Rural Water Security in the Sikkim Himalaya: Status, Initiatives and Future Strategy

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Abstract
Accelerated change in landuse, climate and demography is directly impacting water security in the Himalayas. We conducted a field survey to assess the status of 151 water sources in 84 villages during the lean season in the drought prone zone of the Sikkim Himalaya. We found that an extensive network of rain-fed, micro springs and streams, located largely in farmer's fields, were the only source of water for the rural mountain communities. The lean period discharge of 42% of the water sources has declined by more than 50% over the last decade. While, the chemical quality of water was found to be within prescribed limits, the problem lies in its availability and access during the lean season. Villages located near the crest line where found to be the most vulnerable; as they had fewer water sources with lesser discharge. The future strategy to enhance lean season, rural water security will lie in enhancing the storage of rain water either underground in natural aquifers or above ground in lakes and storage tanks. Learnings from experiments in implementing this strategy are also discussed. As the water sources on the crest are drying up faster, lift water supply schemes from the sources located below the villages will need to be piloted to pump water from downstream water sources to the villages above. Mainstreaming and upscaling this strategy with funding support from ongoing national programmes, building local capacity and bridging the knowledge gap is the way forward.

Keywords: *climate change; ground water; rainwater harvesting; spring; stream*

1 Introduction

Sikkim (27^0 05' to 28^0 07' N latitudes and 87^0 59' to 88^0 56'E longitudes) lies between Nepal and Bhutan and is a small and beautiful state of India renowned for its natural beauty, rich biological diversity manifested by diverse eco-climatic conditions and wide altitudinal variation from 300 m to 8,598 m (Fig 1). Mount Khangchendzonga (8,598m), the third highest peak in the world, strongly governs the relief features of the state which has a total geographical area of 7,096 km^2. It is not only the highest but also the steepest landscape in the country, as the width of the Himalaya across its entire length is narrowest here[1]. The annual mean rainfall and elevation show high variation over short physical distances as shown in Figure 2. It is a part of the Eastern Himalaya global biodiversity hotspot with 47% forest cover inspite of having vast stretches in the alpine zone above the tree line[2,3].

2 Climate Change in the Himalaya

The Himalayas, like many places on earth are experiencing rapid climate change that is likely to significantly impact local ecosystems, biodiversity, agriculture and human well-being[4]. The IPCC report predicts large scale changes in temperature and precipitation over the Asian land mass[5]. Limited studies on temperature and precipitation for a few localized places show that warming in the Himalayas is three times greater than the global average[6]. Long term, reliable data in the Sikkim Himalaya is available only for one station - Gangtok. Climate change related studies, based on the analysis of the data for this station from 1957 to 2005 indicate a trend towards warmer nights and cooler days, with increased rainfall except in winter[7,8,9]. Perception of the local community captured in the recent climate-change studies in Sikkim show that there is a reduction in the temporal spread of rainfall, an increase in intensity, with a marked decline in winter rain[10]. Also, recent studies in the adjacent Darjeeling hills indicate the perceived impact of climate change as - less snow in the mountains, intense but short episodes of rainfall with increasing run-off and insufficient ground water recharge, thereby resulting in the drying up of water sources[11]. There is a growing perception that the climate change impacts, have further reduced the natural groundwater recharge. This pattern of shrinking of the monsoon season and the resultant declining discharge of natural springs and streams has been recently documented in the western Himalayas as well[12].

3 Present state of knowledge

It was found that while there are a number of studies covering the Himalayan rivers and glaciers[13-24], the springs and streams are relatively under-studied. Also, while a few studies covering the states of Uttarakhand and Sikkim have highlighted the declining discharges of Himalayan springs[25-35], the springs in North West Himalayas (states of Jammu and Kashmir, Himachal Pradesh and Arunachal Pradesh), Central Himalayas (Nepal) and in Eastern Himalayas (Bhutan and Arunachal Pradesh) are yet to be adequately studied. Also, few studies are available on the rain and snow fed streams in the Himalaya[36-38].

While reviewing the studies on Himalayan water resources, we found that the focus has been on the climate change impacts like receding glaciers and declining flow of rivers which primarily affect lowland communities. The hydrological significance of the mountains has been largely assessed from the lowland perspective. Consequently, glaciers and rivers have received more attention while springs and streams are still largely unstudied. This may be due to their micro-nature, limited human dependency, insufficient data and greater effort needed to understand this scattered resource. All major Himalayan rivers have been instrumented and their discharge monitored for several decades. However historical discharge data of springs and streams is largely unrecorded and unavailable. There is an urgent need to bridge this gap, especially for those streams which are tapped for drinking purposes. The demand side assessment of water availability status and the water supply systems are also largely unstudied. Also, more extensive ground based meteorology data is needed to calibrate satellite data to a finer scale[39,40,6].

The objectives of this paper are four-fold, firstly, we assess the type and status of the important drinking water sources in the drought prone zone (500-2500 m) of the Sikkim Himalaya. Secondly, through focus group discussions with the water users we ascertain the adequacy and trend in water availability and how the local community is coping with it. Thirdly, we share the learnings of some of the experiments underway relating to spring-shed development, enhancing groundwater recharge contribution of hill-top forests, reviving natural lakes and creating water storage tanks. Finally, based on this field study and learnings from experiments, we propose the future strategy to enhance rural water security in the Sikkim Himalaya.

4 Methodology

4.1 Field survey

During the lean season of 2012, in the months of February and March an extensive field survey was carried out to monitor the important springs and streams in the drought prone region of Sikkim. The study covered the south-central part of the state, spanning across the mid hills (500 – 2500 m) of the East, South and West districts (Fig 2). This zone suffers from the following multiple vulnerabilities, all of which adversely impact the groundwater recharge:

- It is located in the rain shadow of the Darjeeling Himalaya and receives about 150 cm of annual rainfall, which is much less than the 250 cm received in other parts of the state.
- The annual rainfall is received in a concentrated spell of 4–5 months (June–September), with drought like conditions for 3–4 months (January–April).
- The steep physical terrain of the Rangit and Teesta river gorges results in high surface runoff and limited natural infiltration.
- Most of the villages are situated in the upper catchments, while the reserve forests are situated in the valley along the river bank, thereby reducing their natural recharge potential.

During the field survey, 126 springs and 25 streams were studied in 84 villages. These villages were selected as those lying in the most vulnerable zone as per the climate change related vulnerability assessment study of Tambe et al (2011) (Fig 2). Important springs and streams were categorized as those having a dependency of more than 20 households and were identified based on interviews with the local water users. For these important springs and streams the parameters like location (village, lat, long, elevation), name, land tenure, geo-hydrology, dependency, lean period discharge and water quality were collected. Also focus group discussions were held to assess the perception of the water users on the decadal trend of lean period discharge of springs and streams and their coping mechanism.

Garmin eTrex GPS was used in the field to collect the GPS location of the springs and streams. Geo-hydrological information like type of springs, rock type and dip direction was collected after surveying the spring shed area. Water quality parameters like pH, Total dissolved solids (TDS), salinity, electrical conductivity (EC) and temperature was measured using LaMotte TRACER PockeTester and the discharge measured using a stopwatch.

4.2 Limitations

The study focuses on the lean period discharge of important water sources in the drought prone zone of Sikkim when there is maximum water scarcity. Also, in terms of water quality, only the chemical characteristics were tested, while the physical and biological parameters also need to be studied in future.

5. Findings

5.1 Local Geohydrological setting and land tenure

Most of the villages are situated on the flank and crest line which forms the escarpment slope with unfavourable dip resulting in reduced ground water flows. They study area comprises of the Daling and Gondwana group of rocks which together constitute the Lesser Himalayan Domain. The Gondwana group of rocks is represented by a basal pebble slate (Ranjit Pebble Bed), followed by coal-bearing sandstone–shale horizons. The Daling group of rocks comprises quartz–chlorite–sericite phyllite, muscovite–biotite phyllite, slates, quartzose phyllite, and quartzites of the Gorubathan formation, and dolomite, limestone and variegated phyllite of the Buxa formation[41-43]. The sedimentary rocks at the lower elevation are overlaid by low grade metamorphic phyllite and quartzite bands which are highly fractured and fragmented. There are no large underground aquifers, and groundwater occurs in smaller, disconnected zones. This groundwater emanates from these unconfined aquifers as springs which are mostly fracture and depression in nature.

The villages in the drought prone region of Sikkim vary in elevation from 500 to 2000 m with the ridge line at 2000-2500 m. We found the mountain landscape dotted with an extensive network of rain-fed, micro springs and few streams which were the only source of water in these villages. A large number (68%) of these water sources were found to be located in private lands in farmer's fields (Table 1). The spring water is however still considered as a public resource and shared freely downstream.

5.2 Location and dependency on water sources

The average lean period discharge of the water sources was 29 lpm and catered to 35 households (Table 2). Nearly two out of five springs had a discharge less than 10lpm which is a worrying sign for the future. Though the average water availability at the source was 119 liters per capita per day (assuming 12 hours of daily water use), the water accessible to the household was a fraction of this, since often it had to be carried manually to the house. The lean period discharge declined by more than half (from 40 to 18 lpm) from the villages located in the valley to the crest, while the household dependency increased from 31 to 42. This was due to fewer sources with lesser discharge in the villages near the crest, due to which the per capita water availability (at the water source) declined by one third (from 186 to 62) and resulted in an acute water scarcity during the lean season.

5.3 Sustainability of the water sources

During the lean season, it is natural for the local water sources to start drying up since they follow an annual cycle and mirror the rainfall patterns[34]. However, as per the perception of the local water users, over the last decade the lean period discharge of the water sources is declining at an alarming rate. The lean period discharge of 42% of the water sources has declined by more than 50% over the last decade (Table 3). Also, the water sources near the ridge line are showing a faster rate of decline.

5.4 Coping mechanism of water users during the lean season

During the lean season most of the villagers residing the drought prone zone do not have access to piped drinking water. They have to rely on fetching water manually from local sources mostly located downhill. In some of these sources, the discharge is so low, that they have to queue up to fill the vessels. This drudgery of fetching water mostly by women and children compromises their ability to participate in livelihood activities and also in education. Since water becomes a precious commodity during this time, it is used sparingly for drinking and cooking purposes only. Personal hygiene and sanitation are thereby adversely affected.

5.5 Chemical properties of water

The chemical properties of water namely pH, salinity, total dissolved solids and electrical conductivity were found to be within acceptable limits (Table 4).

6. Initiatives to strengthen rural water security

An integrated, landscape level approach was adopted by taking up mapping of these water resources and revival of dried hill-top lakes, critical streams and springs. Some of the experiments taken up over the last few years involve augmenting the infiltration of rainwater in the recharge area of the springs and streams (watershed and springshed), strengthening the water storage infrastructure and undertaking action research.

6.1 Understanding springs and preparation of Village Spring Atlas

Resource mapping of the springs on a GIS platform – “Village Spring Atlas” has been done to better understand this valuable resource. The data has been made accessible online in the webportal - www.sikkimsprings.org. This online database provides information on the location, GPS coordinates, land tenure, catchment status, dependency, discharge (supply / demand) of nearly 700 springs of Sikkim and is also linked to the google earth platform. Analysis of this data by Tambe et al (2012) indicates that the rural landscape is dotted by a network of micro-springs occurring largely in farmer’s fields, with an average dependency of 27 households per spring. The spring discharge generally showed an annual periodic rhythm suggesting a strong response to rainfall. The mean discharge of the springs was found to peak at 51 L/min during the post-monsoon months (September–November) and then diminish to 8 L/min during spring (March–May). The lean period (March–May) discharge is perceived to have declined by nearly 50% in drought-prone areas and by 35% in other areas over the last decade.

6.2 Conceptualizing spring-shed development programme to revive dying springs

The springshed development (*dhara vikas*) approach further refines the spring sanctuary approach in using geohydrology to identify the recharge area. An incentive mechanism is provided to the farmers thereby facilitating the use of private lands and their conservation.

The results of this programme to revive the lean period discharge of springs have been quite encouraging[34]. This approach also differs significantly from watershed development (which adopts the catchment approach) in terms of scale, costs, duration, treatment methods as well as success indicators. Based on these successful pilots, springs-shed development was added in the list of permissible works of the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) national flagship programme in 2012.

6.3 Enhancing the hydrological contribution of hill top forests

The natural ground water recharge in mountain areas is limited and inspite of adequate rainfall, most of it flows away as surface runoff causing soil erosion, landslides and floods. Reviving the dry season discharge of streams by taking up artificial recharge works in their upper catchments to increase their base-flow during the dry season has been initiated. Sloping forest lands above villages are ideal locations to take up ground water recharge structures like staggered contour trenches, ponds and check dams in appropriate locations. Location of these trenches and ponds is vital to ensure that each of them has a micro catchment and captures sufficient surface flow. A new strategy of creating artificial ponds at depressions and trenches along the trekking trails to tap the surface runoff during the monsoons was also experimented (Fig 3). This climate change adaptation initiative also helped in disaster risk reduction by reducing landslides and damage to private lands downstream. Pilot projects to annually recharge 500 million litres of groundwater, covering 300 ha in nine hill top forests located above drought prone villages have been taken up. The unit cost comes to USD 481 per ha (1 USD = 54 INR) and funding support was leveraged from the MGNREGA national programme.

6.4 Strengthening water storage infrastructure

With increasing water scarcity during the winter months of Feb-April, the water storage infrastructure at household, community and village level needs to be augmented. The farmers innovatively utilize these storage tanks by harnessing the flow of springs during night time (which was earlier going waste) to fill up these tanks, which is used during day time for domestic use as well as minor irrigation of kitchen garden, green house crops etc. These water storage tanks with facility of roof-water harvesting as well have helped in transforming many villages with acute drinking water security. Hundreds of such water storage tanks of 10,000 to 40,000 litre capacity have been constructed with funds leveraged from three national programs namely MGNREGA, National Rural Drinking Water Programme (NRDWP) and Rashtriya Krishi Vikas Yojana (RKVY) (Fig 4).

6.5. Reviving dried up lakes by harvesting runoff from spring water sources

Reviving dried up lakes by developing their catchment, de-silting to enhance their water holding capacity and piping water from water sources has been initiated. Healthy lakes translate to adequate ground water recharge, which in turn supplements the dry-period discharge (base-flow) of springs and streams located downstream. There are quite a few natural, dried up lakes strategically located above drought prone villages. These lakes were revived by piping runoff from water sources and functioned as recharge structures (Fig 5).

6.6 Developing a cadre of inhouse trained para hydrogeologists

Existing inhouse staff at Block level was trained in hydrogeology, springshed development and watershed management with the help of agencies such as WWF-India, People's Science Institute, Dehradun, Advanced Centre for Water Resources Development and Management (ACWADAM), Pune and CHIRAG, Nainital. Implementing field pilots to revive springs, streams and lakes helped them to gain experience which is slated for upscaling now.

7. Future strategy

7.1 Bridging the knowledge gap

The sustainability of these springs and streams is vital to ensure water security of the mountain communities, especially in the face of environmental change precipitated by a changing climate that brings with it longer winter droughts, intensive precipitation patterns; developmental interventions like road networks and changes in the catchment's landuse and habitat quality. There is a need for more studies on springs and streams, more detailed weather data, demand side assessment of water availability status across spatial and temporal scales and on the water supply and distribution systems.

7.2 Leveraging funding from ongoing national programmes

Ongoing national programmes can be leveraged to upscale these initiatives to enhance rural water security. These programs include Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), National Rural Drinking Water Mission (NRDWP), Integrated Watershed Management Programme (IWMP), Rashtriya Krishi Vikas Yojana (RKVY) etc (Table 5).

7.3 Diversifying from gravity flow to lift water supply schemes

Often the perennial water sources are located downhill of the village, and fetching this water manually is an undesirable drudgery. There is a need to invest in lift water supply schemes to pump water from lower elevations, where it is in abundant, to the densely populated mid hills above.

7.4 Decentralized planning

There is a need to pilot the preparation of Village Water Security Plans (VWSP) that will analyze the type of water sources available, their discharge patterns and location, demand side analysis, design of the water supply systems in a participatory manner and water use efficiency will help to shift from a top down, contractor-driven to a bottom up people-driven approach. This will result in a more sustainable and need based preparation of village water security plans for future and is the way forward.

8 Conclusions

Since rainwater is the only water available for the villages in the mid hills of the Himalayas, and owing to its increasingly uncertain nature, the solutions will lie in storing it either above ground in natural or artificial reservoirs or underground in natural aquifers. Traditionally, afforestation was the main thrust in forests lands, now there is a need to manage mountains also as "water towers" by enhancing their ground water recharge contribution which will help both upstream and downstream communities, by reduced flooding during the monsoons and increased base flow during the lean season. While ongoing national programmes can be leveraged to fund these climate change adaptation initiatives, scientific planning, bottom up approach and building local capacity are the key challenges for the future.

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Tables

Table 1: Land tenure of the water sources in the drought prone zone of Sikkim

Elevation zone	Community land	Forest land	Private land	Total
501-1000 m	14	6	39	**59**
1001-1500 m	14	3	56	**73**
1501-2000 m	2	9	8	**19**
Total	**30**	**18**	**103**	**151**

Table 2: Variation in spring discharge with elevation during the lean season in the drought prone region of Sikkim

Parameter	500-1000 m	1000-1500 m	1500-2000 m	Total
Number of water sources	59	73	19	**151**
Average discharge in lpm	40	24	18	**29**
Household dependency	31	36	42	**35**
Water availability at source in liters per capita per day (lpcd)	186	96	62	**119**

Table 3: Perception of the water users on the percentage decline in the lean season discharge of water sources in the drought prone region of Sikkim over the last decade

Elevation	0-25%	26-50%	51-75%	76-100%	Don't know	Total
501 -1000 m	8	23	15	11	2	**59**
1001-1500 m	2	44	17	6	4	**73**
1501-2000 m	0	7	10	1	1	**19**
Total	**10**	**74**	**42**	**18**	**7**	**151**

Table 4: Chemical analysis of water from the springs

Water quality	Mean	Permissible range
pH	7.27	6.5-8.5
Salinity (S)	55.9	<500
Total Dissolved Solids (TDS)	137.81	0-300
Electrical Conductivity (EC)	171.25	50-500µS/cm
Temperature (^{0}F)	63.42	

Table 5: Mainstreaming climate change adaptation initiatives to enhance rural water security in various ongoing national programs

CCA initiative	Type of activities	Mainstreaming in national programmes
Spring shed development	Participatory planning, trenches, ponds, check dams, terracing of sloping lands etc	MGNREGA, IWMP
Water shed development on hill top forests	Participatory planning, trenches, ponds, check dams etc	MGNREGA, IWMP
Revival of lakes by piping water from perennial water source	Water supply pipeline, drainage structure to connect perennial water source to lake	MGNREGA, IWMP, NRDWP
Water storage tanks	At household, community and village level with water from roof top and also springs during night time	MGNREGA, NRDWP, RKVY
Lift water supply schemes	At village level from downstream water sources	NRDWP

Figures

Figure 1: Inset map of Sikkim showing its location in India and as a part of the eastern Himalayan region

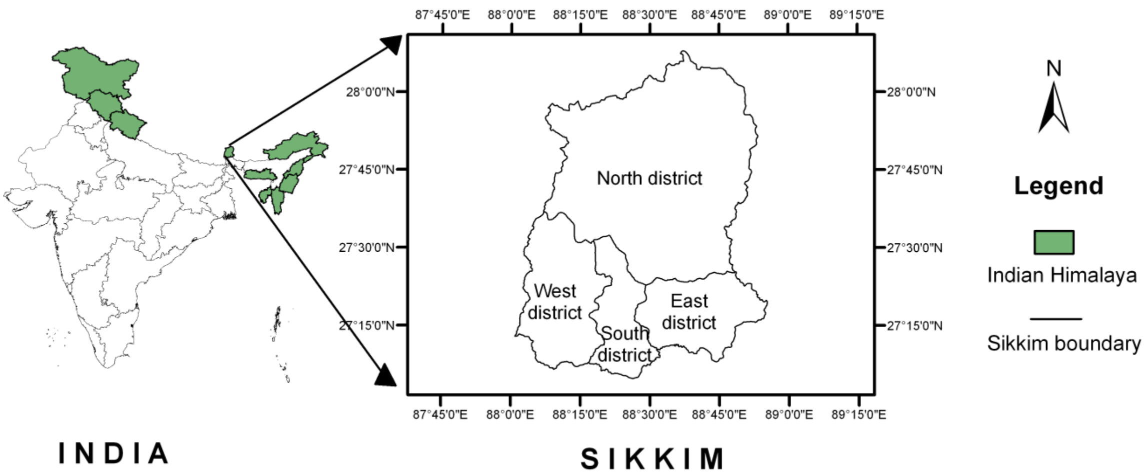


Figure 2: Map showing the spatial variation in mean annual rainfall, elevation, climate change related vulnerability of Sikkim along with location of the springs and streams surveyed

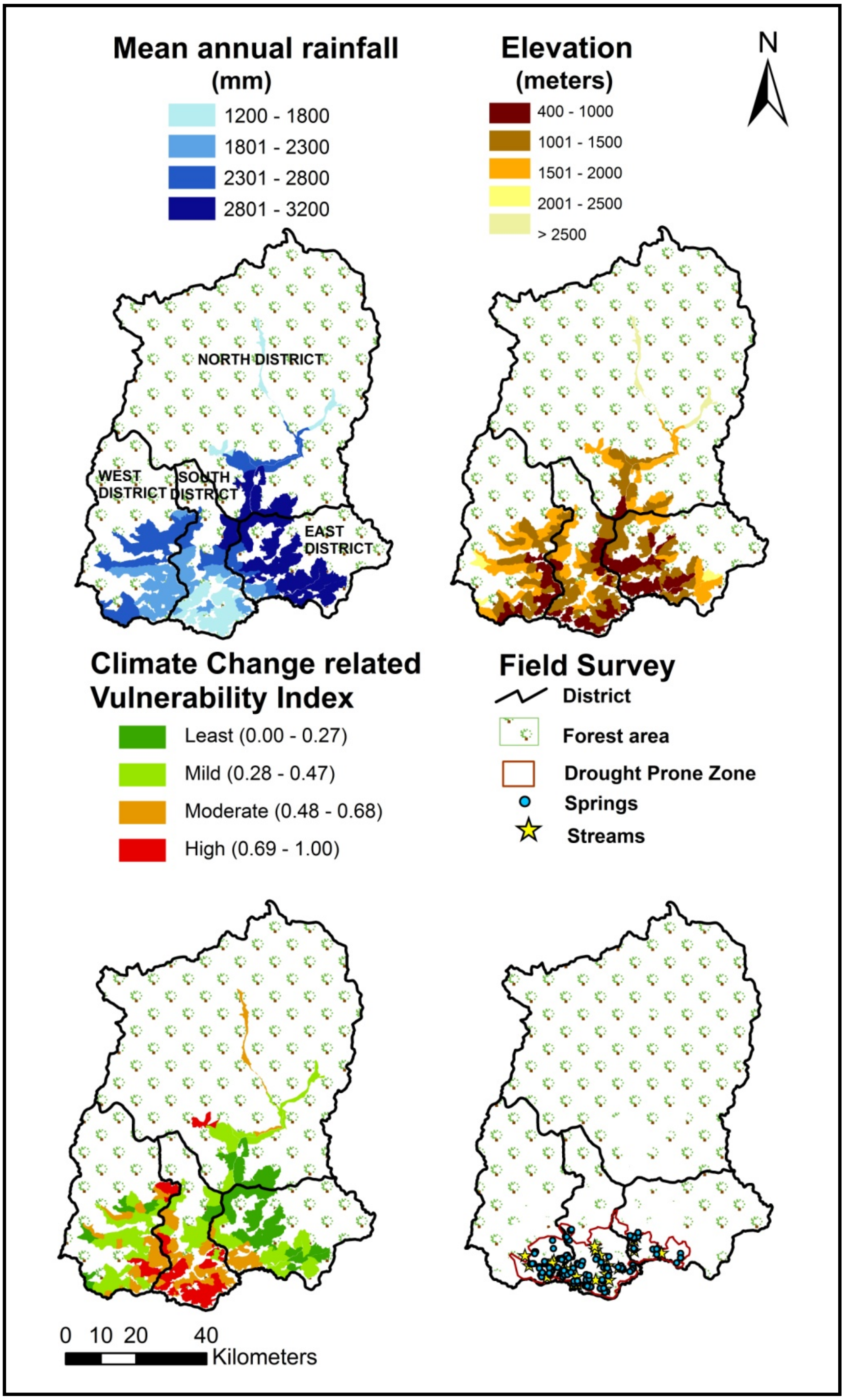
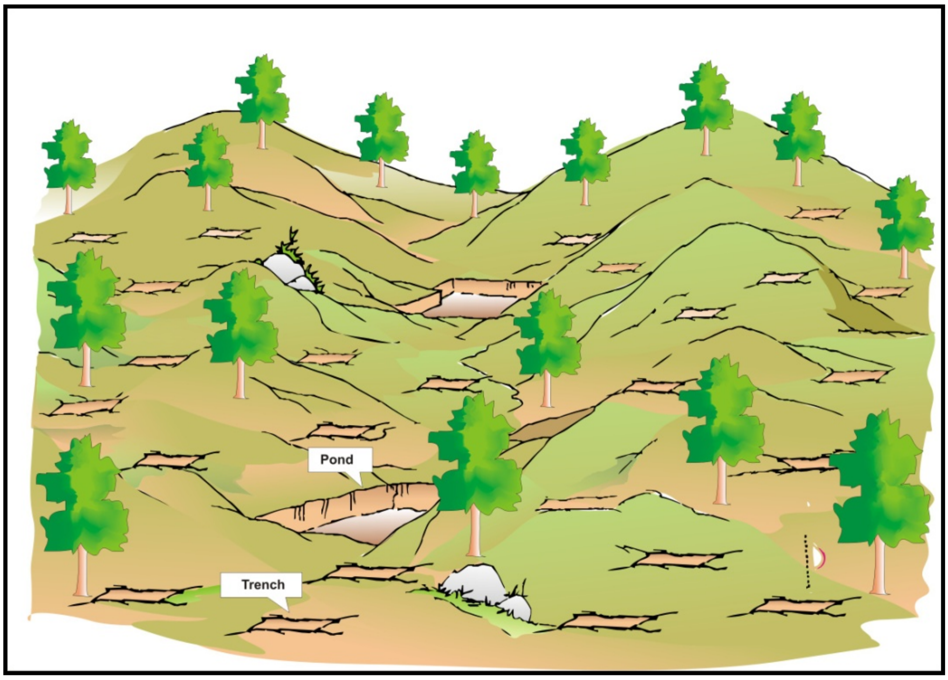


Figure 3: Artificial recharge structures comprising of staggered rows of rectangular staggered contour trenches (2m x 0.8m x 0.6m) on the slopes and rectangular ponds (4m x 4m x 0.6m) in the depressions. Trenches were also made along the trails to tap the surface flow during the monsoons



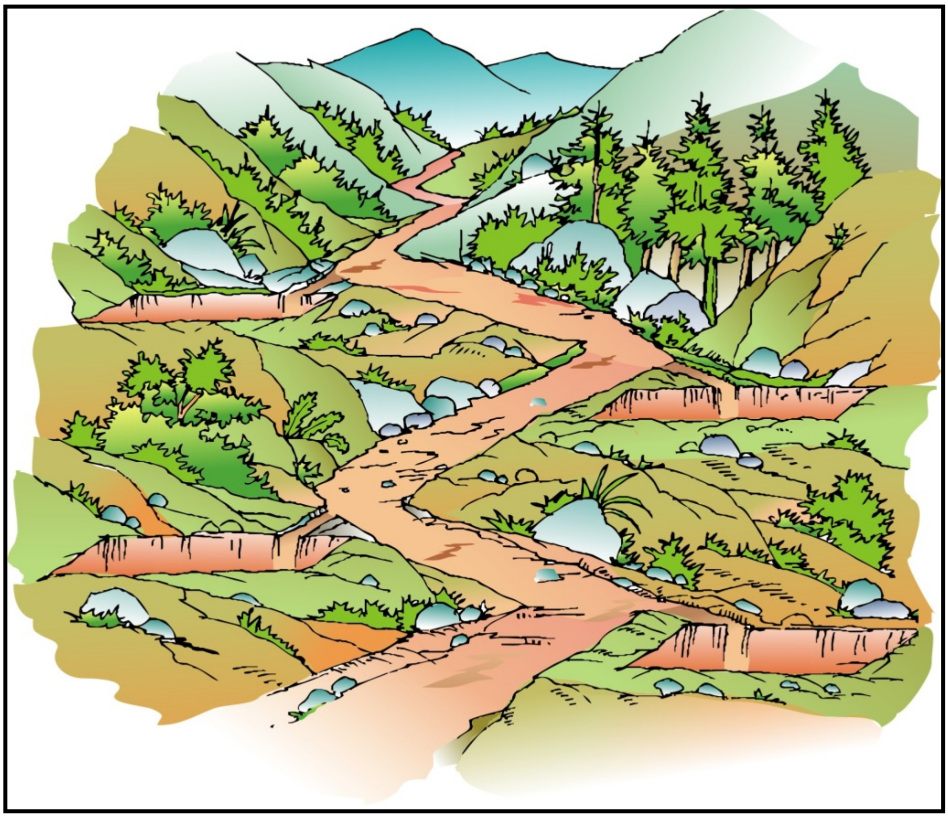


Figure 4: Water storage tanks were used innovatively by the villages by storing the overnight spring discharge (which would otherwise have gone waste) for use during the day for watering the kitchen garden and for domestic purposes.

Figure 5: Reviving dried up hill top lakes by piping surface flow can supplement the ground water recharge for the water sources located downstream