Technical Report

CRYS2017-01MY-Panthi

Rainwater Harvesting for Mitigating Drought in Western Nepal

Project Principal Investigator

Mr. Jeeban Panthi, The Small Earth Nepal (SEN)

The following collaborators worked on this project:

1. **Dr. Yadu N Pokhrel, Michigan State University, USA**
2. **Ms. Fawzia Tarannum, TERI University, India**
3. **Dr. Dhiraj Pradhananga, Tribhuvan University, Nepal and University of Saskatchewan, Canada**

Table of contents

List of figures

List of tables

Project overview

Project duration	:	2 years
Funding awarded	:	US$ 29,850 for 2 years
Key organizations involved	:	Following organizations and persons involved in this project:

S. N	Name of the institution	Country	Persons involved
1.	The Small Earth Nepal	Nepal	1. Jeeban Panthi 2. Piyush Dahal 3. Nammy Hang Kirat 4. Susmina Gajurel 5. Kabi Raj Khatiwada 6. Aashana Shakya
2.	Michigan State University	USA	Dr. Yadu N. Pokhrel
3.	TERI University	India	Ms. Fawzia Tarannu
4.	Tribhuvan University/ University of Saskatchewan	Nepal/ Canada	Dr. Dhiraj Pradhananga

Project summary

This project's goal was to develop a site suitability map for different types of surface rainwater harvesting systems for maximizing groundwater recharge and to develop a communication tool for promoting a roof-top rainwater harvesting system for the Karnali basin (KRB), Nepal. The project provided the techno-commercial information for groundwater recharge and the roof-top rainwater harvesting system to the people in a way they can access, understand and adopt. To prepare a site suitability map for surface rainwater harvesting structures, a variety of data related to runoff estimation such as satellite images for land use classes, digital elevation model (DEM), soil map and precipitation data were collected. A site suitability map for the different rainwater harvesting structures based on the meteorological and geospatial datasets was produced. An android based mobile application was developed to promote household rainwater structures. The application "Aakaashepani" uses technical and commercial information needed for installing household and community-based rainwater harvesting systems. Using this mobile application, people can estimate the optimal size of a rainwater harvesting tank for their houses, schools or community buildings in a few easy steps. The tool presents the results in a comprehensive way so people can use, understand and adopt it easily. The application is downloadable for free from the Google Play store. The research findings from the project were disseminated to the concerned stakeholders from local people in villages to policymakers at the provincial and national levels through a series of workshops and seminars. As a capacity building part of the project, five young researchers were involved from the very beginning of the project and twenty graduate students were trained in groundwater research and management by organizing a short course.

URL and QR for the mobile application:

https://play.google.com/store/apps/details?id=com.rwh.app&hl=en

Keywords: Rainwater harvesting, Drought, Mobile app, Site suitability map, Karnali basin

Project outputs and outcomes

Outputs and outcomes of the project are:

Outputs	Outcomes
1. An android application to help in decision-making for the installation of a rainwater harvesting system in the household and community level.	1. Improved capacity of the individual to estimate an optimal size of a rainwater harvesting tank for their home and community easily with just a few simple steps.
2. Site-specific water requirement for human and livestock use calculated through the household survey	2. Increased scientific knowledge for future researchers on the water requirement in different elevation zones of the basin.
3. Different scientific datasets (Land use, Precipitation, Slope, Drainage network, Soil) were prepared for the Karnali basin, Nepal, and a site suitability map for surface rainwater harvesting structure for the maximization of groundwater recharge was created.	3. Improved capacity of local and province level decision-makers for prioritizing the groundwater recharge sites.
4. Twenty young researchers were trained in hydrogeology	4. Trained researchers are now working in different governmental, non-governmental and academic institutions related to hydrogeology.
5. Sixty-five professionals from governmental, non-governmental and academic institutions were made aware of the sustainable use and management of groundwater resources	5. Improved capacity in informed decision-making processes at the national level.

Key facts/figures

1. One hundred and thirty households in three districts located in three different elevation bands of the Karnali basin were surveyed to identify the water requirement of people and livestock systems.
2. An android based mobile application “Aakaashepani” was developed to assist local people in estimating the optimal size of their rainwater harvesting system.
3. An instructional video on installation and use of the mobile application was produced.
4. An educational brochure was prepared for the mobile application in both Nepali and English languages.
5. Five young researchers were trained on-site suitability mapping for rainwater harvesting systems.
6. Two posters from this project were presented at MtnClimate International Conference in Rocky Mountain, Colorado, USA, 17-21 September 2018
7. A poster was presented in the American Geophysical Union (AGU) Fall Meeting, Washington DC, 10-14 December 2018.
8. A poster was presented at the International Youth Conference on Science, Technology and Innovation (IYCSTI) on 21-23 October 2019 in Kathmandu organized by Nepal Academy of Science and Technology (NAST), Nepal.
9. An invited talk was presented at the AGU Fall Meeting, San Francisco, 9-13 December 2019
10. More than 100 individuals participated in water resource management workshops focusing on groundwater and rainwater harvesting through district, regional, and national level workshops and seminars
11. Twenty young researchers were trained on hydrogeology organizing ‘Graduate Course on Hydrogeology’ from 12 to 16 August 2019.
12. A peer-reviewed article was published in an international journal and one more is currently under review.

Potential for further work

At the current scope, the mobile application (app) is designed to work only for the districts of the Karnali basin in Western Nepal. However, it has a wider potential to be customized to other river basins of Nepal and beyond through simple adjustments. It is recommended to scale up to other countries in the region too, as it has great potential to enhance the adaptive capacity of local people.

The rainwater harvesting suitability map for rainwater harvesting structures has been prepared for the Karnali basin. The method applied for the analysis is highly customizable and can be expanded to the other regions of Hindu Kush Himalaya and beyond. The information is now available at the basin level, but it must be downscaled to the local level using higher resolution geospatial information to have policy relevancy.

Publications

1. Panthi, J., Khatiwada, K.R., Shrestha, M.L., Dahal, P., 2019. Water poverty in the context of climate change: a case study from Karnali river basin in Nepal Himalaya. Int. J. River Basin Manag. 17, 243–250. https://doi.org/10.1080/15715124.2018.15314212019
2. Poster and oral presentations on international forums like AGU 2018, MtnClimate Conference 2018, AGU 2019, International Youth Conference on Science, Technology and Innovation (IYCSTI), Nepal National Water and Weather Weeks, district and province level sharing workshops (Detailed in project dissemination section)

Awards and honors

Project PI Mr. Jeeban Panthi was awarded the Centennial grant by the American Geophysical Union (AGU) to disseminate the findings of this project. He presented the project activities and findings at a special Centennial Session at the AGU Fall Meeting in San Francisco, USA in December 2019.

Pull quote

Ms. Susmina Gajurel, Young Researcher

Through this project, I got an opportunity to travel to the remote districts of Western Nepal for field data collection and result dissemination which I really treasure. Having worked in the project from the very beginning, the grim reality of water-scarce conditions in the Karnali region has been lesson learning for me. I learned about the application of GIS and Remote Sensing techniques in rainwater harvesting to cope with the changing climate. Also, I gained knowledge of using ICT to teach the community people while developing the mobile application "Aakaashepani" to promote rainwater harvesting at household level which I found is an innovative approach to adapt to the changing climate and increasing weather extremes like drought.

Acknowledgments

We would like to extend our sincere gratitude to the Department of Hydrology and Meteorology (DHM), Government of Nepal for providing hydro-climatic data for research and hosting local and regional level workshops. We are thankful to the Nepal Climate Change Support Programme (NCCSP), a project of Government of Nepal implemented by the Ministry of Population and Environment (MoPE), for field coordination during the field assessment. We acknowledge the support of the District Coordination Committee (DCC), Jumla for hosting a district-level sharing workshop and a community campaign. We appreciate the support of the Chandannath Municipality in Jumla in the community campaign of the mobile application. We would like to thank the Nepal National Water and Weather Week (NNWWW-2019) organizing committee for providing a platform to organize a session for the final sharing workshop of the project. More than a hundred people representing policymakers, academia, civil societies participated in the session. We also would like to thank the Kathmandu Valley Water Supply Management Board and Prof. Dr. Thomas Boving from the University of Rhode Island (URI) for their technical support to the hydrogeology training program for young researchers and to organize the groundwater seminar in Kathmandu, Nepal.

We have received valuable feedback and suggestions from many experts since the inception of the project which are duly considered. We are equally thankful to the graduate students and the research assistants (listed in Appendix A) associated with the project.

We are thankful to Hon. Minister Nanda Singh Buda, Ministry of Industry Tourism, Forestry and Environment, Karnali Province for officially launching the mobile application. We are indebted to the continuous support from Dr. Madan Lall Shrestha, Academician at Nepal Academy of Science and Technology (NAST) and Scientific Planning Group member from Nepal of APN for providing feedbacks and active participation in key events of the project.

Asia Pacific Network for Global Change Research (APN) was greatly acknowledged for providing financial support to carry out the project. Also, we are thankful to the AGU Centennial program for providing a grant to disseminate the research findings to the end-user and wider scientific community.

1. Introduction

1.1 Background

The Himalayan region is the “water tower” supplying water to the agrarian communities living downstream (Joshi and Negi, 1996; Mukherji et al., 2015). The Himalayas are in no exception and are often characterized by reduced evaporation, humidity associated with dry soils, temperature increase, and intense but less frequent rainfall, leading to more severe drought conditions (Dai, 2011). Intense rainfalls events are more frequent (Goswami et al., 2006; Kitoh et al., 2013), and monsoon patterns and timing have been changing in recent years (Ramesh and Goswami, 2007) across the Himalayan region. Gautam and Regmi (2013) stated that there has been a notable shift by 10 days delay on the onset and withdraw of summer monsoon in Nepal after 1997.

Natural springs are the main source of water for domestic water supply in the rural communities of hilly areas in the Himalayan region. When these natural springs dry up or decline, the resulting water shortages become a major environmental threat (Merz et al., 2003). In the case of Nepal, about 80% of the hill and mountain people rely on springs as their primary source of water (Tambe et al 2012; Sharma et al 2016). Many researchers (Negi and Joshi 2002, Tambe et al 2012, Agarwal et al 2014, ICIMOD 2015) have reported that over the past decade, there was a significant decline in dry-period spring discharge in different drought-prone areas of the Himalaya, causing serious water shortages during the dry period. This water scarcity has adversely affected human and ecological health in the region (ICIMOD 2015).

Precipitation is the governing factor that regulates the hydrological cycle. Nepal receives an average of about 80% of its precipitation in the monsoon season (June - September) and the monsoon is more dominant in the eastern part of Nepal and as we go towards the west it decreases (Practical Action, 2009). Too much and too little precipitation have an adverse impact on livelihood, causing water-related environmental problems like flood and drought.

The annual precipitation in Karnali basin, one of the major basins of western Nepal, has remained relatively stable, but the extremes such as high-intensity precipitation and consecutive dry days have increased in past decades (Khatiwada, 2016), The winter monthly precipitation in western part of Nepal is 50 mm or less and this region has experienced consecutive and worsening winter drought conditions since 2000 (Wang et al., 2013).

The Karnali basin is the least developed in terms of infrastructure as well as human capacity. The Human Development Index of this region is 0.4 which is the least among other regions of Nepal (NPC/GoN/UNDP 2014). However, the vulnerability of the people to climate change and variability is the highest in the Karnali basin compared to other basins in Nepal (ADB 2012). Recent assessment (Panthi et al. 2016) of water poverty in the Karnali basin identified that the poverty level is higher in all the three elevation zones (lowland, mid-hills, and mountain) of the Karnali basin compared to the national average. The major factors contributing to this high level are climatic and environmental change, water availability and reliability, and the people’s capacity to manage the available water resources.

Rainwater harvesting technology is pragmatic for water conservation especially in rain-fed agriculture; however local farmers are not aware of its advantages in cropping system (Kattel, 2015). A lack of knowledge about the installation of components of rainwater harvesting systems, such as the size of the tank, is another hindrance in promoting roof-top rainwater harvesting systems in

Nepal (Kattel, 2015). Small-scale water structures such as community ponds and tanks have played an important role in rural life, particularly for agricultural practices in different parts of the world including Nepal. People construct ponds for community or private use for washing clothes and feeding livestock, and excess water is used for vegetable farming, primarily in kitchen gardens. A critical feature of these small-scale water harvesting systems is the size of the pond, which is determined based on land availability, household needs, and slope considerations. In general, small ponds are better suited for porous soil and over-topping concerns. Location is an equally important feature as the pond can hold runoff in landslide-prone areas and increase soil moisture in strategic places (FAO 2017). Seepage and evaporation losses are also among other potential problems related to both the size and location of ponds. Therefore, the identification of proper size and location is of great importance.

In this context, the overall goal of this project was to reduce the impacts of climate change and variability to the water resource by identifying appropriate locations for rainwater harvesting and providing a suitable environment for the end-users and policymakers to cope with water scarcity situation. Specifically, we aimed to develop a site suitability map for surface rainwater harvesting structures for maximizing aquifer recharge in the drought-prone basin and to develop a communication tool for promoting the roof-top rainwater harvesting system at the household level.

1.2 Objectives

The specific objectives of the project were:

1. Preparation of potential surface rainwater harvesting sites suitability map using geospatial information and tools
2. Development and testing of a user-friendly and interactive mobile application for providing information about technical and financial aspects for the installation of rainwater harvesting systems at the household and community level.

2. Methodology

2.1 Description of the project area

The Karnali basin (KRB) is in western Nepal (Figure 1) and is the largest river basin of Nepal in terms of area. It has an area of 42,457 km^2. Karnali River is the trans-boundary river and it originates from the south of Mansarovar and Rokas lakes located in China, flows through the western part of Nepal and ultimately joins to the Ghaghara River in India. KRB is characterized by high climatic and geographical variability as shown in Figure 2. The elevation varies from 163 m at southern low land to 7,747 m at higher mountains in the north. Highland of the Karnali basin is dominated by snow/glaciers and grassland; and lowland by forest and agriculture lands (Figure 2). In the entire basin, dominated land cover is the forest which occupies 33.2 % of the basin area followed by agriculture lands (16.2%). The KRB is largely rainfed (~80%) river basin (Bookhagen and Burbank 2010). The climate of the basin is influenced by the monsoon in the summer system and westerlies in the winter season (Nayava 1980; Shrestha 2000). The annual average precipitation in the basin is 1479 mm but it has large seasonal, spatial and inter-annual variations (Khatiwada et al. 2016). During the four-month summer season--June to September--the area receives from 55% (at highland) to 80% (at lowland) of the annual precipitation (Shrestha 2000). The northern region of the basin is the driest part, and it receives less than 300 mm precipitation in a year, but there are some pocket areas in the mountainous areas receiving more than 2400 mm in a year (Figure 2). The hydrology is dominated by the strong precipitation events in summer and snow and glacier melt in winter as baseflow.

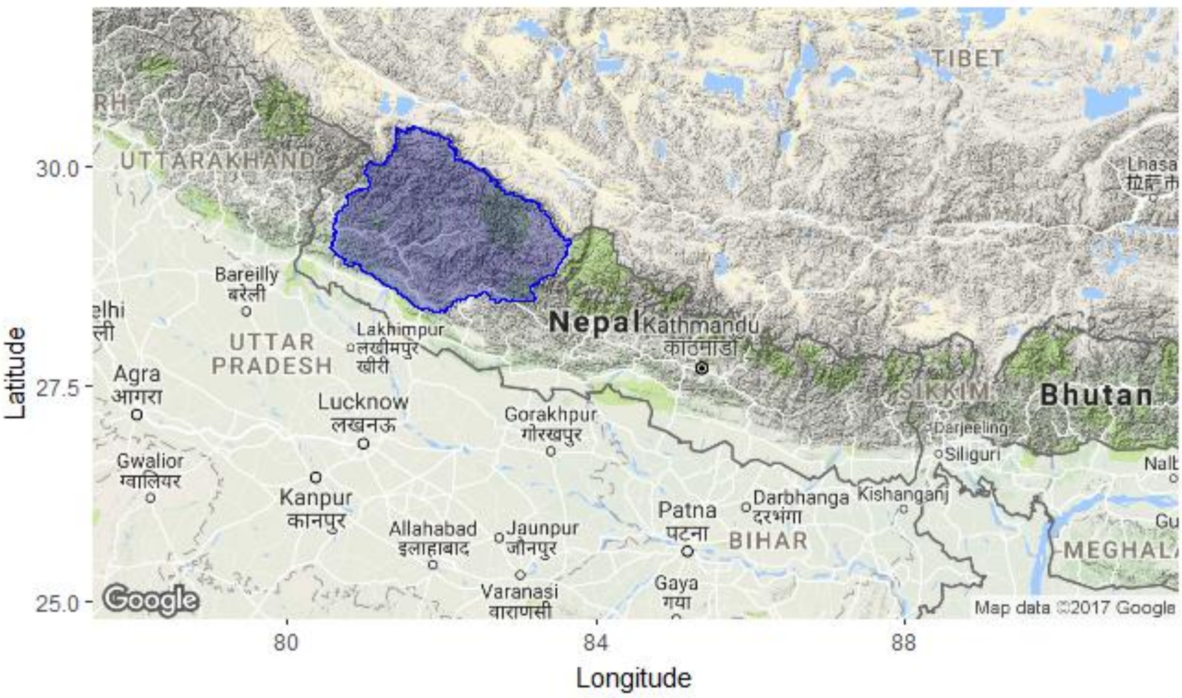


Figure 1: Location map study area

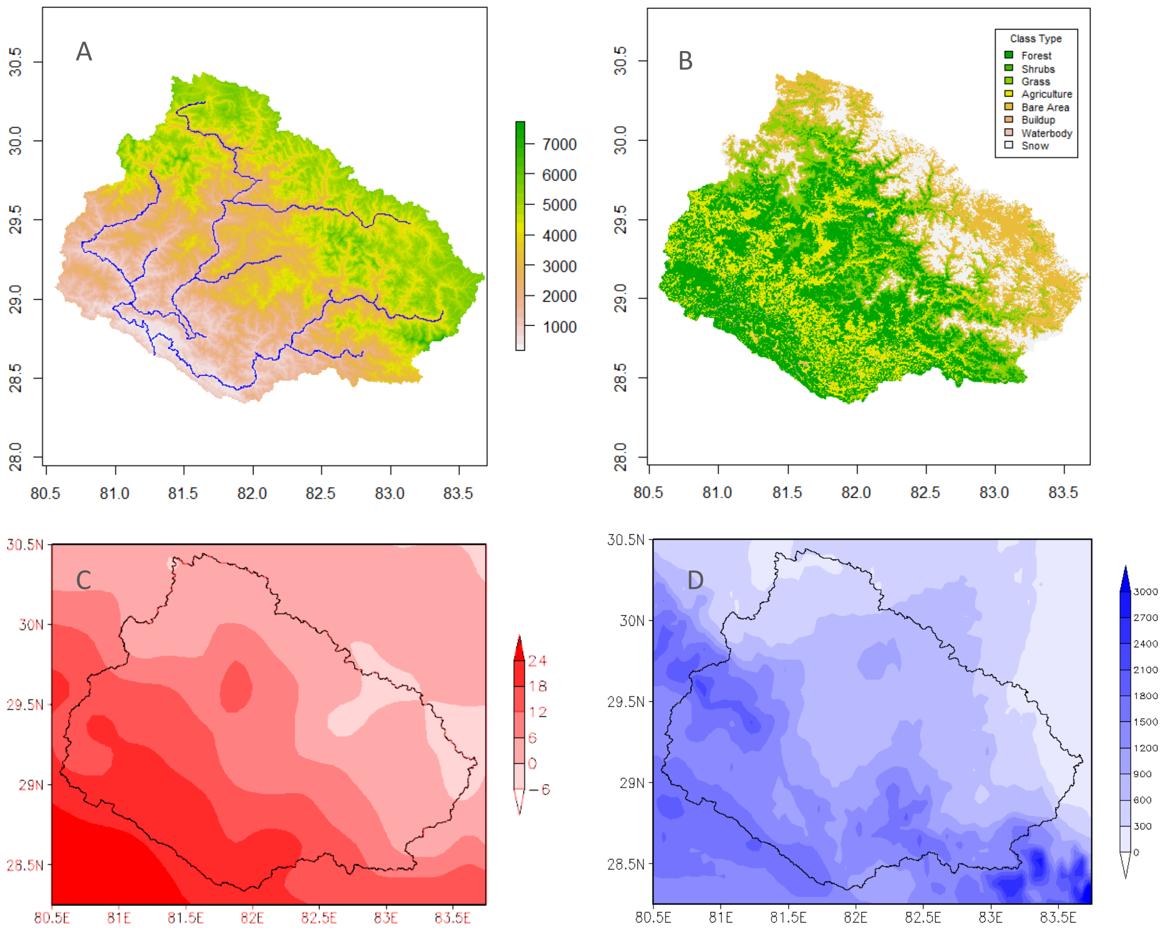


Figure 2: Maps showing the spatial variability in A) altitude in m, B) land cover type, C) annual temperature in oC, and D) annual precipitation in mm in the KRB.

2.2 A glimpse of the project methodology

The project has two parts viz. site suitability mapping for surface rainwater harvesting and development of a mobile application for rainwater harvesting system for domestic use. These two parts and the overall project framework are shown in a schematic diagram below:

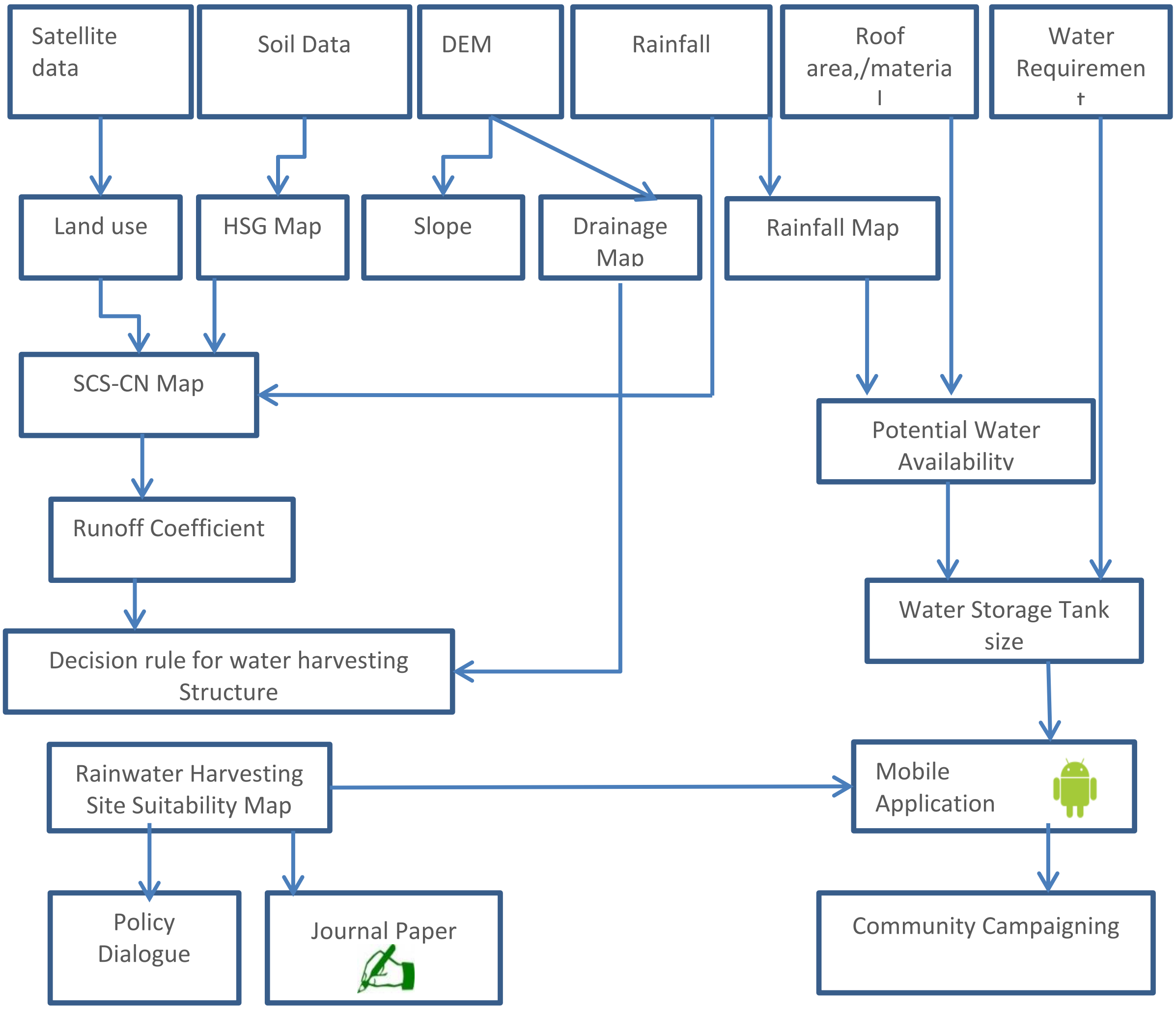


Figure 3: Schematic diagram of the project activities

2.3 Site suitability map for rainwater harvesting structure

Soil Conservation Service Curve Number (SCS-CN) method coupled with GIS interface was used to identify the potential surface rainwater harvesting sites. This enhances the accuracy and precision of runoff prediction, contributing to better identification of potential rainwater harvesting structures for cost-effective water resource management. This method accounts for many of the factors affecting runoff generation including soil type, land cover and land use practice, surface condition, and antecedent moisture condition and then incorporates them in a single curve number parameter.

The concept is mainly based on a runoff coefficient, landcover, slope, rainfall and stream network. Most of the modeling works were done in the ArcMap platform. The schematic diagram of the conceptual framework of the model is presented in Figure 4.

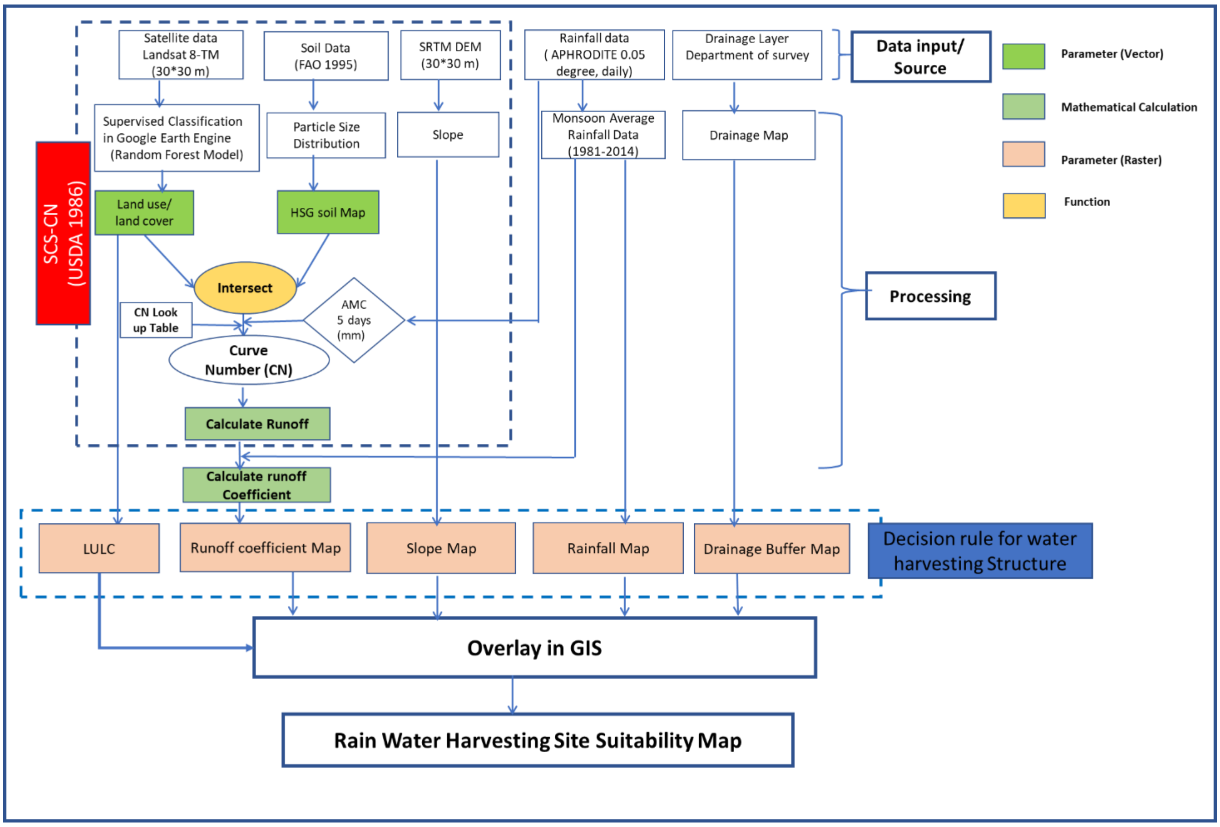


Figure 4: Conceptual framework of rainwater harvesting structure site suitability model

2.4 Data used for the site suitability mapping

The sources and the formats of the datasets required for site suitability map are described below:

Digital Elevation Model (DEM)

For DEM, Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) was used. The elevation data of the SRTM is available at 1-arc seconds (approximately 30m) resolution in WGS 1984. The image was downloaded from http://dwtkns.com/srtm30m/ for the region.

Land cover

Land cover map produced by the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal in 2010 was used to create the land use map. ICIMOD developed a harmonized land cover database for Nepal over different time slices (1990 and 2010) derived from Landsat images using object-based image analysis. The spatial resolution of the map was 30 x 30 m.

Soil data

A digital soil map of the world prepared by the Food and Agriculture Organization (FAO) of the United Nations was used for the preparation of hydrological soil groups. The database consists of the soil particle size distribution of sand, silt and clay. Based on the particle size distribution, soil was first classified into different textural classes using the soil texture triangle developed by USDA. The hydrologic soil classification was then prepared a Hydrological Soil Group (HSG) (USDA-SCS, 1986) pertaining to soil texture class. Soils were classified into four hydrologic classes A, B, C, D.

Precipitation data

We used gridded precipitation data at 0.05° spatial resolution produced over Nepal by Asian Precipitation-Highly Resolved Observational Data Integration Towards Evaluation (APHRODITE) of Water Resources project (Yatagai et al. 2012). Though the data is available for the period of 1951-2015 we have used data for the period 1981–2015 for our study. APHRODITE data is available on the daily time scale and is created primarily with data obtained from rain-gauge observations of entire Nepal.

Data analysis

Stream network

Stream network was prepared from SRTM DEM of resolution 30 m using GRASS GIS modules based in R.

Runoff coefficient

To calculate runoff coefficient, ArcMap 10.4 was used. First, soil data and land cover data of the region were prepared and were intersected. A Curve Number (CN) table was used to provide the CN values of each of the intersect units, depending upon the AMC. A raster containing CN value was generated. This CN value was used to compute runoff depth.

Runoff depth was calculated using the Soil Conservation Service Curve Number (SCS-CN) method developed by Soil Conservation Services (SCS) of United States Department of Agriculture (USDA). SCS-CN method is simple in application, predictable and fairly accurate (Ponce and Hawkins, 1996); hence, it has been widely used in runoff calculation in south East Asian context (Adham et al., 2016; Latha et al., 2012; Patel et al., 2017; Rawat et al., 2017)). This method computes direct surface runoff volume from rainfall depths (Bansode and Patil, 2014; Kadam et al., 2012; Mistry et al., 2017). The SCS-CN method commonly known as Curve Number (CN) method calculates potential runoff using an empirical equation from Curve Number (CN) from a water balance equation that can be expressed as,

$$P = I_a + F + Q$$

$$\frac{Q}{P - I_a} = \frac{F}{S}$$

$$I_a = \lambda \times S$$

For Nepal Condition,

The value of the Initial abstraction I_a to be approximately equal to 30 % of the watershed storage S (Latha et al., 2012; Mistry et al., 2017).

Where,

F= Actual Retention (mm),

S= Potential Maximum Retention (mm) or infiltration,

Q=Actual Direct Runoff (mm),

P= Total Rainfall (mm),

I= Initial Abstractions (mm),

λ = initial abstraction coefficient

$Q = \frac{(P - I_a)^2}{P - I_a + S}$ If Rainfall > 0.3 S

$Q = 0$ If Rainfall ≤0.3 S

The relation between S and CN can be expressed as:

$S = \frac{25400}{CN} - 254$ in mm, SI units

CN, a dimensionless number ranging from 0-100 (USDA-SCS, 1986), is a function of hydrologic soil group, land use and antecedent moisture condition (AMC) (Kadam et al., 2012; Mishra et al., 2008; Patel et al., 2017). It predicts runoff from a hydrologic soil cover complex and varies with (AMC). The antecedent moisture conditions are determined by total rainfall in the 5-day spell preceding a storm event. The favourable AMC conditions are listed in a table below (Geetha et al., 2007)

Table 1 Classification of antecedent moisture condition

AMC Type	Total Rain in Previous 5 Days (mm)		Condition
	Dormant Season	Growing Season	
I	< 13	<35.6	Dry
II	13- 28	35.6-53.3	Normal
II	>28	>53.3	Wet

(Source: Geetha et al., 2007).

Runoff coefficient is the ratio between the runoff volume from an area and the average rate of rainfall depth over a given duration for that area. So, runoff was calculated using the equation below:

$$\text{Runoff coefficient} = \frac{\text{Runoff}}{\text{Rainfall}}$$

As the runoff coefficient value ranges form 0-1; the higher the value of runoff coefficient the higher the surface runoff. A potential runoff coefficient greater than 0.5 is more favourable for rain water harvesting (Mahmoud, 2014).

To generate rainwater harvesting site suitability map, five conditioning factors were selected: runoff coefficient, land cover, slope, rainfall, and stream network.

2.5 Mobile application development

An android based mobile application was developed that gives various aspects of technical and financial information to aid in the installation of rooftop rainwater harvesting systems. In addition to taking information of local precipitation patterns, this application requires roof type, dimension and their runoff coefficients including households' water requirements for estimating the size of the tank. For the collection of social data, following data collection techniques were applied in field:

Household survey

The entire basin was stratified into three zones based on rainfall and physiographic information: Highland (Jumla district), Midhill (Dailekh district) and Churia (Surkhet district). Sample villages within each district were surveyed in April 2018 to identify water demand, sources and deficit. Altogether the field surveyor collected information from 130 households. Prior to the survey, semi-structured and open-ended questionnaires were developed and tested to gather required data and information for all indicators defined (See Appendix B). The indicators include information on water sources, availability, and uses, as well as household size, livestock, and roof size, among others.

Figure 5: Field data collector taking information during household survey

Focus Group Discussion:

Focus Group Discussions (FGD) with various community groups such as women’s group, farmers, community water users’ group, Government water supply schemes, were organized to identify social dimension, existing institutions in the communities related to water and to assess community well-being in terms of water supply and drought.

Key Informants Interviews (KIIs):

Key informants were interviewed to collect information pertinent to the project activities. Key informants were focal people in the community including farmers, local NGOs and INGOs representatives, Government officials, officials working on water supply projects.

2.6 Dissemination of project findings

Stakeholders campaign

A campaign was conducted in the study area where the household survey was carried out to train local people to use and promote the application.

Information sharing to policy makers

Meeting and seminars with key government agencies such as National Planning Commission (NPC), DHM, were organized to share the project's lessons so that the idea can be replicated in other parts of the country. A regional level workshop was organized in Karnali to launch the mobile application. At national level, a session was organized during the NNWWW-2019 as a final sharing workshop which was attended by scientists, experts, and relevant stakeholders from government, non-government, private sector and educational institutions working in water, environment, governance, and climate change. A groundwater seminar was organised to sensitise the different stakeholders on sustainable use of groundwater.

3. Results & Discussion

3.1 Mobile application

An android based mobile application “Aakaashepani” was developed to provide a user-friendly and interactive interface for the calculation of an optimal tank size required for household use and other financial aspects of rainwater harvesting systems. This application incorporates the information of local precipitation patterns, roof-types and dimensions, and the runoff coefficients including households’ water requirements. The algorithm of the application dynamically adjusts to the users input considering the water availability, demand and potential storage. Being freely available and highly customized to the local context of Nepal, this application has great potential to increase the adaptive capacity of the local people.

Water use patterns included in the application include the amount of daily water usage, the chores that require water, number of family members and livestock. In addition, information on nearby vendors and an estimated cost for the purchase of tools for installing rainwater harvesting systems were collected and uploaded to the application system.

Algorithm

The algorithm encompasses the information of local precipitation, runoff coefficients, roof-type and households’ water requirement to calculate monthly water budget for calculating the required tank size. Decision is made by the algorithm in following steps:

1. The volume of total collectable water for each month was calculated based on the rainfall in the area, user's roof area and its efficiency.
2. Taking May (just before the start of the Monsoon season) as the cut off month for emptying the tank, the surplus amount of water at the end of each month is accumulated. This algorithm takes June as a starting month of water year for KRB. The maximum amount of rainfall for any month is the maximum collectable water and considered the maximum tank size.
3. The cumulative amount of surplus water that user must have to fulfil water deficiency in preceding month is calculated throughout the year considering May as the month for emptying the tank. The maximum value in any month is maximum water that will be enough and considered as required maximum tank size.
4. The smaller value between potential and required maximum tank size is the suggested tank size by the algorithm. The algorithm suggests whether the water will be enough to fulfil water deficiency in the preceding months. It also suggests the month from when the tank will be empty.

3.2 Rainwater harvesting site suitability map

The spatial information on runoff coefficient, lithology, slope, drainage and rainfall played a critical role in site selection for runoff harvesting/recharging structures. Information on these primary and secondary thematic layers are calculated and are presented below:

Topography

The figure below shows the topography of the KRB. The altitude of the basin ranges from 181 m in lowland Terai to 7746 m in high Himalaya.

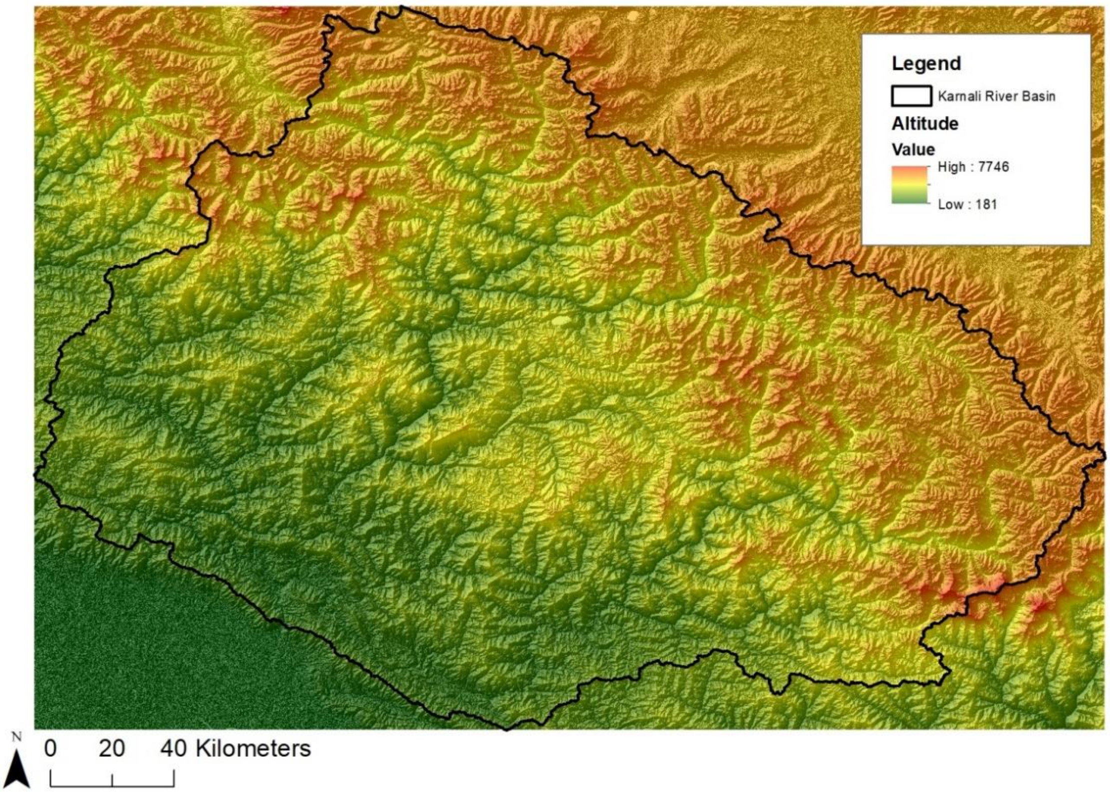


Figure 6: Elevation map of KRB produced using the STRM 30 m DEM

The average elevation of the basin is 3,180 m. Based on variations in elevation and topography, the basin can be broadly divided into four physiographical regions -the Terai region extends up to 200 m in elevation; above this are the hill regions (200–4000 m) and mountain regions (above 4000 m); the trans-mountain region lies north of the Himalaya Mountains.

Landcover

Information on land use and pattern of their spatial distribution is one of the criteria in selecting a CN. Highland of the Karnali basin is dominated by snow/glaciers and grassland; and lowland by forest and agriculture lands. In the entire basin, dominated land cover is the forest that occupies 33% of basin area followed by agriculture land which covers about 16% of the area. Landcover map and its distribution are presented in Figure 7 and in table 2 below:

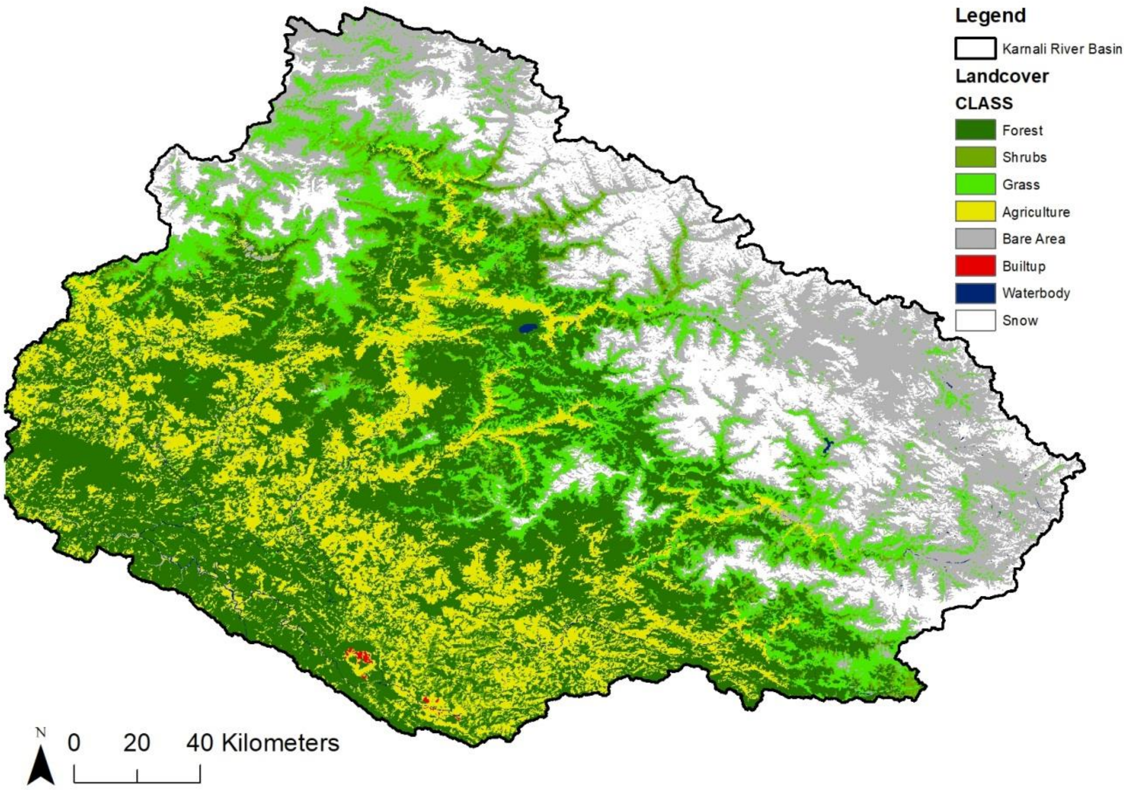


Figure 7: Land cover map of Karnali basin

Table 2: Major land cover class and distribution in the Karnali basin

Land Cover Type	Area (Sq. km)	Percentage (%)
Forest	13717	33.06
Shrubs	1682	4.05
Grass	5675	13.68
Agriculture	6607	15.92
Bare Area	7908	19.06
Built-up	18	0.04
Waterbody	159	0.38
Snow	5728	13.81
Total		

Slope

Since slope of the area affects the runoff, recharge, and flow of surface water; it is one of the important parameters for site selection for rainwater harvesting structure. Based on the DEM we prepared slope map (Figure 8) and is classified into six categories such as very gentle (0–5°), gentle (6–10°), moderate (11–15°), moderately steep (16–25°), steep (26-35°) and very steep (>35°).

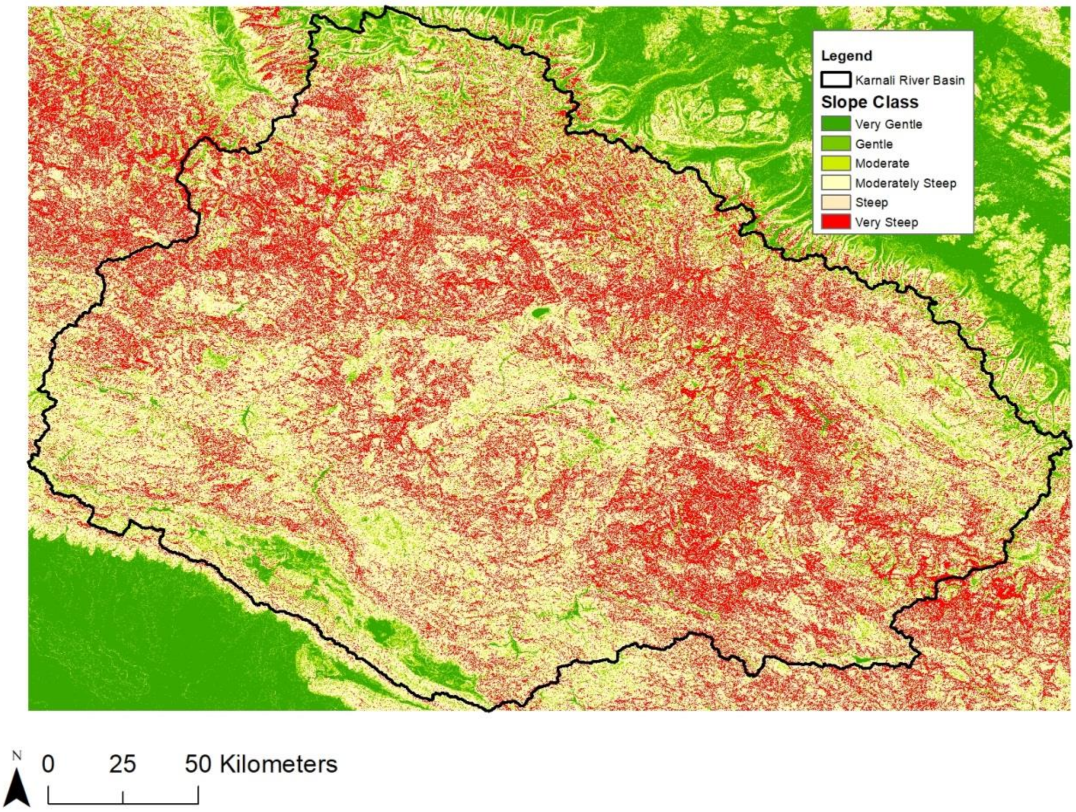


Figure 8: Slope map of the Karnali basin

Hydrological Soil Group

Hydrological soil groups (HSG) of the basin are determined based on the information of silt, sand and clay present in the soil. Information on HSG of KRB is shown in Figure 9.

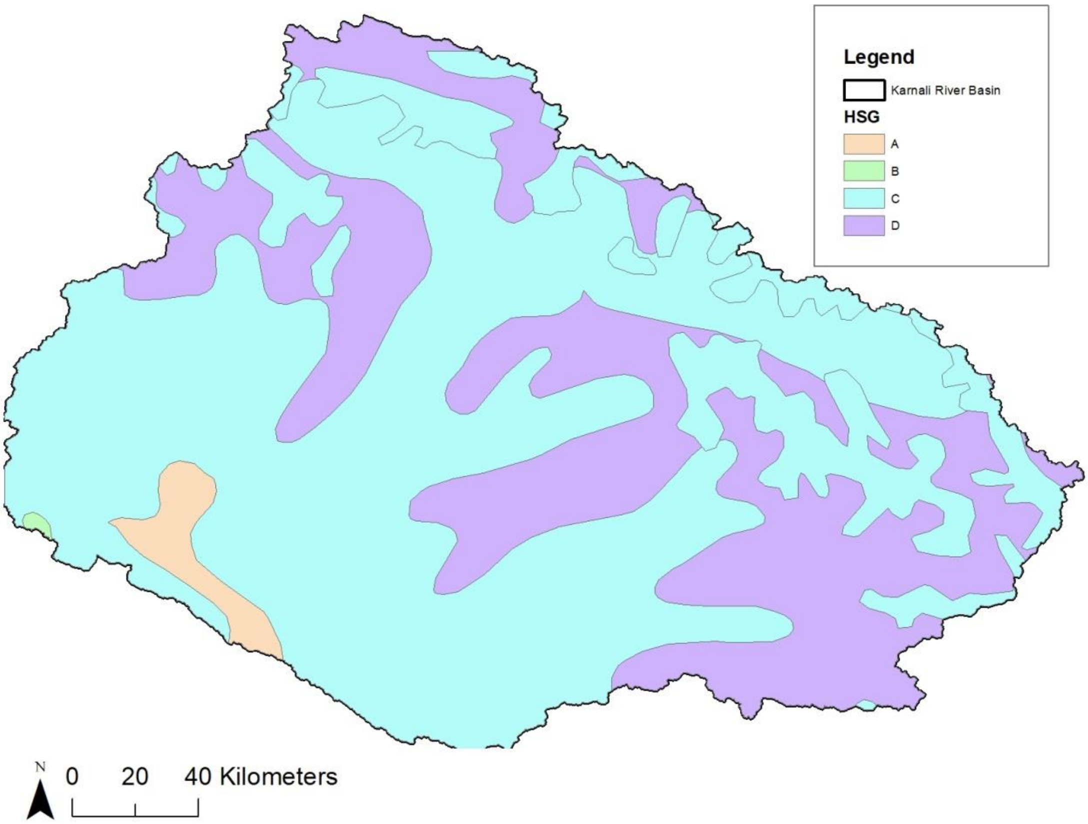


Figure 9: Map showing the distribution of HSG classes in KRB.

It is evident from the figure that the KRB predominantly comprises of HSG C (66%) and D (32%). This suggests a high surface runoff tendency of the Basin.

Table 3: Hydrological soil groups and their distribution in the KRB

HSG	Area (Sq. Km	Percentage (%)
A	827.32	1.96
B	37.41	0.09
C	27823.66	65.86
D	13560.98	32.10
Total	42249.37	100.00

Stream network

Karnali River at Chisapani, at the border of Bardia and Kailali district receives water from three major sub-basins viz. West Seti, Bheri, and Upper Karnali. The schematic representation of the drainage network in KRB in Figure 10.

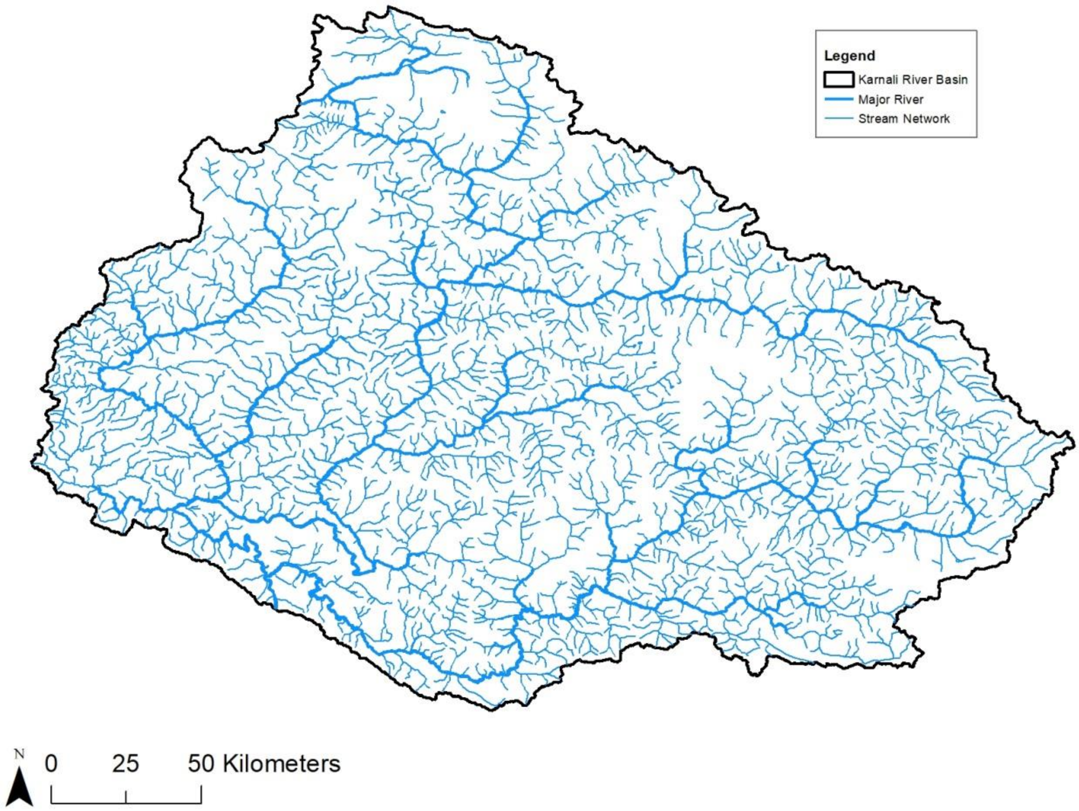


Figure 10: Map of river network in KRB

Precipitation

The annual average precipitation in the basin is 1479 mm (Khatiwada et al. 2016) but it has a large seasonal, spatial and inter-annual variation. During the four-month of summer (June to September) the basin receives about 80% of the annual precipitation. The distribution of the monthly average rainfall in the KRB shows that highest precipitation occurs in July (about 375 mm) and lowest in November (about 10 mm).

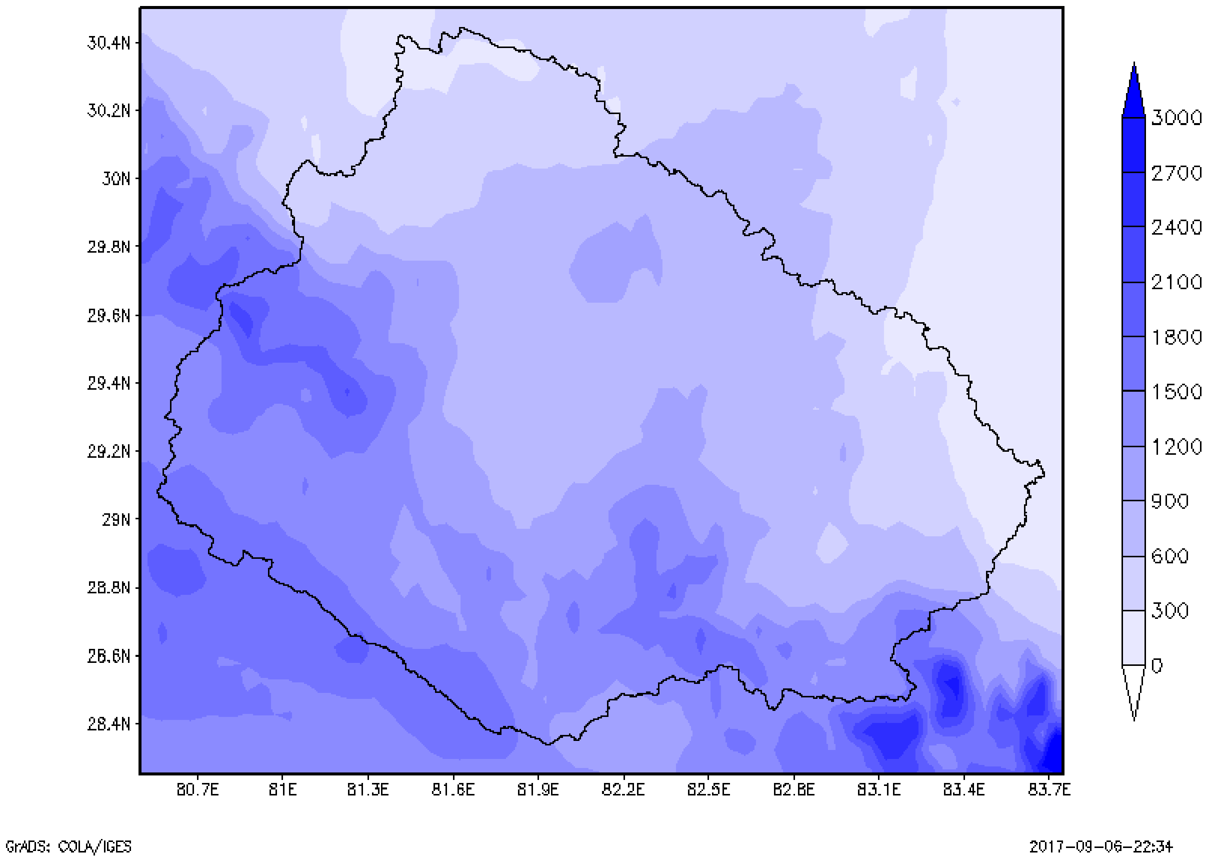
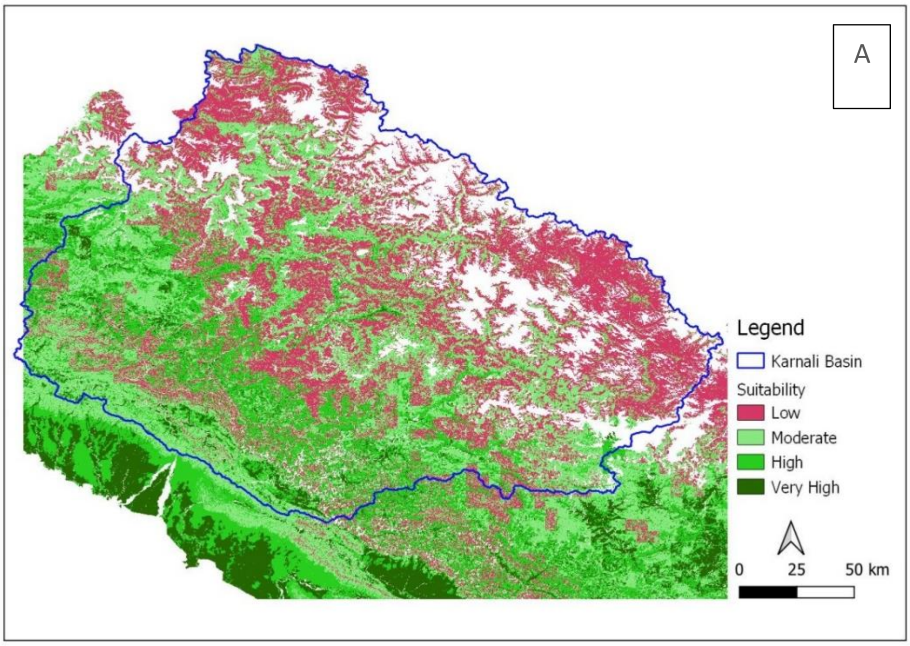


Figure 11: Map of spatial distribution of average precipitation in KRB (Unit in mm)

Site suitability map

The obtained required information as discussed above then coupled with GIS interface to identify the potential water harvesting sites. This method predicts runoff and eventually helps for better identification of potential rainwater harvesting structures for cost effective water resource management. The rainwater site suitability map for Karnali Basin is presented in the figure below:



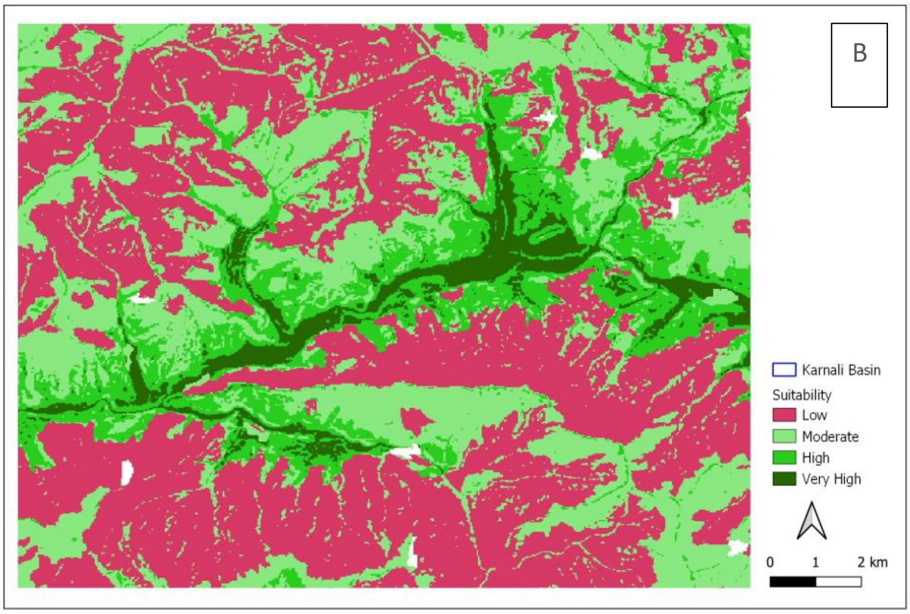


Fig 10: Surface rainwater harvesting site suitability map for A) Karnali basin of Nepal B) Zoomed in version of the same map for smaller location.

3.3 Dissemination of project outcomes

Project outcomes were disseminated through many platforms such as international conferences, publications, community campaigns and workshops.

3.3.1 Poster presentation at the MtnClimate Conference, 2018

Mr. Jeeban Panthi and Mr. Piyush Dahal presented the research findings as posters at MtnClimate conference organized at Rocky Mountain Biological Laboratory (RMBL) in Gothic, Colorado, USA from 17 to 21 September 2018. The conference was attended by 100 scientists, university professors, and graduate students from across the world who are working on mountains in climate, hydrology, ecology, and social issues. The MtnClimate conference is organized every two years in a mountain to highlights the importance and research carried out in mountain areas. The details of the conference are available at http://www.rmbl.org/mtn-clim-2018/

The first poster was about the climate and river runoff scenarios in the Karnali basin. Analysis of historical climate and extremes, making future climate projections, analysing the climate model data and developing river runoff for different climatic scenarios in two-time scales (2040-2069, 2070-2099 BS) were the important aspects of the poster. The second poster was about the rainwater harvesting in the Karnali basin. It was focused on rainwater harvesting site suitability mapping for the Karnali basin and the development of a mobile application as a decision support system for rainwater system installation. One of the highlights of the research was its use of open access tools which can motivate researchers based in developing countries who cannot afford software. The posters were well-received and conference participants were interested to learn about the climate and water situation in the Himalayan region,

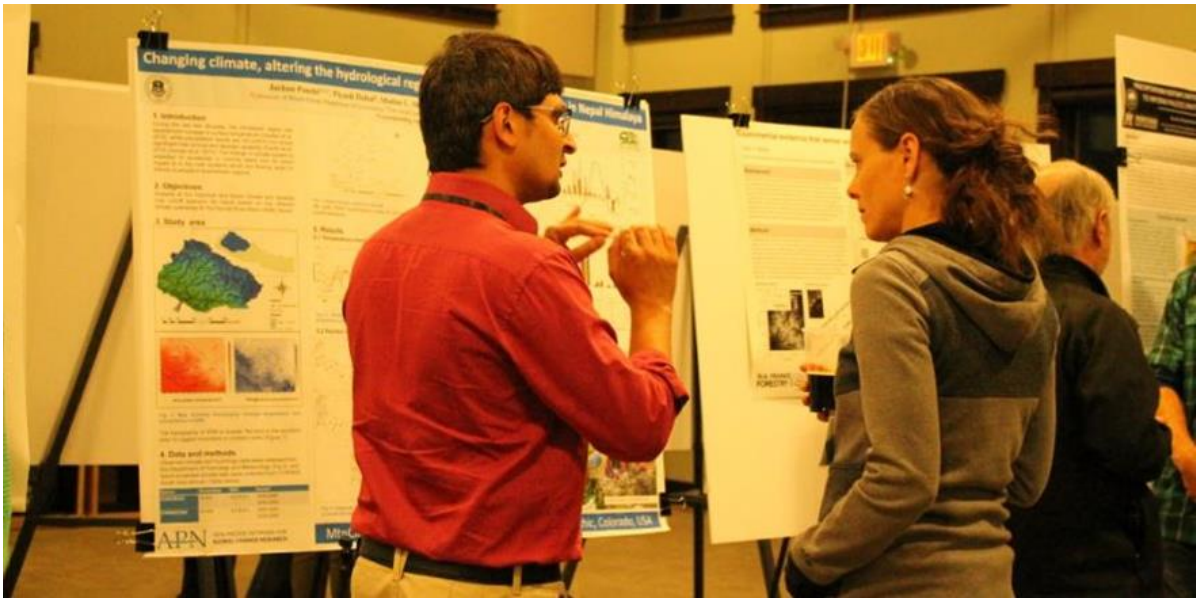


Figure 12: Poster Presentation by Mr Jeeban Panthi in MtnClimate Conference, 2018 in Colorado

3.3.2 Poster presentation at the American Geophysical Union (AGU) 2018

A poster from the project was presented at the American Geophysical Union (AGU) Fall Meeting 2018. The conference was organized in Washington DC from 10 to 14 December 2018. The title of our poster was “ICT for Combating Drought in the Karnali basin of Nepal Himalaya”. Many visitors from around the world appreciated the idea of mobile application and provided constructive comments. The detail of the poster presentation is available at the conference webpage: https://agu.confex.com/agu/fm18/meetingapp.cgi/Paper/466675

Figure 13: Mr. Jeeban Panthi presenting a poster at the AGU Fall Meeting 2018

3.3.3 Presentation at the American Geophysical Union (AGU) 2019

Project PI Mr. Jeeban Panthi delivered a talk at the AGU Fall Meeting in San Francisco, USA in December 2019. AGU organized a special Centennial session inviting centennial project leaders from around the world to share their project activities. Jeeban’s presentation was about the findings of the rainwater harvesting mobile application project from the Karnali basin in Nepal, primarily focusing on communicating developing cutting-edge technology (mobile applications) for water harvesting. Paper abstract is available at the AGU webpage: https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/501942

3.3.4 Paper presentation at International Youth Conference on Science, Technology and Innovation (IYCSTI-2019), 2019

Ms. Susmina Gajurel presented at talk at International Youth Conference on Science, Technology and Innovation (IYCSTI-2019) organized by Nepal Academy of Science and Technology (NAST) and the Government of Nepal from 21 to 23 October 2019. She presented on the topic “Rainwater Harvesting Map for Mitigate Drought in Western Nepal (Karnali basin)”. The presentation was primarily based on the usefulness and application of rainwater harvesting map to cope with water scarcity in the Karnali basin.

3.3.5 Community campaign and workshops

District level workshop

We organized a community campaign workshop in Chandannath Municipality, Jumla in coordination with the District Coordination Committee (DCC) on 10 January 2019. The purpose of the community campaign was to raise awareness for the innovation in rainwater harvesting through “Aakaashepani - an android based mobile application”.

The program comprised of a technical session to disseminate information regarding the project background, importance of rainwater harvesting, and the usefulness of mobile application “Aakaashepani”. Thirty-six participants were present at the event.

Figure 14: District Level Meeting at DDC of Jumla

In the workshop, Mr. Jeeban Panthi emphasized that water poverty and excess runoff induced by the changing climate led to the development of the concept of rainwater harvesting as a best management practice for water resources in Karnali basin. Mr. Piyush Dahal, talked about the changing climate in Karnali Basin. He shared that temperature is rising at an alarming rate with a decreased precipitation. Though the overall discharge at river remains the same throughout the year much of the river discharge is attributed to the melting of snow and glaciers. Mr. Nammy Hang Kirat introduced about rainwater harvesting suitability mapping and rainwater harvesting mobile application in detail.

Several issues were raised in discussion session. Multiple uses of water in off season, drying rivers, quality control measures of rainwater storage for drinking, agriculture and livestock, and subsidies for the implementation of sprinkler irrigation in agriculture were the main concerns of people attending workshop. In addition to this, Vice-chair of Tila Rural Municipality Bishnu Maya Buda, stated that decreasing amount and frequency of precipitation (i.e. snowfall) is affecting the livelihood of Jumla.

Figure 15: Remarks by the Vice Chair of Tila Rural Municipality

A member of DCC, Mr. Harsha Shahi, said that there has been a shift in winter precipitation (Nov-Dev to Feb-March) in the recent years and water resources are drying due to rampant road construction. In his closing remark, he said that climate change is beyond our control, so we need to take necessary actions to mitigate these impacts of climate change in collaboration with local government.

Regional workshop (13 January 2019)

In collaboration with Department of Hydrology and Meteorology (DHM) Regional Office at Surkhet we organized a regional workshop in Surkhet on 13th January 2019. The objective of the workshop was to officially launch the mobile application “Aakaashepani” and discuss water related science and policy issues of the Karnali basin.

Figure 16: Official launch of Android based mobile application "Aakaashepani"

More than 60 participants were present representing state governments and different organizations working in the Karnali Basin. Dr. Dhiraj Pradhananga, President of the Small Earth Nepal (SEN) described the vulnerability of the Karnali Basin to climate change and its impacts. Limited research activities are being conducted in Karnali Basin. He stressed making useful information usable for the improvement of livelihood of community, and SEN is working towards it since its establishment.

Figure 17: Dr. Madan Lall Shrestha, Academician at NAST delivering keynote presentation at the regional workshop

Special guest Dr. Madan Lall Shrestha, academician of NAST delivered the keynote speech on Climate Change: Global to Local Perspective. He presented key facts and figures related to climate change from global to Nepal. According to the IPCC fifth Assessment Report in 2014, global temperature is rising at an alarming rate due to emission of greenhouse gases during industrial evolution. It has been predicted that rising temperature by 0.2^{0}C in a decade suggesting that within next 50 years temperature will rise by 1^{0}C. In Nepal, the rate of temperature increase is 0.7 ^{0}C per decade which is more than the global average.

The Chief Guest of the program, Hon. Minister Nanda Singh Buda, Ministry of Industry Tourism, Forestry and Environment, Karnali Province officially launched the mobile application. He said that the remoteness of the Karnali Basin is hindering development activities and makes it highly vulnerable to climate change. “Melting of snow and glaciers and off seasonal changes are beyond anticipation; so, awareness at a household, ward and community level will help in prosperity of this basin” he said.

Mr. Kulmani Devkota, a member of the Drinking Water Users Committee in Surkhet District stated that there is little knowledge of climate change and there is no information centre at a district level. He highlighted the fact that sources of water such as springs and rivers are drying, groundwater table is reducing.

In addition to this, the chair of the session Dr. Rishi Ram Sharma, Joint Secretary, Water and Energy Commission Secretariat, Ministry of Energy, Water Resources and Irrigation mentioned that Nepal gets sufficient rainfall; however, due to lack of knowledge on water resource management we have to face water scarcity in a province like Karnali where there is a great variation of rainfall and climate pattern. Dr. Sharma said that to reduce constraints of water scarce condition we need to harvest rainfall.

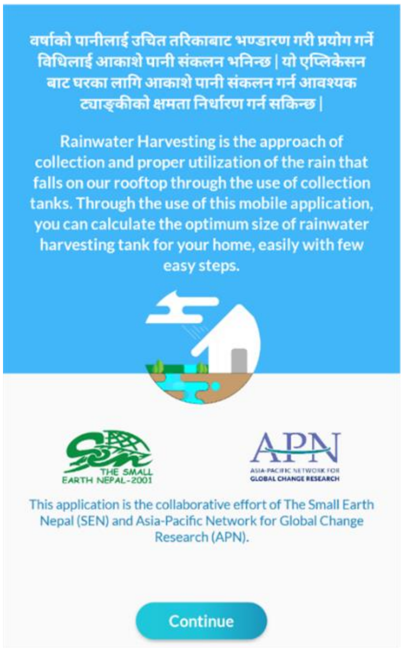


Figure 18: Interface of Mobile Application “Aakaashepani” (left) and launching of Mobile Application by the Hon. Minister Nanda Singh Buda, Ministry of Industry Tourism, Forestry and Environment, Karnali Province (right)

Figure 19: Participants at the Regional Workshop in Surkhet, Karnali Province.

The technical session was chaired by Er. Mahendra B. Gurung, The Executive Director of SEN. He highlighted the importance of rainwater harvesting in the context of Nepal by giving an overview of Rainwater harvesting mobile application. The session comprised of three technical papers. “To connect human civilization with innovation and development at an individual level rainwater harvesting mobile application was developed,” he stressed.

Mr. Nammy Hang Kirat presented a research paper on **Aakeshepani** mobile application. There is a dire need for water resource management in Karnali because there are no reliable water resources in uphill areas. The sources of water like rivers are located at a lower elevation; people have to spend more time and energy in fetching water. With this intention, Aakaashepani mobile application was developed realizing the growing penetration of smartphones.

Mr. Piyush Dahal talked about the objective of the project (i) collection and use of rainwater (ii) site suitable for groundwater recharge through a site suitability map using rainwater harvesting structures like check dams, farm-ponds and percolation ponds. The site suitability map for check dams, farms ponds and percolation ponds for the Karnali basin were presented.

Mr. Abdul Ansari, NCCSP regional coordinator delivered his overview presentation on water resource management for climate change and adaptation. He highlighted the working areas of NCCSP, formulation of NAPA, NAP designed by the Government of Nepal.

Jeeban Panthi shared a summary note to media persons. Developing countries like Nepal are facing the impacts of climate change such as excess rainfall in the monsoon and much less rain in winter along with the rise in temperature. So, as an adaptation measure, RWH has been proposed and targeted to local communities to improve their livelihood using innovative tools.

National workshop (22 March 2019)

The final project sharing workshop of the project was held in Kathmandu, Nepal during Nepal National Water and Weather Week (NNWWW-2019) on March 23. NNWWW is a week-long event celebrated annually since 2009 with a set of activities throughout the week on the occasion of UN World Water Day and World Meteorological Day. The object of this national level workshop was to share the project outcomes to a wider group of experts, relevant stakeholders, the government line agencies and representatives from NGOs and INGOs.

Figure 20: Final sharing workshop to the policymakers

Groundwater seminar (18 August 2019)

The seminar was held on 18 August 2019 at Hotel Summit, Kathmandu which brought together 72 participants from various organizations to discuss on the overarching theme of groundwater resources. The objectives of the seminar were to highlight the importance of groundwater, the grave reality of groundwater mining, and potential options for sustainable use and management of groundwater. In this context, when the groundwater pollution is increasing and groundwater tables are declining due to over-pumping of water through unregulated boreholes, such events play a crucial role in sensitizing policymakers and the relevant stakeholders towards undertaking urgent action. Intensive discussions regarding water demand and groundwater management were carried out where participants including government officials, researchers, academia, graduate students and other stakeholders from civil society were present at the event.

The following papers were presented in the technical session of the seminar:

Unconventional Water Treatment Technologies for Decentralized Applications, Prof. Thomas Boving, University of Rhode Island (URI).

Prof. Boving highlighted the traditional knowledge of water treatment technologies existing in Nepal, which at present is being lost or replaced by public water services that are insufficient for meeting household demand. Prof. Boving shed light on the applicability of wastewater treatment in context to Nepal. He recommended the application of riverbank filtration (RBF) for plain areas, like the Terai of Nepal, floating wetlands for lakes likes Phewa Lake in Pokhara, and artificial wetlands in the Kathmandu Valley for wastewater treatment.

Figure 21: Prof Thomas Boving presenting keynote talk during ground water seminar

Experience on groundwater exploitation, exploration and management for sustainable use in Nepal, Mr. Pratap Singh Tater, Senior Hydrogeologist, Nepal Hydrogeology Association (NHA).

Mr. Tarter stated that groundwater is an important mineral and he proposed detailed study on groundwater extraction, exploration, and management prioritizing research and awareness for the sustainable management of groundwater. Because of this, he emphasized the importance of the formulation of stringent regulations, laws and policies at the local, state and central level and need for research at university level. According to him, groundwater is not depleting but is a temporary phenomenon of groundwater recharge in an unconfined aquifer.

Giving his closing remarks, Prof. Chalise shared that knowledge is required to solve any problem and groundwater is in no exception. He reiterated on the broader collaboration with academia, experts, development partner, state and non-state actors in addressing the current groundwater issues and the challenges.

The technical session was followed by a panel discussion on **“Groundwater: Constraints and Ways Out”**. Following were the panellist in this session:

Dr. Sanjiv Bickram Rana, Executive Director, Kathmandu Valley Water Supply Management Board

Dr. Rana focused on the bitter reality of water scarcity data generated by Kathmandu Upatyaka Khanepani Limited (KUKL) which shows a huge gap in water demand and supply and which has caused a greater reliance on groundwater. This is aggravated by rapid economic development and a huge influx of city dwellers. Probable solutions for sustainable groundwater management could be rainwater harvesting (RWH), study and validation of data for the shallow and deep aquifers separately, and the introduction of necessary guidelines.

Mr. Andy Prakash Bhatta, President, Nepal Hydrogeological Association (NHA)

Mr. Bhatta criticized the government’s policy making process. Developing policies targeting a project is making the implementation of groundwater policy complex. He urged prompt action from the two major government bodies involved in groundwater management, the Department of Irrigation (DoI) and Department of Water supply, in the sustainable management and use of groundwater resources. He further added the media plays a crucial role in disseminating information. He urged the need for an agency that is responsible for the data collection of the existing wells, bore holes and the deep boring to prioritize groundwater exploitation.

Mr. Kabindra Pudasaini, Wash Programme Lead, Water Aid Nepal

Mr. Pudasaini showed his concern about depleting groundwater and he recommended installation of rainwater harvesting system for household level for harvesting excess rainfall in Kathmandu Valley. He added that promulgation of groundwater billing system would help in regulating groundwater. Lack of expertise and inadequate research are the biggest challenges to groundwater resource management.

Ms. Anisha Karna, Chief Operating Officer, Smart Paani

Ms. Karna raised her concern on the use of groundwater and rainwater harvesting system for our daily use. “Rainwater can be tapped and used as an option for mitigating water scarcity in Kathmandu Valley,'' she claimed. Increasing recharge in Kathmandu Valley using rainwater can be a solution for the time being while no other solutions are introduced. She said that people are often unwilling to change their behaviours which is a hindrance while solving problems.

The participants of the seminar reiterated the issues related to groundwater resource depletion, drying of wells and springs along with increasing groundwater pollution and thus suggested the promotion and installation of rainwater harvesting (RWH), conservation of tradition water resources like springs, ponds and wells mobilizing community through formulation and implementation of enabling policy framework. The speakers highlighted the necessity of gathering greater data points to point out with certainty about depletion of spring water. The speakers also talked about the necessity of collecting water from areas where houses were clustered close to each other and therefore rainwater harvesting was not possible. In such cases, the speakers proposed that water from such areas be collected in some open area or community wells.

Figure 22: Panelists expressing their views during panel discussion in ground water seminar

Graduate course on hydrogeology

As a part of the capacity development of young researchers, the Small Earth Nepal (SEN) organized ‘Second Graduate Course on Hydrogeology’ from 12 to 16 August 2019 at Kathmandu Valley Water Supply Management Board (KVWSMB) in collaboration with the Fulbright Specialist Program, University of Rhode Island (URI), Tribhuvan University Alumni Association Nepal (TUAAN), Centre for Hydrology of University of Saskatchewan (C4H-Usask) and KVWSMB. The main objective of the course was to strengthen the knowledge on hydrogeological concepts, principles, components and approaches. Eighteen graduate students and early career professionals representing academic institutions, government agencies, research organizations and a Fulbright-National Geographic Storytelling Fellow, gained skills to execute hydrogeology-based projects. The course consisted of a combination of lectures, hands-on exercises, group works, poster presentations and a field trip complemented with five lectures by Dr. Vishnu Prasad Pandey, Dr. Neera Shrestha Pradhan, Ms. Suchita Shrestha, Mr. Madhukar Upadhyaya, and Prof. Narendra Man Shakya. Following are the summary of each lecture in graduate course:

Prof. Thomas Boving, University of Rhode Island

Prof. Thomas Boving elucidated the core concepts of groundwater hydraulics and modelling, aquifer safe yield and sustainability considerations, groundwater contamination, water management and water resources protection approaches. He discussed the status of groundwater resources and water supply in Nepal particularly in the Kathmandu valley. He recommended the application of Riverbank Filtration (RBF) for Terai plains of Nepal, whereas Floating Wetland for lakes like Phewa in Pokhara and artificial wetland in the Kathmandu Valley for the treatment of wastewater in Nepal. He urged the need of research and monitoring actions against Leaking Underground Storage Tanks for reducing groundwater contamination by fuel. He further combined the theoretical concepts with hand on exercises focusing on geologic cross section of wells and borewells, groundwater flow/potentiometric surface, data quality check and piper diagram and groundwater modelling in excel.

Dr. Dhiraj Pradhananga, SEN and C4H-Usask

Dr. Dhiraj Pradhananga shared findings of his research on Cold Region Hydrology of the Canadian Rockies thereby showing the applicability of Cold Region Hydrological Modelling (CHRM) Platform in Nepal Himalayas. Dr. Pradhananga briefly talked about tools for effective research and communication. and shared the working modality of SEN.

Groundwater Vulnerability to Climate Change, Dr. Vishnu Prasad Pandey, International Water Management Institute (IWMI)

Dr. Vishnu Prasad Pandey highlighted the rising threats to quality and quantity of groundwater resources in the face of climate change. He illustrated the methods and approaches for evaluating vulnerability of groundwater to climate change through estimation of groundwater recharge, groundwater level and groundwater storage. He shed light on the need of scientific research to identify potential areas for recharge, estimate sustainable yield, monitor and evaluate groundwater resources so as to design and implement programs to conserve potential recharge areas.

Effective water management in the context of Hindu Kush-Himalayan Region (HKH), Dr. Neera Shrestha Pradhan, International Centre for Integrated Mountain Development (ICIMOD)

Dr. Neera Shrestha Pradhan shared the issues and challenges posed to the HKH region by climate change. Urging the need for Integrated Water Resources Management (IWRM) and Integrated River Basin Management (IRBM), Dr. Pradhan emphasized on three pillars of IWRM: ecological sustainability, economic efficiency and social equity for the effective and efficient management of water resources. Dr. Pradhan further shed light on the international events focussing on IWRM including Dublin Principles (1992), World Water Council Water Vision (2000), The Global Water Partnership Framework (2000), Groundwater Framework (2000).

Earth Observation data for water resource management by Mr. Nammy Hang Kirat, SEN

Mr. Nammy Hang Kirat familiarized the participants with Google Earth Engine by demonstrating its application for water resource management.

Experience sharing on Climate Adaptive Water Management Practices in Nepali municipalities: Connecting Research and Policy by Ms. Suchita Shrestha, Southasia Institute of Advanced Studies (SIAS)

Ms. Suchita Shrestha accentuated the major threats and challenges to urban water management as a result of population growth, rapid and unplanned urbanization, poor governance and institutional capacity. She likewise shared an overview of Climate Adaptive Water Management Plans for Cities in South Asia (CAMPS) projects carried out in Dhulikhel and Dharan. She highlighted that water management approaches like Water Forums promoted inclusive water governance by involving diverse stakeholders for deliberate discussion on their local water issues, challenges, and solutions using both scientific and indigenous knowledge. She shared that water scarcity coping mechanisms such as rainwater harvesting and ground water recharge systems were established at household level which showed the acceptance and implementation of water policies and programs by local government.

Water resources management in Nepal in the context of climate change by Mr. Madhukar Upadhya, Watershed Expert

Considering the increased pressure on water resources in the face of climate change, Mr. Madhukar Upadhya emphasized on the importance of systemic approach using evidence-based platform for effective water resource management.

Drought in western Nepal and its implications for water resources, vegetation, and agriculture by Mr. Piyush Dahal, SEN

Mr. Piyush Dahal summarized the findings of the recent research works carried out by SEN, particularly in Karnali basin of Nepal. Mr. Dahal discussed the implications of climate change in terms of increase in drought severity and frequency, increase in extreme events, reduction in crop yield, inter-annual variability in streamflow discharge, reduction in groundwater storage, increase in area of glacial lakes, and decrease in snow cover area, deducing that climate change is actually contributing to change in available water resources of Nepal.

Water Resources and Issues in the Context of Nepal by Prof. Narendra Man Shakya, Institute of Engineering, Tribhuvan University

Prof. Narendra Man Shakya accentuated the contribution and importance of snow and glaciers in groundwater recharge in Nepalese context. He depicted the present status of water supply i.e. Kathmandu Upatyaka Khanepani Limited (KUKL) in Kathmandu valley and the potential of Melamchi Water Supply Project on coping with supply deficit. Prof. Shakya highlighted the facts and figures which showed the water stress problem as a consequence of disruption in groundwater flow suggesting the need of IWRM of water resources to maximize the resultant economic and social welfare in an equitable manner.

As a part of the course, a field visit was organized to Sundarijal, Kathmandu which allowed the participants to understand the hydrogeological setting of Gokarna Basin and the mechanism of water supply treatment plant and reservoir of Melamchi Project. The field trip was coordinated by Mr. Prabin Chandra KC and Mr. Ram Chandra Paudel from KVWSMB.

During the closing session, the participants presented their technical approach to groundwater issues in various parts of the country through poster presentations. This activity allowed the participants to work within groups to discuss their project proposals and receive constructive feedback from the fellow participants, Prof. Boving, Mr. Pradhananga, Er. Mahendra B. Gurung.

Figure 23: Dr. Dhiraj Pradhananga during his lecture in graduate course

3.5 Publications and policy briefs

To date, we have published one paper in an international journal and presented three posters in international conferences. The published paper and posters are listed below:

Paper publication

1. Panthi, J., et al. "Water poverty in the context of climate change: a case study from Karnali river basin in Nepal Himalaya." International Journal of River Basin Management 17.2 (2019): 243-250 DOI:10.1080/15715124.2018.1531421

Poster presentation:

1. Panthi, J.; Kirat, N. H.; Pradhananga, D.; Dahal, P.; Khatiwada, K. R.; Gajurel, S. 2018. ICT for Combating Drought in the Karnali River Basin of Nepal Himalaya, AGU Fall Meeting 2018 http://adsabs.harvard.edu/abs/2018AGUFM.H53Q1821P
2. Dahal P., Panthi, J, Kirat, N. H.; Pradhananga, D.; Gajurel, S 2018. Rainwater Harvesting Suitability Map Using Free Data And Tools – An Application in Mountainous Basin in the Himalayas MtnClimate conference organized at Rocky Mountain Biological Laboratory (RMBL) in Gothic, Colorado USA http://www.rmbl.org/mtn-clim-2018/
3. Panthi, J.; Dahal, P.; Shrestha, M. L.; Khatiwada, K. R. 2018. Changing Climate Altering the Hydrological Regime – A Case from Karnali Basin in Nepal Himalaya. http://www.rmbl.org/mtn-clim-2018/
4. Panthi, J.; Dahal, P; Kirat, N. H.; Pradhananga, D..; Khatiwada, K. R.; Gajurel, S. 2019. Useful to usable: Application of geospatial information in community water management in Karnali basin in Western Nepal, AGU Fall Meeting 2019, https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/501942

The three papers are on progress on write-up:

1. Site suitability mapping for groundwater recharge in Karnali basin
2. ICT for Combating Drought in the Karnali basin of Nepal Himalaya
3. Drought in western Nepal and its implications for water resources, vegetation, and agriculture

3.6 Media coverage

During our community campaign in Chandannath Municipality of Jumla District, we have given an interview at Karnali F.M of Jumla. Mr. Jeeban Panthi and Nammy Hang Kirat took part in the interview. The team member talked about the climate change scenario at the Karnali basin and its implication in water security. "To cope with the variability of climate change, we have proposed the project "Rainwater Harvesting for Mitigating Drought in Western Nepal" through an APN funding", said Mr. Jeeban Panthi, Project Leader. Similarly, Mr. Kirat also highlighted the importance of ICT in mitigating drought in drought prone watershed like KRB.

Figure 24: Mr. Nammy Hang Kirat and Mr. Jeeban Panthi giving an interview at Kalika F.M., Jumla.

Similarly, during our regional level workshop for the official launch of mobile application our project activity was featured by several local newspaper in Surkhet, Capital of Karnali Province. The links of featured news are listed below:

https://nagariknews.nagariknetwork.com/news/66513/

https://www.nepalgatha.com/samaj/detail/11171

https://radiobheri.com.np/

Figure 25: Media coverage of Regional Workshop in Surkhet of Karnali Province (in Nepali language).

4. Conclusions

The water availability is becoming unpredictable globally because of the change and variability in climate system. The precipitation pattern and the amount are changing from the previous decades. In Nepal, due to the harsh tomography and underdeveloped infrastructure, the impacts of climate change in water resources are further scaled up. Studies have found that though there is not much change in an annual precipitation in the Karnali basin, however there is a big variability in monsoon and non-monsoon season. Therefore, harvesting rainwater from monsoon season to use in in dry season in an appropriate way to mitigate the impacts of climate change and variability. Though the rainwater harvesting system has been used traditionally for a long time, however, it needs to be updated with the current updates in science and technology. In this project, we developed a mobile application 'Aakaashepani' which enables local people and decision makers to estimate the size of the rainwater harvesting tank, estimated cost and location to buy the parts of the system. The rooftop rainwater harvesting system may not be enough for kitchen gardening and feeding their livestock in dry season. To address this problem, we developed a site suitability map for surface rainwater harvesting structures for the entire Karnali basin. The map is useful to the province/basin planner, local government bodies and community people to identify the suitable sites for constructing community structures such as check dams, percolation ponds. Both the mobile application and the suitability map are of high potential to scale up and scale out in other regions of Nepal and beyond.

5. References

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6. Appendix

A. List of Young Scientists

Name	Involvement	Institution	Country	Email
Mr. Piyush Dahal	He has worked together with the team to prepare the rainwater harvesting suitability map.	The Small Earth Nepal	Nepal	piyush@smallearth.org.np
Mr. Nammy Hang Kirat	He has worked for algorithm development for the android based mobile application. Also, he has worked together with the team to prepare the rainwater harvesting suitability map.	The Small Earth Nepal	Nepal	nammyhang@gmail.com
Mr. Kabi Raj Khatiwada	He has worked for the primary data collection and algorithm development for the android based mobile application. Also, he has worked together with the team to prepare the rainwater harvesting suitability map.	The Small Earth Nepal	Nepal	kabirajkhatiwada@gmail.com
Ms. Susmina Gajurel	She has worked together with the team to prepare the rainwater harvesting suitability map. She has helped to prepare the different input files for this suitability map.	The Small Earth Nepal	Nepal	susmina07@gmail.com
Ms. Aashna Shakya	She has worked together with the team to prepare the rainwater harvesting suitability map. She has helped to prepare the different input files for this suitability map.	The Small Earth Nepal	Nepal	ashanashakya644@gmail.com

B. Questionnaire for Household Survey (digital based, no paper used)

KoBo Toolbox

Household survey on Rainwater harvesting

Name of District:
- [ ] Surkhet, Birendranagar NP
- [ ] Dailekh, Narayan NP
- [ ] Jumla, Chandannath NP

Ward no:

Track no of GPS:

Name of the respondant:

Age of respondant :

Household size:

What is the roofing material ? *
- [ ] Jastako
- [ ] Straw
- [ ] Iron/metal sheet
- [ ] Tiles
- [ ] Metal
- [ ] Other
- [ ] Flat roof/cemented
- [ ] Flat roof/mud

State if any other roofing type :

Do you use smart mobile system ?
- ( ) Yes
- ( ) No

If yes, how many members in the family are using smart phone ?

Do you have access to internet ?
- ( ) Yes
- ( ) No

If yes, how do you access internet access ?
- [ ] Wi-Fi
- [ ] Local cyber
- [ ] Mobile Data (Ncell)
- [ ] Mobile Data (NTC)
- [ ] Mobile Data (Smart or other)

Major source of water for household purpose:
- [ ] Tap/Pipe water
- [ ] Spring
- [ ] Well/Tube well
- [ ] River
- [ ] Kuwa/Inar
- [ ] Rainwater harvesting
- [ ] Other

What is the other source of water for household purpose :

What is the souce of water for cooking purpose :

- [ ] Tap/Pipe water
- [ ] Spring
- [ ] Well/Tube well
- [ ] River
- [ ] Kuwa/Inar
- [ ] Rainwater harvesting
- [ ] Other

What is the source of water for washing clothes :

- [ ] Tap/Pipe water
- [ ] Spring
- [ ] Well/Tube well
- [ ] River
- [ ] Kuwa/Inar
- [ ] Rainwater harvesting
- [ ] Other

What is the source of water for cleaning purpose :

- [ ] Tap/Pipe water
- [ ] Spring
- [ ] Well/Tube well
- [ ] River
- [ ] Kuwa/Inar
- [ ] Rainwater harvesting
- [ ] Other

What is the source of water for bathing purpose :

- [ ] Tap/Pipe water
- [ ] Spring
- [ ] Well/Tube well
- [ ] River
- [ ] Kuwa/Inar
- [ ] Rainwater harvesting
- [ ] Other

Amount used (litres/day) from Tap/Pipe for household purpose :

Amount used (litres/day) from Spring for household purpose :

Amount used (litres/day) from Well/Inar for household purpose :

Amount used (litres/day) from River for household purpose :

Amount used (litres/day) from Rainwater harvesting tank for household purpose :

Amount used (litres/day) from other source of water for household purpose :

Major livestock

- [ ] Cattle
- [ ] Goat/Sheep
- [ ] Pig
- [ ] Other

Name of the other livestock if any :

Major source of water for cattle :

- ☐ Tap/Pipe
- ☐ Spring
- ☐ Well/Tube well
- ☐ River
- ☐ Kuwa/Inar
- ☐ Rainwater harvesting
- ☐ Other

Major source of water for goat/sheep :

- ☐ Tap/Pipe
- ☐ Spring
- ☐ Well/Tube well
- ☐ River
- ☐ Kuwa/Inar
- ☐ Rainwater harvesting
- ☐ Other

Major source of water for pig :

- ☐ Tap/Pipe
- ☐ Spring
- ☐ Well/Tube well
- ☐ River
- ☐ Kuwa/Inar
- ☐ Rainwater harvesting
- ☐ Other

Major source of water for other livestock :

- ☐ Tap/Pipe
- ☐ Spring
- ☐ Well/Tube well
- ☐ River
- ☐ Kuwa/Inar
- ☐ Rainwater harvesting
- ☐ Other

Water used by cattle (litre/day):

Water used by goat/sheep (litre/day) :

Water used by pig (litre/day) :

Water used by other livestock (litre/day) :

Major Vegetables at Home Gardening

Major vegetables for kitchen gardening :

- ☐ Leafy vegetable (saagharu)
- ☐ Beans and legumes (bodi, simi, kerau)
- ☐ Flower (kauli, banda)
- ☐ Roots (mula, gazar)
- ☐ Fruits (eskush, karela)
- ☐ Tuber (potato, tarul, lasun, pyaz)
- ☐ Other

Name of other vegetable :

Area used for kitchen gardening (with unit)
Daily water used in kitchen gardening (litres/day)
Source of water for kitchen gardening : ☐ Tap/Pipe ☐ Spring ☐ Well/Tube well ☐ River ☐ Kuwa/Inar ☐ Rainwater harvesting ☐ Other
Any additional information :
Contact no of the respondant :
Status of water resource in your nearby :
If change in water resouce, how did it impact your livelihood; What arternive approach did you use
Traditional approaches for the water resource conservation :
Remarks:

C. Instructional brochure of "Aakaashepani" android application

Aakaashepani (आकाशेपानी)

Mobile Application for Rainwater Harvesting Advisory

What is Aakaashepani (आकाशेपानी)?

Aakaashepani (आकाशेपानी) is an android app developed to help in decision-making for installation of a rainwater harvesting system. Using this mobile application, you can calculate optimum size of rainwater harvesting tank for your home, with few easy steps. It uses monthly rainfall data, available roof area, type of roof and monthly water requirements based on family size, water use activities and type and number of livestock to estimate the tank size. This application is currently limited to the Karnali River Basin, Nepal.

How to install?

Aakaashepani (आकाशेपानी) app is available freely in Google Play Store. You can also scan the alongside QR code, which redirects you to install this app.

Contact

If you have any suggestions or comments on this app, please let us know! You can reach us at info@smallearth.org.np

How to Use?

1. Location:

First, select the name of district and rural/urban municipality from dropdown menu where your house is located. This will show average annual precipitation of your area on the blue strip below. Please tap on Next button at top right to go to the next section.

2. Roof:

Enter the length and width of your roof in meter and also select type of roof of your house from pictures below. If you wish to collect rainwater from more than one house into a single tank, tap Add roof+ to provide the information of additional roof.

3. Water requirement:

Provide the number of people residing in your house and number of cattle, goat/sheep and pigs. Taping Next will display summary of the data you provided. If all the information is correct you may tap Calculate to calculate tank size, if not you can correct them using Back button.

4. Result and cost estimation:

This page shows suggested tank size. In addition, it shows the maximum amount of water that can be collected and the month when the tank will be empty due to inadequate rainfall. Tap on Cost estimation and vendor to get information on tentative cost of the tank and nearest vendor.

Disclaimer : The accuracy of results from this calculator depends on the quality of data input and actual precipitation, which is highly variable in this region. There is no warranty that the tank size calculation is accurate, it should be used as an advisory only.

This application is a collaborative effort of The Small Earth Nepal (SEN) and Asia-Pacific Network for Global Change Research (APN).

आकाशेपानी (Aakaashepani)

आकाशेपानी सङ्कलनमा सहयोगी मोबाइल एप्लिकेसन

आकाशेपानी

आकाशेपानी सङ्कलन गर्ने कार्यमा सहयोग पुर्याओस भन्ने ध्येयले यो "आकाशेपानी" मोबाइल एप्लिकेसन बनाइएको हो । यो एप्लिकेसनबाट घरका लागि आकाशेपानी सङ्कलन गर्न आवश्यक ट्याङ्कीको क्षमता निर्धारण गर्न सकिन्छ । अहिलेको लागि यो एप्लिकेसन कर्णाली जलाधार क्षेत्रमा सिमित रहेको छ ।

कसरी इन्स्टल गर्ने ?

आकाशेपानी एप एण्ड्रोइड मोबाइलको लागि बनाईएको हो । यो एप गुगल प्ले स्टोरमा उपलब्ध छ । तपाईले सँगैको QR Code स्क्यान गरेर पनि प्ले स्टोरमा पुग्न सक्नुहुनेछ ।

स्क्यान गर्नुहोस्

सम्पर्क

यस एपको बारेमा तपाईको कुनै सल्लाह / सुझाव भएमा हामीलाई info@smallearth.org.np मा सम्पर्क गर्न सक्नुहुनेछ ।

कसरी प्रयोग गर्ने ?

१. ठाउँ :

तपाईले आकाशेपानी एप खोलेपछी यसलाई शुरु गर्न Continue बटन थिच्नुहोस् र चित्रमा देखाए जस्तै आफ्नो जिल्ला र गाँउपालिका वा नगरपालिका छान्नुहोस् । तल निलो बारमा तपाईको क्षेत्रमा हुने औषत वार्षिक वर्षाको जानकारी पाउन सक्नुहुन्छ । अब माथिको Next बटन थिच्नुहोस् ।

२. छानो :

यस पेजमा छेउको स्क्रिनमा देखाइए अनुसार तपाईको घरको लम्बाइ र चौडाई मिटरमा लेख्नुहोस् र आफ्नो छानोको प्रकार चित्रबाट छान्नुहोस् । यदि एक भन्दा बढी छानो बाट एउटै ट्याङ्कीमा पानी सकलन गर्नुपर्ने भए Add roof + थिचेर अरु छानोको जानकारी राख्न सकिन्छ । सबै काम सकिए पछि फेरी Next बटन थिच्नुहोस ।

३. आवश्यक पानी :

यस पेजमा छेउको स्कृनमा देखाईए अनुसार तपाईको परिवार सख्या र घरमा पालिएका गाईवस्तुको सख्या राख्नुहोस् । फेरी Next बटन थिच्नुहोस् । यस पछि तपाईले अहिलेसम्म राख्नुभएको सबै जानकारी देखिन्छ । जानकारी सही भएमा Calculate बटन थिच्नुहोस् वा केही जानकारी गलत भएमा Back बटन थिचि फेरी सच्याउनुहोस् ।

४. ट्याङ्कीको क्षमता र लागत :

यस पेजमा तपाईलाई आवश्यक ट्याङ्कीको क्षमताको साथै छानाबाट बढीमा कति पानी सकलन गर्न सकिन्छ भन्ने जानकारी दिन्छ । यदि तपाईको छानाबाट पर्याप्त पानी सकलन गर्न नसकिने रहेछ भने, तपाईको ट्याङ्की कुन महिनामा खाली हुन्छ भन्ने जानकारी पनि दिन्छ ।
यसका साथै ट्याङ्की निर्माण गर्दा लाग्ने लागत र नजिकैको हार्डवेयर पसलको बारेमा पनि मोटामोटी जानकारी पाउनको लागि Cost estimation and vendor भन्ने बटन थिच्नुहोस् ।

डिस्क्लेमर : यो एप्लिकेशन आकाशेपानी संकलनमा सहयोग गर्ने उद्देश्यले बनाईएको भएपनि यस एपको नतिजामा मात्र रहेर निर्णय नलिनुहोला ।

यो एप्लिकेशन द स्मल अर्थ नेपाल (SEN) र एसिया-प्यासिफिक नेटवर्क फर ग्लोबल चेन्ज रिसर्च (APN) को सहकार्यमा तयार गरिएको हो ।