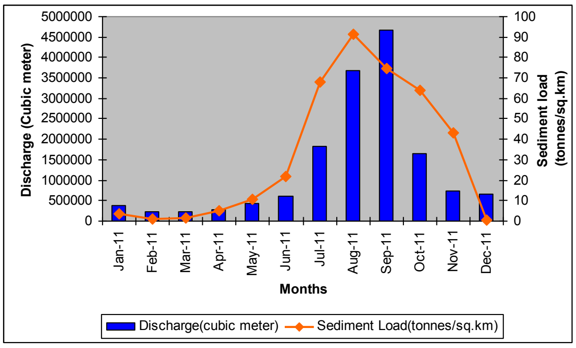


Fig. 7: Relationship between discharge (runoff) and sediment load for the year 2011

An analysis of the Rainfall, runoff and sediment load generated for the watershed reveals the fact that the rainfall decreases sharply from the month of Aug. 2009 (628.5 mm) to November 2009 (28.5), contributes only 36.5 mm in the three months of Dec.

2009, Jan. 2010 and Feb. 2010. Thereafter, increases sharply from the month of March 2010 (135 mm) to July 2010 (693.4mm). Runoff was highest in the month of August 2009 (86.64 mm) while lowest in the month of February 2010 (5.75 mm). Sediment load was highest in the month of July 2010 (72.41 tonne/sq.km) followed by August 2009 (66.69 tonne/sq.km) and September 2009 (35.52 tonne/sq.km.).

## C. Development of local water availability and demand ratio

Month wise water availability and demand ratio for different sectors [Households(HH), Agriculture (Agr.) and Livestock (LS)] was develop for the watershed for each years from 2008-2011(Table 1). This was done to find out the gaps in the available water and water demand for different months of the year. From the table 1, it is clear that the months of April to June has a very less water availability and demand ratio suggesting the need to take water conservation measures in these months in the watershed.

Table 1: Availability and Demand ratio from 2008 - 2011

| Months/Years | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|
| January | 11.53 | 6.29 | 5.99 | 7.10 |
| February | 8.71 | 4.41 | 3.62 | 4.13 |
| March | 2.26 | 0.86 | 1.02 | 1.10 |
| April | 2.10 | 1.12 | 1.20 | 1.02 |
| May | 1.87 | 1.01 | 0.84 | 0.76 |
| June | 23.04 | 2.26 | 2.04 | 2.10 |
| July | 137.24 | 2.63 | 2.18 | 2.51 |
| August | 7.39 | 3.96 | 4.66 | 4.70 |
| September | 3.49 | 5.65 | 8.67 | 10.35 |
| October | 1.66 | 2.35 | 2.57 | 3.35 |
| November | 1.95 | 2.40 | 2.38 | 2.49 |
| December | 1.24 | 1.75 | 1.93 | 1.65 |

(*Source: Field survey, Primary data)*

## D. Population forecast

The population forecast model of for watershed was developed (Fig. 8). The method was adopted from Bhatti and Nasi, 2010. The previous population growth rate of the watershed is taken from past census reports and depending on the previous patterns, the population is projected up to the years 2030. The population forecast is done on the basis of four social scenarios: low, medium, high and constant growth rate and water demand forecast is done on the basis of three scenarios: low, constant and high per capita water demand. The high water demand is assessed considering growing population and urbanization in the watershed. The low water demand indicates the possibility of conservative water use due to growing awareness.

Population forecast and water demand forecast model indicates that under the constant growth rate scenario, population of the Taktsom Chu watershed will be 5728 in the year 2020 and 6713 in the year 2030. Under the low growth rate scenario, the population will be about 5449 and 6305 in the year 2020 and 2030 respectively. While under high growth rate it will be 6963 and 8579 in the year 2020 and 2030 respectively. The previous population data trends showed that the medium growth rate is realistic approach for further analysis. Therefore for the water demand forecast, medium growth rate is accepted. Under the most likely middle grow rate scenario watershed population will touch the figure of 6475 and 7831 respectively in the year 2020 and 2030 respectively.

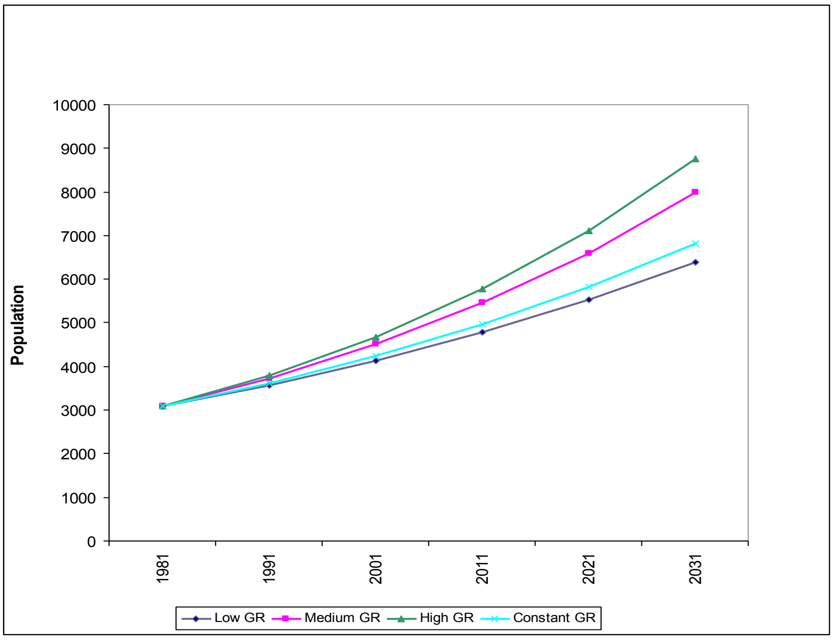


Fig. 8: Population forecast till 2031 under different growth rates

## E. Results of water demand forecast

40 LPCD, and 155 LPCD are standard values. 44.6 LPCD is based on the socio-economic survey of the villages of the watershed. For low water demand scenario, it will increase by 1.35 times and 1.82 times while for the high water demand scenario, demand will be 1.96 times and 3.87 times more than base year 2010 by the year 2020 & 2030, respectively for Low (40 LPCD) consumption rate. Under the constant water demand scenario, the water demand will be 1.41 times and 2.01 times more than the base year 2010 by the year 2020 and 2030. For Medium (44.6 LPCD) consumption rate, under low demand scenario it will be 1.35 and 1.82 times more than the base year 2010 by the year 2020 and 2030. For Medium (44.6 LPCD) consumption rate, under constant water demand scenario, the water demand will be 1.41 and 2.01 times more than base year 2010 by the year 2020 and 2030. For Medium (44.6 LPCD) consumption rate, under high water demand scenario demand will be 1.96 and 3.87 times more than base year 2010 by the year 2020 and 2030. For high (155 lpcd) consumption rate, under low demand scenario it will be 1.41 and 2.01 times more than the base year 2010 by the year 2020 and 2030. For high (155 LPCD) consumption rate, under medium demand scenario it will be 1.41 and 2.01 times more than the base year 2010 by the year 2020 and 2030. For high (155 LPCD) consumption rate, under high demand scenario, it will be 1.96 and 3.87 times more than the base year 2010 by the year 2020 and 2030 (Fig. 9 - 11). Fig. 12 - 14 shows the water availability and water demand by different sectors (Households, Agriculture and Livestock) when the population with a 40 LPCD, 44.6 LPCD and 155 LPCD is considered.

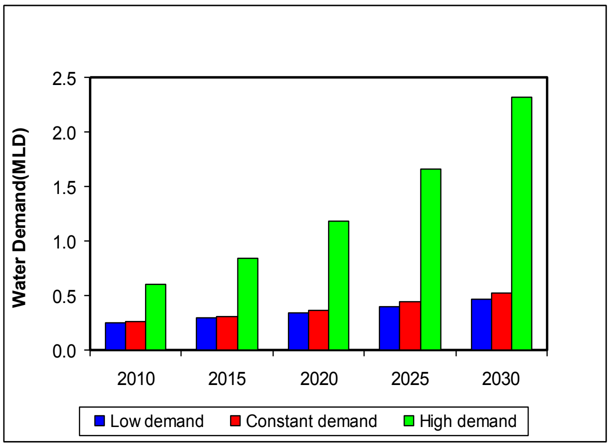


Fig. 9: Water demand forecast under different scenarios with minimum water demand (40 LPCD)

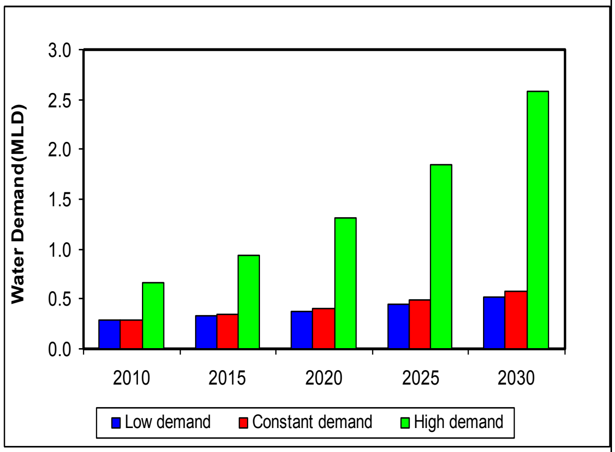


Fig. 10: Water demand forecast under different scenarios with medium water demand (44.6 LPCD)

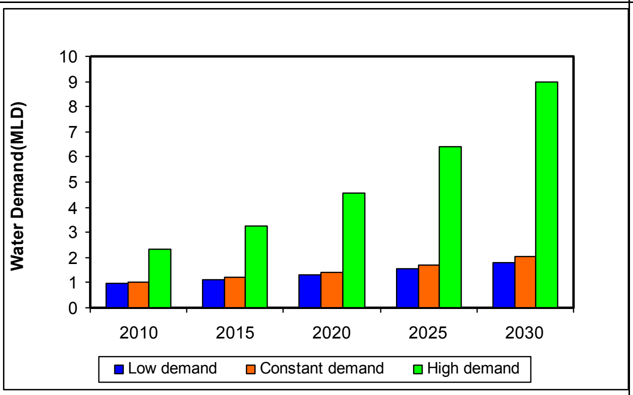


Fig. 11: Water demand forecast under different scenarios with highest water demand (155 LPCD)

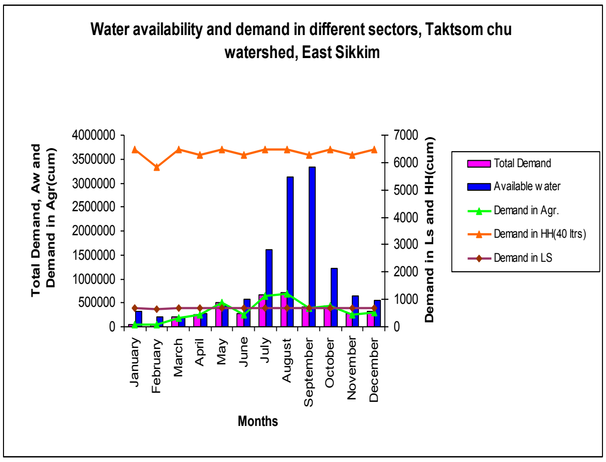


Fig. 12: Water availability and water demand by different sectors when the population when 40 LPCD is considered.

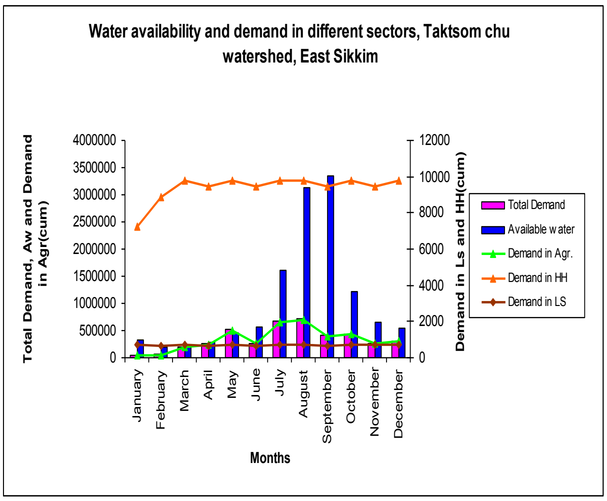


Fig. 13: Water availability and water demand by different sectors when the population when 44.6 LPCD is considered

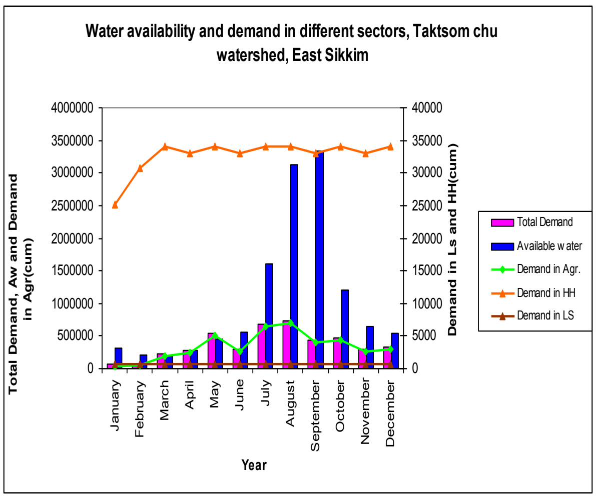


Fig. 14: Water availability and water demand by different sectors when the population when 155 LPCD is considered.

## (2) Sikkim

### A. Water Resources

The state of Sikkim is gifted by enormous water resources available through various rivers and hill streams. There are altogether 84 glaciers covering an area of about 440 km$^2$ with the total extent of permanent snow fields being 251 km$^2$ (SAC, 2001). This unique geomorphology has resulted in more than 315 glacial lakes located at an average altitude of 4,700 (±500) m (CISMHE, 2005). A large rainforest covers more than 76% of the total area (Misra and Das, 2009). Most of the monsoon clouds travel up the Teesta valley crawling over the tributaries in the river system and battering the mountains with torrential rain. The annual rainfall varies from less than 400 mm in the north to more than 3,400 mm in the south-eastern parts (Fig. 15), with the river Teesta and Rangit and their tributaries being the main drainage. The catchment area for the river Teesta in the hills is estimated to be 8,051 sq.km, of which 6,930 sq.km lies in Sikkim and the remaining 1,121 sq.km in the Darjeeling hills of West Bengal (Avasthe *et al.,* 2013). The total riverine length is 753 km (river)+147 km(canals/jhora) and lakes, reservoirs, ponds etc., covering and area of 3000 ha. More than 220 wetlands are present in Sikkim of which 150 lacustrine are and 59 riverine systems. As many as 2,000 natural springs are found in Sikkim (Avasthe *et al.,* 2013). The variable topography of Sikkim and the wind flows therefore has resulted in microclimates where rainfalls can change considerably just within a few kilometers (Personal observations).

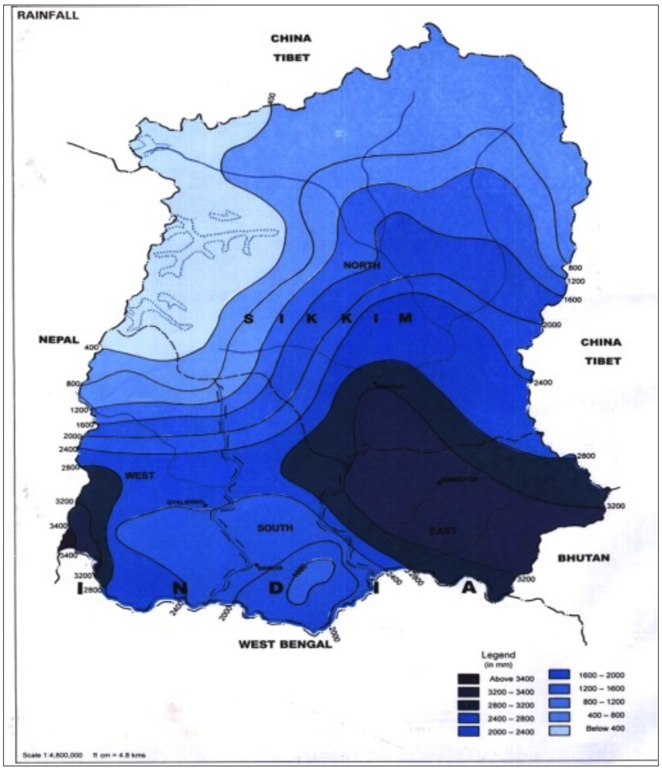


Fig. 15: Rainfall contour map of Sikkim
*(Source: ICAR, Sikkim)*

### B. Water security and scarcity concerns

The state of Sikkim solely depends upon “springs and streams” to meet its water demand. Natural springs are important as compared to any other sources of water in Sikkim. Springs ( “*Mohaan* and *Dhara” in local parlance*) in the state provide the main source of water to the 80 percent of the rural population for drinking as well as irrigation purposes (Tambe *et al.,* 2009) (Plate 5). A study carried out in the springs of the state suggests the chemical quality spring water in different lithological formations is excellent and completely suitable for drinking and other domestic purposes as well as for irrigation purposes (Hossain, 2009).The constraints of terrain do not allow piped water to be transported to the remote villages, nor can canals be dug for water to reach every farming plot as in the plains. Changes in the timing and volume of the water available for rural water supply and irrigation can threaten water security and agricultural productivity (IPCC, 2001b).

The small hamlets are strewn all over the state in hill slopes mostly along roads and not all are bestowed with spring sources. The pattern of shrinking of the monsoon season and the resultant drying up of natural springs and declining discharge of streams has been recently documented in the western Himalayas as well (Rawat *et al.,* 2011). Recent studies in the adjacent Darjeeling hills indicate the perceived impact of climate change as - less snow in the mountains and intense but short episodes of rainfall increasing run-off, causing poor accumulation and recharge of water, thereby resulting in the drying up of water sources (Chaudhary *et al.,* 2011). While no count of springs which have disappeared from the different landscape has officially been made, there is sufficient number of evidences of decline in the number of water sources across the various parts of the state of Sikkim. In the past few years the natural springs in the mid-hills of Sikkim are becoming seasonal with reduced discharge. There used to be good number of springs between Rangpo and Gangtok out of which only two - one at Martam and the other at Tadong are still surviving (Poudyal, 2009). But the volume and the intensity of flow has noticeably reduced. Tambe *et al.,* 2012 showed and evidence for declines in spring water availability during the dry season. In the state at many places these sources are drying up (Plate 2). The snapping of the Ratey Chu source water supply pipe which has been regular feature in the past few years has been causing water scarcity problems among the people of Gangtok during the past few years during every monsoon. Plate 4 shows the distribution of drinking water to the residents of Tadong in East Sikkim when Ratey Chu source water supply pipe was snapped by continuous rainfall (Plate 3). Local newspapers and public meeting often echo the problem of water scarcity. Water scarcity was observed during the lean season in one of the suburb of Gangtok i.e. Arithang when only two hours of drinking water per day is received by the residents (Sikkim express, 15th Mar. 2011) which gets further reduced to about 90 minutes per day only.

Plate 2 : Dried spring, Assam lingzey (24.02.2010)

Plate 3: Water supply pipes broken due to heavy rains in Ratey Chu (2nd week of April, 2007) *(Source: C.D. Bhutia)*

Plate 4: Drinking water distributed in suburb of Gangtok, Tadong on 06.06. 2006 *(Source: V. Joshi)*

|  |  |
|---|---|
| Plate 5 : Mohaan – the source of springs or *dharas*, Assam Lingzey, East Sikkim | Plate 6: Devithan or (sacred springs) at Duga, East Sikkim |

The residents of old children park area of Gangtok faced the drinking water shortage for the past two weeks (Sikkim express, 16th May, 2011). Similarly, scarcity of water also has hit agriculture in Pakyong posed a threat to standing seasonal crops and the local farmers a few years back who were anxious about low yield from the standing crops and the consequent fall in their income. Most of the villages in this subdivision were gripped by water scarcity. Since water plays a vital role in the sustenance of this population, a wealth of traditional knowledge exists regarding their conservation and management. Water sources were preserved traditionally preserved as Devithan (considered as sacred and protected) and kept free from biotic interferences (Plate 6). However, the religious approach towards protection of the spring and its catchment is slowly but surely losing its influence and spring sheds which earlier comprised of well-forested catchments are increasingly being reduced to a few trees or a bamboo clump.

South and West districts of the state are comparatively dry areas of the state. Namchi and the entire South district is fast becoming a favourite tourism destination because of Chardham, Samdruptse and Buddha Park putting stress on the civic amenities and we need to address the water problem at Namchi urgently. The monsoon clouds does not precipitates the Rangit valley where lies Namchi, the headquarter town of South district. As a result Namchi receives almost one third of the rainfall received by Gangtok, which receives almost 3250 mm of annual rainfall. The lean period discharge of Bermeli stream for Namchi is gradually reducing (PHED annual report, 2010). The left bank of stream and the adjacent areas forms the recharge zone and rain water harvesting structures like pits, trenches etc need to be created to supplement the natural rain water recharge which will increase the base flow of Bermelli stream specially in the lean season which is winter (Dec to April) which could be tapped and supplied to the Namchi township through the existing water storage and distribution network of the PHE Department (SAPCC, 2012).

The hill side along the teesta valley is teeming with perennial streams that have huge volume of water flowing. Even in winter these streams have copious spring fed water in them. To combat Namchi's water woes, we could consider drilling a 7 km long 2.5 metre diameter tunnels from Ben near Tarku, to a point slightly above Namchi and divert the water from the streams on Teesta valley side of the hill to the Rangit Valley side. This could be done through any one of the many hydroelectric companies drilling tunnels in the state. A schematic diagram alongside shows how this can be done (Fig. 16).

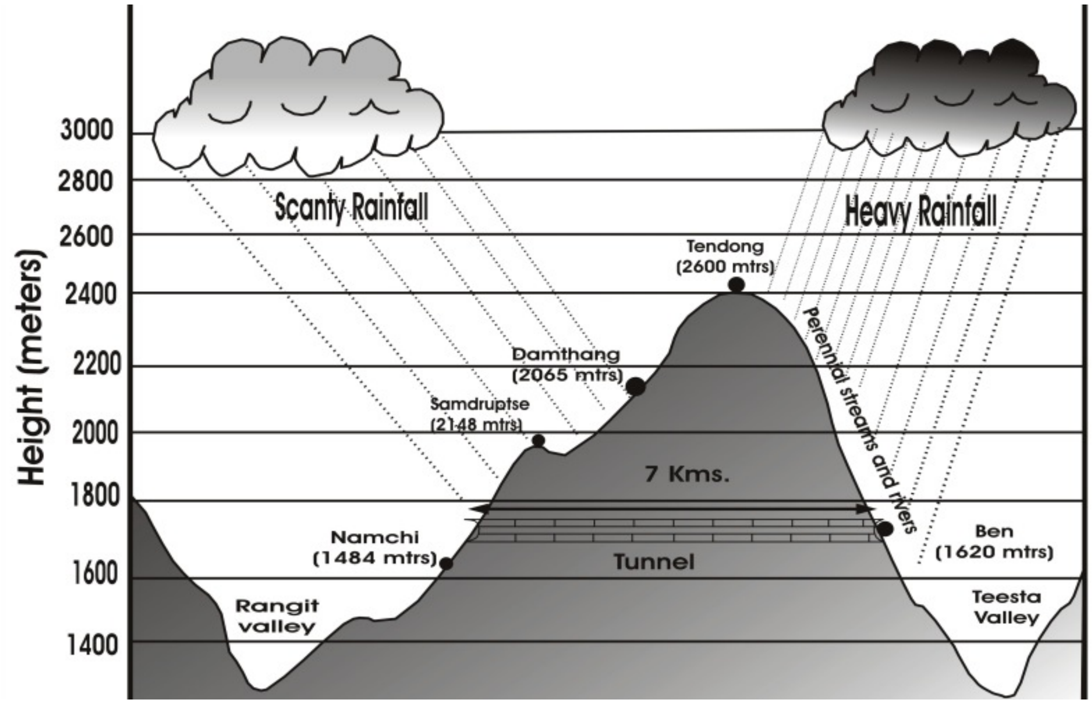


Fig. 16: Schematic diagram showing the way of solving Namchi's water scarcity (Based on the idea of Rajesh Verma and published in Sikkim Express, 26.06.2013)

Hence, Namchi's water scarcity could be solved by either Increasing base flow of Bermelli streams by rain water harvesting or by the drilling a tunnel that connects the rain drenched Teesta valley to parched Namchi.

## C. Dry years and regions vulnerable to water availability

The state of Sikkim unprecedented long spell of dryness during 1986, 1988, 1989, 2006 and 2009. These years state received 13-21% lower rainfall (2458.86-2707.70 mm/year) than the average of 30 years. This deficit rainfall caused adverse effects on the economy of Sikkim, drinking water supply, irrigation to rabi crops, vegetable, orange etc (Rahman *et al.,* 2013). A study carried out by Tambe *et al.,* 2009 for developing strategies for enhancing rural water security, identified 10 of the total 26 Blocks in the state as drought prone areas. These fall fully in rain shadow of Darjeeling Himalayas, located in the gorge of the Teesta and Rangit rivers and having steep and rocky terrain, with little or no forest cover in the upper catchments. These drought prone areas lie in the lower belt of East, South and West District spanning across 10 Blocks of Duga, Rhenock and Khamdong in East, Namthang, Melli, Jorethang, Namchi, in South; Soreng and Kaluk in West; few parts of North district comprising of *Shorea robusta* (Sal) and middle hill forests (Fig. 17). Many of the watersheds especially in the south and west districts have forests along with river valley while the villages are in the upper catchments. Consequently surface runoff is high, ground water recharge is low and there is a need for rainwater harvesting to revive the ground water. But there is a growing perception that the climate change impacts, which manifest in the form of more intense precipitation patterns and longer winter drought, have further reduced the natural groundwater recharge (Tambe *et al.,* 2011).

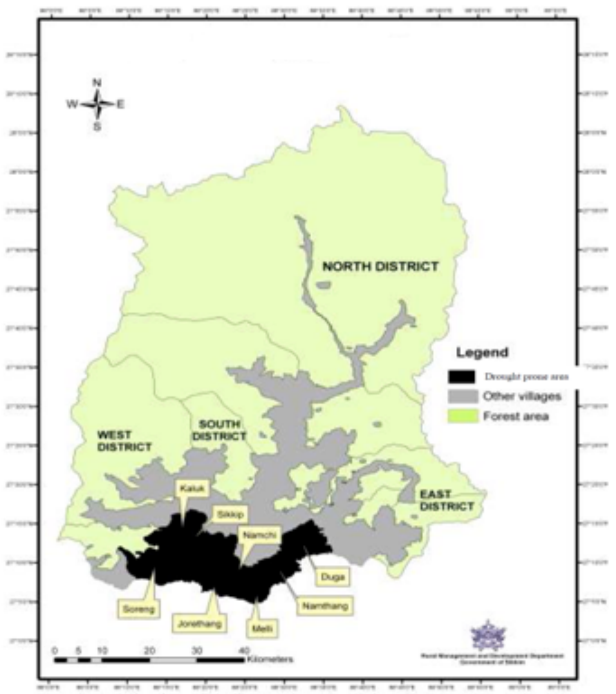


Fig. 17: Drought prone areas of Sikkim
*(Source: RMDD, Govt. of Sikkim)*

## D. Demand and projection of water requirement of various sectors

Almost every human and economic activity needs water as an essential requirement. Both urban and suburban requirements need to be estimated on a regular basis for meeting the water demand of the ever increasing population, especially in the urban areas where the rural population migrates for employment opportunities as is clear from fig. 18 which shows decrease of rural population from 480981 – 455962 during the decade 2001 to 2011. Projections of water requirements by various sectors for the years 2020, 2030, 2040 and 2050, has been made for the state of Sikkim by the irrigation department (Table 2).

Table 2: Projections of water utilisation by various sectors in Sikkim

| **S. no.** | **Sector** | **Year wise tentative projections** | | | | |
|---|---|---|---|---|---|---|
| | | **2010** | **2020** | **2030** | **2040** | **2050** |
| | Irrigation use | | | | | |
| | a. Kharif | 1764.00 | 2058.00 | 2352.00 | 2499.00 | 2646.00 |
| | b. Rabi | 371.00 | 464.28 | 557.05 | 649.89 | 742.74 |
| II. | Urban Suburban Areas (PHED) | 23.70 | 42.51 | 55.27 | 71.86 | 93.41 |
| III | Rural areas (RMDD) | 17.00 | 20.72 | 25.26 | 30.79 | 37.53 |
| IV | Maximum requirement of water for Kharif season (IA+II+III+IV) | 0.42 | 0.53 | 0.66 | 0.83 | 1.03 |
| V | Industries (Department of Commerce and Industries) | **1805.12** | **2121.76** | **2433.19** | **2602.48** | **2777.97** |
| VI | Minimum requirement of water | **412.12** | **528.04** | **638.24** | **753.37** | **874.71** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | during Rabi season (IB+II+III+IV) | | | | | |
| *Source: Irrigation Department, Govt. of Sikkim* | | | | | | |

## E. Changing rainfall pattern: impact on agriculture

An understanding of the spatial and temporal distribution and changing patterns in rainfall is a basic and important requirement for the planning and management of water resources (Jain and Kumar, 2012). The frequent deficits in rainfall and the recurrent droughts in the Northeast Region substantiate the climate change-induced alteration in the rainfall pattern. Particularly noteworthy is the projected decline (approx. 10%) in *rabi* season rainfall and increase (approx. 20%) during the rest of the year in the latter half of this century (Kumar, 2011). Delay in monsoon is yet another dimension of the same problem. Sowing of maize and production of rice seedlings is delayed due to inadequate/delayed rainfall during the pre-monsoon. Delayed transplanting of rice would result in poor grain filling *vis-a-vis* low yields (Avasthe *et al.,* 2013). Community observations on recent climate change impacts indicate that in the subtropical belt (less than 1000 m) there is hardly any rainfall for the six months from October to March resulting in frequent and ascending forest fires, drying of spring water sources and decline in the production of winter crops and vegetables (Tambe *et al.,* 2012). Thirty years of monthly rainfall data from 1981-2010 recorded at Tadong meteorological station located in the mid-hill location (1350 m msl) of Sikkim reveals that the dry spells would occur from November to February. There has been decrease in both number of rainy days and quantity of rainfall during monsoon season as well as in winter (post monsoon) season. However, the rate of decrease during the monsoon season was comparatively higher than during winter season. The number of rainy days has decreased at the rate of 4.50 days/30 years (0.15 day/year) during winter, whereas the decrease was higher during monsoon period i.e. 8.10 days/30 days (0.27 day/year). The average seasonal rainfall has decreased at the rate of 53.43 mm/30 years (1.78 mm/year) during winter, whereas the decrease was higher during monsoon period i.e. 139.01 mm/30 years (4.63 mm/year) (*Rahman et al., 2012)*. Table 3 shows decade-wise and season-wise changes in rainfall pattern at Tadong (Sikkim). Although the decrease of rainy days and rainfall was much higher during monsoon period than winter. Comparison of long term meteorological data available for Gangtok station (1957 to 2005), with the trend over the last five years (2006-10), shows winters becoming increasingly warmer and drier now, with October to February being the exceptionally dry period. There has been decreasing trend of winter rainfall at the rate of 0.7 mm per 10 year from 1957 to 2005 (Seetharam, 2008). Irrigation facilities must be augmented during this period for raising winter season crops such as mustard, cabbage, cauliflower, radish, wheat etc life saving irrigation should also be augmented for cattle and perennial/plantation crops like citrus and large cardamom.

Table 3: Decade-wise and season-wise changes in rainfall pattern at Tadong (Sikkim)

| Season/Rainfall decade | Pre monsoon (May-June) | Monsoon (July-Oct) | Winter (Nov- Feb) |
|---|---|---|---|
| **Rainy days** | | | |
| Mean 1981-1990 | 64.60 | 77.30 | 11.60 |
| Mean 1991-2000 | 66.50 | 83.50 | 12.20 |
| Mean 2001-2010 | 71.90 | 75.40 | 7.70 |
| **Decade-wise increase /decrease in rainy days** | | | |
| 1981-1990 to 1991-2000 | 1.90 | 6.20 | 0.60 |
| 1991-2000 to 2001-2010 | 7.30 | -1.90 | -3.90 |
| 1981-1990 to 2001-2010 | 5.40 | -8.10 | -4.50 |
| **Rainfall (mm)** | | | |
| Mean 1981-1990 | 1344.93 | 1491.80 | 118.91 |
| Mean 1991-2000 | 1411.97 | 1680.09 | 165.64 |
| Mean 2001-2010 | 1426.73 | 1541.07 | 112.21 |
| **Decade – wise increase/decrease in rainfall (mm) days** | | | |
| 1981-1990 to 1991-2000 | 67.04 | 188.29 | 46.73 |
| 1991-2000 to 2001-2010 | 81.81 | 49.27 | -6.70 |
| 1981-1990 to 2001-2010 | 14.76 | -139.01 | -53.43 |
| *(Source: Rahman et al., 2012)* | | | |

## F. Population trends and developmental impacts on springs

Statistics shows that increasing population has resulted in reduction in per capita consumption of water every year in India (Shashikumar, 2005). The population decadal growth rate in IHR is 17.34% (2001-2011) which is higher than the country's average 17.6% (2001-2011). Indian Himalaya registered 24.75% growth during the 1991 to 2001 which was higher than the country's average (21.34%) (Census, 2001; Census, 2011). In case of Sikkim, it has gone up, from 28.47% in the previous decade to 32.98% in the current decade (Pant, 2003). Sikkim registered decadal growth rate of 12.36% (2001-2011) against 33.07% in the previous decade (1991-2001) and with an increase in population density from 76 (2001) to 86 (2011) (Census, 2001; Census, 2011). Population growth, pollution and climate change are likely to combine to produce a drastic decline in the world's water supply in a few decades. Global per capita water availability decreased from 13,000m$^3$ in 1970 to 6,600m$^3$ in 2004. By the year 2025, one-third of the world's population is expected to face severe and chronic water shortages. In India per capita availability of water is likely to go down from 1545 cubic metre/year in 2011 to 1341 cubic metre/year in 2025 (Gupta, 2013). By 2030, India will be extremely close to becoming 'water scarce', a condition that is defined by the World Bank to be when a country's per capita water availability reaches 1000 cubic metres (Raj, 2010). Studies reflecting per capita availability of water has not been conducted in Sikkim in the past and so should be initiated now and projected till the year 2050 based on the projected population database and the water availability from different sources taking into account the changed climate change scenario. Reviewing population information in conjunction with land use change and other indicators can explain changing demand for natural resources such as water, land, forest etc. It also presents insights on the future patterns of resource use and related pressures on ecosystems. Approximately 7.6–10.4 lakhs tourists would visit Sikkim during the year 2017, which would also have implications on the infrastructure, environment, natural resources, culture and eco-tourism of the state (Joshi and Dhyani, 2009). Urban centres like Gangtok, the capital of Sikkim, which is visited by 90% of the tourists coming to Sikkim and acts as a base point for visits to eco-tourism sites/destinations, would experience shortage of drinking water (Joshi and Dhyani, 2009). In this regard, the Govt. of Sikkim is very foresight in taking appropriate initiative in the direction of enhancing water works at Selep from 13.5 MLD to 25 MLD with state-of-the art treatment for solving the drinking water problem of Gangtok and adjoining areas. It would solve the perennial water scarcity of Gangtok and adjoining areas to a significant extent.

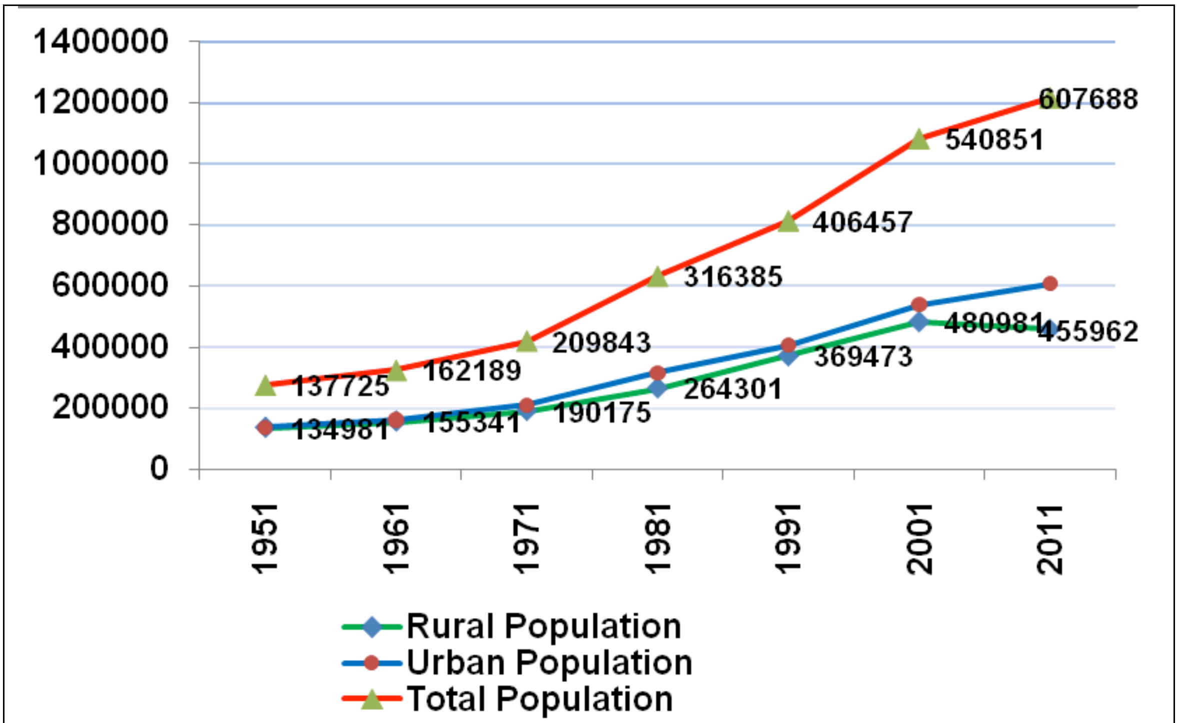


Fig. 18 : Population increase of Sikkim from 1951 to 2011

If we take only the road construction as an indicator of development in Sikkim the total length of increase have increased from 1889.0 km to 3672.32 km then in a span of not even two decade (Fig. 19). While catchment degradation was identified as the main cause for the drying up of the springs in the last century, climate change is now emerging as the new threat in the 21st century (Tambe *et al.,* 2012). Water is a resource which can neither be produced nor added as and when required by any economical technological means. Water cannot be treated as a free commodity and availability of it as a free resource is no longer assured. Many of our springs have dried up because of various developmental activities (road cutting, building construction) taking place at a hectic pace across different districts of Sikkim which has resulted in destroying of aquifer and have been reducing the **"sponge action"** the land. Besides this shift in monsoon, landslides, increasing pressure on land have also been responsible for disappearance of our traditional source of water i.e. springs.

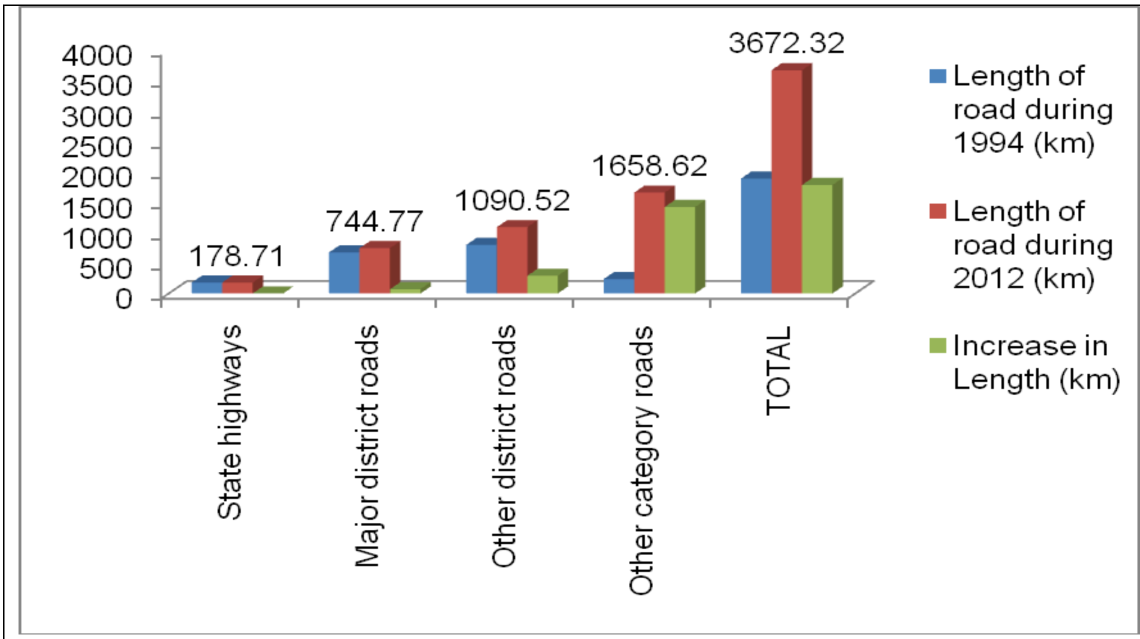


Fig. 19: Increase in road network in Sikkim from 1994 to 2012
*(Source : The Sikkim Reporter, 27th July, 2013)*

## 4. CONCLUSIONS

The aim of water security is to attain improvements in food security, health, human productivity and poverty alleviation alongside environmental sustainability. The special emphasis in water security is to extend services to unserved population, and find the right balance between meeting social needs of water and using water for economic development. The problem arising out of changing hydrological cycle and increasing and competing demands for water are becoming more acute in terms of availability and quality (Singh, 1999). Social conflicts on issues relating to access to water for drinking and other uses have increased (Prasad and Prasad, 2009). According to experts, most of the social conflicts in the future are going to be water-based and pure water will be a heavily priced commodity. Water tax, rationing of piped water, water laws and water politics are going to be a norm rather than an exception (Jai Kiran, 2000). The Gandhian quote ***'There is enough on the earth for everyone's need, not for everyone's greed'*** is true about our water resources too. The burgeoning population and its consequent impact is exhausting the available freshwater resources leading towards a water crisis. Realising this, the Government of India has declared the year 2013 as ***"Water Conservation Year-2013".*** Given the acute shortage of water that many are likely to face in the near future, the direct exploitation of the natural, simple and most fundamental source of renewable fresh water rain should not be ignored (Postel, 1992). Water conservation entails diverse issues, and therefore calls for multi-pronged strategies tuned in consonance with regional practices. It encompasses the policies, strategies and activities. Although the state is endowed with several ice melt water fed rivers and streams, still because of their flow along very deep gorge like channels, it is very difficult to lift water in hills where habitations (both in rural and urban) exist. It is also one of the reasons of prime dependency of the entire state on spring water (Kar, 2011). Water management is a local issue (on the scale of a state or a few neighbouring states, sometimes on the scale of a few Districts). It is necessary for each state to examine how to conserve its water resources and think of local solutions (Sreenivasan, 2007). The annual replenishable groundwater water resource of the state of Sikkim is 0.08 BCM. This is also the net annual ground water availability of the state, while the state of ground water development is 16% (CGWB, 2012). There is also need to generate and/or analyse extensive scientific data on hydrogeological/ geophysical/Hydrochemical/ Ground water exploration in the state. The facilities for artificial recharge to ground water established in Sikkim is about 2,100 spring development, 2,5 cement plugs/nala bunds, 5,300 gabion structures, 69,596 roof water harvesting and in all, the quantity of surface water to be recharged is around 44 MCM. The receding glaciers will hamper recharging in the future (Avasthe *et al.,* 2013).

Watersheds, needs to continue to become units of management, founded on rational concepts of water budgeting and adaptive strategies, geared to early detection of unexpected impacts in the state of Sikkim. The geographical area of the state of Sikkim is delineated into 607 micro-watersheds on the basis of GIS technology (WMS, 2013). A micro-watershed is the basic unit of development, whose average area is around 500 ha (Naik, 2010). In all these watersheds studies similar to the one attempted in the Taktsom Chu watershed in the present study should be attempted with focus on population projection, water availability and water demand for various sectors with water allocation strategies and decision support systems devised for better resolving the water scarcity issues for achieving the goal of water security.

Integrated monitoring of water and ecosystems must become an intrinsic and permanent part of water management. The success of such water management will depend on an active, water-literate public (Narasimhan, 2005). Water resources are inextricably linked with climate, and therefore the prospect of global climate change has serious implications for water resources and regional development (Prasad and Prasad, 2009). Acquiring quantified knowledge about the spatial and temporal distribution of the different components of the local, regional hydrological knowledge is vital to plan and develop water resources of the state of Sikkim. Stream gauging stations, which keep records of water flow in streams for many years, are one of the most important tools we have for understanding water resources. The network of Automatic Weather Station (AWS) should be increased for scientific understanding of the various meteorological and hydrological parameters in the state. Stream gauge records are used to estimate water availability for drinking and for irrigation and many other types of information. There are 11 gauge and discharge observation sites being maintained by the Central Water Commission over the river Teesta up to Tarkhola, a village between Melli and Rangpo. But the stream/ river flows/runoff/discharge data are not at all analysed on a consistent basis with respect to the implications of Climate Change (Sharma, 2013). The permanent rainfall and runoff monitoring stations should be increased with watershed as a unit in Sikkim in other rivers/streams of the state in order to have a better understanding of their relationships and the impact of climate change on hydrology. There is a need for study regarding the impact of climate change on discharge rates of streams and rivers in the state. It should be given top priority in the state (Bawa and Ingty, 2012). There is need to validate if the hydrologic response at watershed scales is changing due to climate change in Sikkim or not. Rainfall runoff relationships for annual, pre monsoon, monsoon and post monsoon periods for the different watersheds needs to be developed and are scientifically adopted for estimating the water yield of watersheds for developing appropriate agricultural water management strategies. Moreover, availability of water in the context of climate change may be highly variable seasonally, with water in monsoon season and no water in the ever drying winter months, and water available through extreme precipitation. Hydrological studies are required to be taken up for assessment of water resources under changing climatic scenarios (Kumar *et al.,* 2005).

The Integrated Watershed Development Programme (IWDP) is an important step in harvesting rainwater in rural India. It promotes groundwater recharge, checks soil erosion, improves soil texture and quality, vegetation, etc. (Naik, 2008). IWDP was launched during 2009-2010 by the Department of Land Resources, Ministry of Rural Development in Sikkim and since then 11 watershed management projects are being implemented by Forests, Environment & Wildlife Management Department, Govt. of Sikkim (WMS, 2013). The targeted areas have immensely benefited from the positive impacts of such projects in terms of various types of trainings and developmental (construction) aspects. The research components needs to be integrated in all such projects with emphasis on hydrology and a team comprising of experts from interdisciplinary fields while implementing such projects in the future for research outcomes which would add to the knowledge of understanding the hydrogeological aspects. Emphasis should be on types of spring, spring discharge in relation to rainfall, geology and geomorphology, land use, vegetation, anthropogenic interference etc. The impact of soil and water conservation measures on watershed basis has not been evaluated on flow regimes at the micro and macro-scales in a systematic manner. Therefore, upstream-downstream linkages in conservation and management of rainwater and groundwater recharge needs to be critically analysed. Also the impact of land use changes on the availability of water resources and perenniality of streams needs to be quantified, in view of the rapid growth in urbanization and industrialization. IWDP should form the cornerstone of water governance in Sikkim. Bhattacharya *et al.,* (2012) outlined the different strategies for ensuring water security in the state of Sikkim. All such strategies needs to be implemented in the state in general and the water scare/drought prone lower belt areas of the state in particular where the potential of perennial streams like Khani, Seti, Rolu, Manpur, Reshi, Rohtak etc could be utilized for meeting the irrigation needs of the adjoining rural areas.

In Europe all water remains in public domain, with limited provisions for private ownership. Regardless of ownership, all users must obtain permits for specific water use. Ownership of land does not entitle a landowner to the use of surface water or groundwater. Except for small quantities of water, all users are required to obtain permits issued within the framework of scientific water management (Narasimhan, 2007). In the state of Sikkim water from most of the springs is used by private parties for drinking purposes. Most of these private parties are big landlords and/or hoteliers who can afford the cost of pipelines connecting the spring sources of the Government and the private supply locations. Because there is no law that deprives people from using any spring they like to once these springs occur in the forestland, there is no control on the ownership of springs. It is thus recommended that parties that use/tap a spring in Government's land must seek permission from the Government for the same and/or sign a bond with the local Government or public authority that whenever there is a requirement to tap these springs for public use, they may not resist it and give way to its authorized tapping. Emphasizing only on local human needs may lead to severe intercommunity conflict and negative environmental consequences (Naik and Prakash, 2006). There have also been attempts to use optimization in water resource management under different conditions and develop decision support systems (Green and Hamilton, 2000; Babel *et al.*, 2005). An effort in this direction will also be needed for

Sikkim in the near future for the optimization of water allocation policy considering seasonality of water source, inaccessibility of perennial water resources with population growth and urbanization.

In the draft copy of the Sikkim Action Plan on Climate Change (2012-2030) (SAPCC, 2012) various strategies to address Climate Change concerns to ensure water security in Sikkim that can be implemented in phases through the next 20 years are detailed, viz Artificial recharge to revive springs by harvesting rainwater, reviving dried up hill top lakes, increasing base flow of critical streams by rain water harvesting and exploring possibility of harnessing stream water for meeting household and irrigation needs etc. However, all such strategies have to be examined based on the techno-economic feasibility, i.e. by integrating technical possibility with economic viability as also the environmental compatibility in the context of Sikkim.

The National water policy (2012) adopted last year has certain key features (i) Rapid growth in demand due to population growth. The over strained condition should be eased by all possible steps (ii) Optimized uses of water in agriculture, navigation, domestic purposes etc. (iii) Adaptation to climate change: better demand management, increasing water storage (iv) Enhancing water available for use: to map the aquifers, to recharge them by natural ways (v) Demand management and efficiency in water use (vi) Water pricing: Establishing water regulatory authority in states. (vii) Conservation of river corridors, water bodies through scientific planning, community participation. All these features needs to be critically examined and necessary strategies and mechanism needs to be devised for dealing with the water scarcity and security issue of the state of Sikkim.

Sustainable mountain development in Indian Himalayan Region (IHR) is under the shadow of regional instability (Kuniyal, 2013). Water scarcity may become a security threat in the future (Agoramoorthy, 2007). Water is no longer only a resource, but also a topic of conflict. It is limited and cannot be expanded; so the only option is its efficient management (Malhotra, 2010). In order to minimize the negative impacts of population growth and development in the coming decades we need to treat water as an endangered resource and policies should be formulated to save and conserve it. Capacity building is also needed for the water resources managers and developers for updating the knowledge and technology in the area of water resources management (Kumar *et al.,* 2005). Apart from the engineering interventions change in behavioural practices could also play a major role in water resources management. Water conservation and management should become part of our culture rather than a technique (Jai Kiran, 2000). It is not a job that is limited to a particular group like technician, soil scientist, hydrologist, etc. It is a job for the everyday person who just likes to have access to the life sustaining resource of water.

Water will continue to be a scarce resource in the future as long as steps leading to the retention of rainwater and groundwater recharge do not find a place in the drinking water schemes. In conclusion, Sikkim needs to shift its focus from 'water resources development' to **'water resources management'** by restructuring and strengthening existing institutions for better service delivery and resource sustainability.

## 5. ACKNOWLEDGEMENTS

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