FACTORS AFFECTING THE EFFECTIVENESS OF RUNOFF HARVESTING DAMS IN NEPAL

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ABSTRACT

The objectives of this study were to measure the level of effectiveness and analyze the factors affecting the effectiveness of runoff harvesting dam (RHD) projects that have been implemented in the *Dhanusha* district of Nepal as an activity of watershed management. 6 sampled runoff harvesting dams and 71 households representing the water user groups were studied. A questionnaire for interviewing households, a check list of questions for key informant interviews, and a checklist for desk reviews and field observations were administered covering the variable indicators of effectiveness and factors of effectiveness of RHD projects. The data were analyzed by applying scoring and ranking, descriptive statistics, Cross Tab matrix and factor analysis method.

It was found that 3 RHD projects were highly effective and the other 3 were moderately effective. Highly effective runoff harvesting dams showed positive changes in all indicators: increased water availability for irrigation, household use and livestock; decreased soil erosion and water induced disasters; improved moisture retention and microclimate; increased agriculture and forest production; increased household income and enhanced capacity of water user groups. Unlike highly effective RHD projects, moderately effective RHD projects did not bring positive changes in water availability for irrigation, agriculture and forest production and household income.

The level of influence of all eight factors (location, soil type, siltation, upstream management, participation, conflict of objectives, operation and maintenance and budget allocation) towards the effectiveness of ***Dhanauji*** RHD projects was high. Soil type, siltation, participation and conflict of objectives were at a high level while location and operation and maintenance were at a moderate level and upstream management was at a low level of influence towards the effectiveness of ***Sabedanda*** **RHD.** Soil type, siltation, participation, conflict of objectives, operation and maintenance and budget allocation were at a high level while location and upstream management were at a moderate level of influence towards the effectiveness of ***Aurahi*** **RHD**. Siltation, upstream management, participation, conflict of objectives and operation and maintenance were at a high level while location, soil type and budget allocation were at a moderate level of influence towards the effectiveness of ***Madhubasha*** **RHD.** Location, participation, conflict of objectives and budget allocation were at a high level while siltation and operation and maintenance were at a moderate level and soil type and upstream management were at a low level of influence towards the effectiveness of ***Chireshwor*** **RHD**. Location, soil type, participation, conflict of objectives and budget allocation were at a high level while operation and maintenance were at a moderate level and siltation and upstream management were at a low level of influence towards the effectiveness of ***Haripur*** **RHD** project.

The levels of effectiveness of runoff harvesting dams were significantly correlated with the factors of upstream management and operation and maintenance (p= 0.01) and insignificantly correlated with the other remaining six factors. Thus, the level of effectiveness of RHD projects was greatly limited by upstream management and operation and maintenance factors. It is suggested that RHD projects should be implemented following the principle of integrated watershed management and development so that level of effectiveness of RHD projects can be increased.

KEY WORDS: WATERSHED MANAGEMENT / RUNOFF HARVESTING DAMS / EFFECTIVENESS / INFLUENCING FACTORS / NEPAL

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LIST OF ABBREVIATIONS

Abbreviation or symbol	
cu.	Cubic
cu. ft.	Cubic feet
DSCO	District Soil Conservation Office/Officer
DSCWM	Department of Soil Conservation and Watershed Management
DFSP	District Forest Sector Plan
FAO	Food and Agriculture Organization
F.Y.	Fiscal Year
GDP	Gross Domestic Product
GTZ	German Agency for Technical Cooperation
ha	hectare
hh(s)	household(s)
ICIMOD	International Center for Integrated Mountain Development
IFAD	International Fund for Agriculture Development
IGA	Income Generating Activities
INGO(s)	International Non-governmental Organization(s)
IUCN	International Union for Conservation of Nature
kg	Kilogram
km	Kilometer
MOFSC	Ministry of Forests and Soil Conservation
MU-IRB	Mahidol University - Institutional Review Board
NGO(s)	Non-governmental Organization(s)
no.	Number
NRs	Nepalese rupees
NTFP(s)	Non-timber forest product(s)
Obs	Observations
PIWMP	Participatory Integrated Watershed Management Program
qtl	Quintal

LIST OF ABBREVIATIONS (cont.)

Abbreviation or symbol	
RHD(s)	Runoff Harvesting Dam(s)
SCA(s)	Soil Conservation Assistant(s)
SCWM	Soil Conservation and Watershed Management
SNV	Netherland Development Organization
SPSS-15	Statistical Package for the Social Sciences version 15
Sq	Square
UG(s)	User group(s)
UGC(s)	User Group Committee(s)
UNEP	United Nations Environment Program
UNCCD	United Nations Council for Combating Desertification
VDC(s)	Village Development Committee(s)
WC(s)	Ward Committee(s)
yr	year

CHAPTER I
INTRODUCTION

1.1 Background and justification

Water is essential for survival of every life and a vital resource for economic activities. In a wide range of ecological systems, water is a dominant component. Water allows ecosystems to produce services such as fish, pasture, forest, agricultural/food products and industrial raw materials which often provide high economic values (World Resource Institute, 2008).

According to Menon, (2008), watershed is the area of land from which water drains into a body of water such as river, lake, stream, or bay. It is topographically delineated area from where water drains into a common outlet. A watershed is an area of land that consists of natural and manmade resources. The interaction of these resources makes the biological system in a watershed complex and dynamic. The existing ecosystem functions in a watershed support the life systems including livelihood of the people. Watershed is also considered as a combination of biological, physical, economic, and social systems.

Wagner et al. (2002) described watershed management as the management of land, water, and vegetation in a coordinated and integrated manner in watershed scale. Watershed management aims at maintaining and enhancing water quality and quantity, pollution management, better land husbandry, forest biodiversity and agro-biodiversity so that well-being of the people living in a watershed can be enhanced.

The world has plenty of water but 97.5 % are salt water, only 2.5 % are available for various uses. Water scarcity is mostly prevalent in dry land of arid, semi arid and hyper arid areas where agricultural and forest productivity is limited by poor availability of moisture. Those areas comprise not less than 40 % of global surface land (6.4 billion ha.) found in more than 100 countries and are home to about 1.2 billion people and 350,000 plant species, of which 300 species are known to be useful to mankind (UNEP, 2002).

Population density within the dry land decreases with increasing aridity from 71 to 10 people per square kilometer due to acute shortage of water. The largest number of population (i.e. 42%) is concentrated in dry land of Asia. About 41 % of population in Africa lives in dry land with harsh environment and poor socio-economic conditions. Similarly about 30% of population lives in dry land in South America. In the early 1990, global assessment of soil degradation based on expert opinion estimated that 10-20 % of dry land, excluding hyper-arid areas, was affected by soil degradation due to water scarcity (Millennium Ecosystem Assessment, 2005).

Current water shortage in dry lands is considerably increasing due to population increase, land cover change, and global climate change. From 1960 to 2000, global use of fresh water including in dry land has expanded, on average, 25 % per decade. This implies that water stress will increase. There is a high degree of certainty that global climate change, land use development and land cover changes will lead to an accelerated decline in water availability and biological production (UNEP, 2002).

According to the United Nations Environment Program described in Sekar and Randhir (2007), more than two billion people will live under conditions of high water stress by the year 2050, suggesting that water could be a limiting factor for development in several regions of the world. Desertification will affect 70 % of the dry land, amounting to 3.6 billion ha, or one fourth of the world land surface (UNCCD, 2008). Asia has the largest land area affected by desertification, 71 % of which is moderately to severely degraded. For Latin America, this proportion is 75%. In Africa, two thirds of which is desert or dry land, 73% of the agricultural dry land is moderately to severely degraded. Therefore, water management is so important in many parts of the world.

Throughout the world, ancient water harvesting systems took place due to the spatial and temporal variations in water availability that made human settlements possible in a wide range of ecosystems. Local water harvesting dropped out with the development of large irrigation systems in which water is carried out long distance sometimes miles through canals and pipes or pumped from great depths below the ground. However, growing scarcity and inter-sectoral competition for water, along with groundwater depletion and the problems facing major surface water control systems, have raised interest in revitalizing water harvesting systems that capture rainwater wherever it falls. The monsoonal runoff, if flows uncontrolled, causes soil erosion and disaster, but if used appropriately can improve crop production in rain-fed areas and reduce land degradation and water induced disaster (Hudson, 1987).

Nepal is a country where 83 % of its people have been engaged with agricultural business. National economy has also been depending on agriculture which contributes about 66 % of the total GDP (Gross Domestic Product) (Central Bureau of Statistics, 2001). Water is the essential factor for successful agricultural production. Nepal has been facing with problems of too much water and too little water as more than 80 % of the rainfall occurs during the monsoon season, while rest of the year gets very low amount of rainfall. Both too much and too little water is problematic for agriculture production and water-induced disaster prevention. On average, 65 % of the total cultivated land is rain-fed. About 0.95 million ha (i.e. 24 %) of the cultivated land has received irrigation facilities. Running water is not a source of water for the hilly areas for irrigation and household uses as it is not feasible due to physical, technical, and financial constraints. The only sources of water for those remote districts are rainwater, natural springs, and lakes nearby the settlements (Chapa, 2002).

Making ponds to collect runoff water in rural areas of Nepal is indigenous practice. Traditionally, conservation ponds are very popular for storing excess runoff water, reducing erosion, allowing water to seep into the ground and to improve soil moisture in to the down-slope. The stored water is used for purposes such as watering cattle (*aahale*), raising fish, irrigation, and recreation. Thus, water harvesting is considered as a prudent and viable way to increase water availability in rural areas of Nepal (ICIMOD, 2007). Later on, runoff harvesting system has been developed under soil conservation and watershed management program since the establishment of the Department of Soil Conservation and Watershed Management (DSCWM) in 1974. At least two types of runoff harvesting system have been so far developed namely digging (dugout) type and dam type. The latest development of runoff harvesting system is dam type which has been practiced since 1996 (Department of Soil Conservation and Watershed Management, 2002).

Water harvesting is a useful technology to increase food security and biodiversity in drought prone areas and helps erosion control, pollution management, water-induced disaster prevention, and ground water recharge. Water harvesting in an area can solve to some extent the problem of water scarcity for household uses, livestock watering, irrigation, and disaster such as flooding, bank cutting, erosion, and sedimentation to keep people and their properties safe from disasters. These ultimately contribute to livelihood and overall wellbeing of the people living in the watershed. Hence, runoff harvesting systems of digging type and dam type have been implementing as an activity of watershed management in Nepal.

1.2 Statement of problems

Department of Soil Conservation and Watershed Management (DSCWM) of Nepal has been implementing various activities for soil conservation and watershed management, among them runoff harvesting system is one. The run off harvesting structures that have been practiced in Nepal are of digging type (i.e. dug out pond) and dam type for collecting runoff to create a reservoir for various uses such as household consumption like rinsing pots, washing clothes, bathing, cleaning house; livestock watering; irrigating farm land and homestead garden; recharging ground water; moisture retention; reducing water induced disasters like flooding, stream and gully bank cutting, siltation and soil erosion.

Runoff harvesting system of dam type has been implemented at later stage on a trial basis since 1995 especially in *Siwalik-Bhawar* area of *Terai* and inner *Terai* physiographic regions. Digging type has been implemented in hilly regions of Nepal after establishment of DSCWM in 1974. Dam type is a new type of runoff harvesting structure in Nepal and is being promoted in *Siwalik-Bhawar* area. Its scope of replication in terms of socio-economic, environment and technical aspect is still under consideration. How far it is effective for soil conservation and watershed management has not been studied yet.

Various problems have been faced by Runoff Harvesting Dam projects. Location of dams contributes to effectiveness of Runoff Harvesting Dams (RHDs). Some dams are ineffective as they are located far way from settlements. Some have long distance and physical constraint for conveyance system. Soil types at the site of the dam and ponding area determine the strength of the dam. The dams constructed in the sandy soil and conglomerates are not strong enough as it is easily eroded and water holding capacity is less.

District Soil Conservation Office (DSCO), Village Development Committee (VDC) and beneficiaries, i.e. User Group (UG) are the main stakeholders of watershed management activities. Some RHDs are not functioning well due to lack of proper participation of user groups in site selection and implementation. After 3-5 years, some RHDs completely silted up and the water quantity and quality decreased.

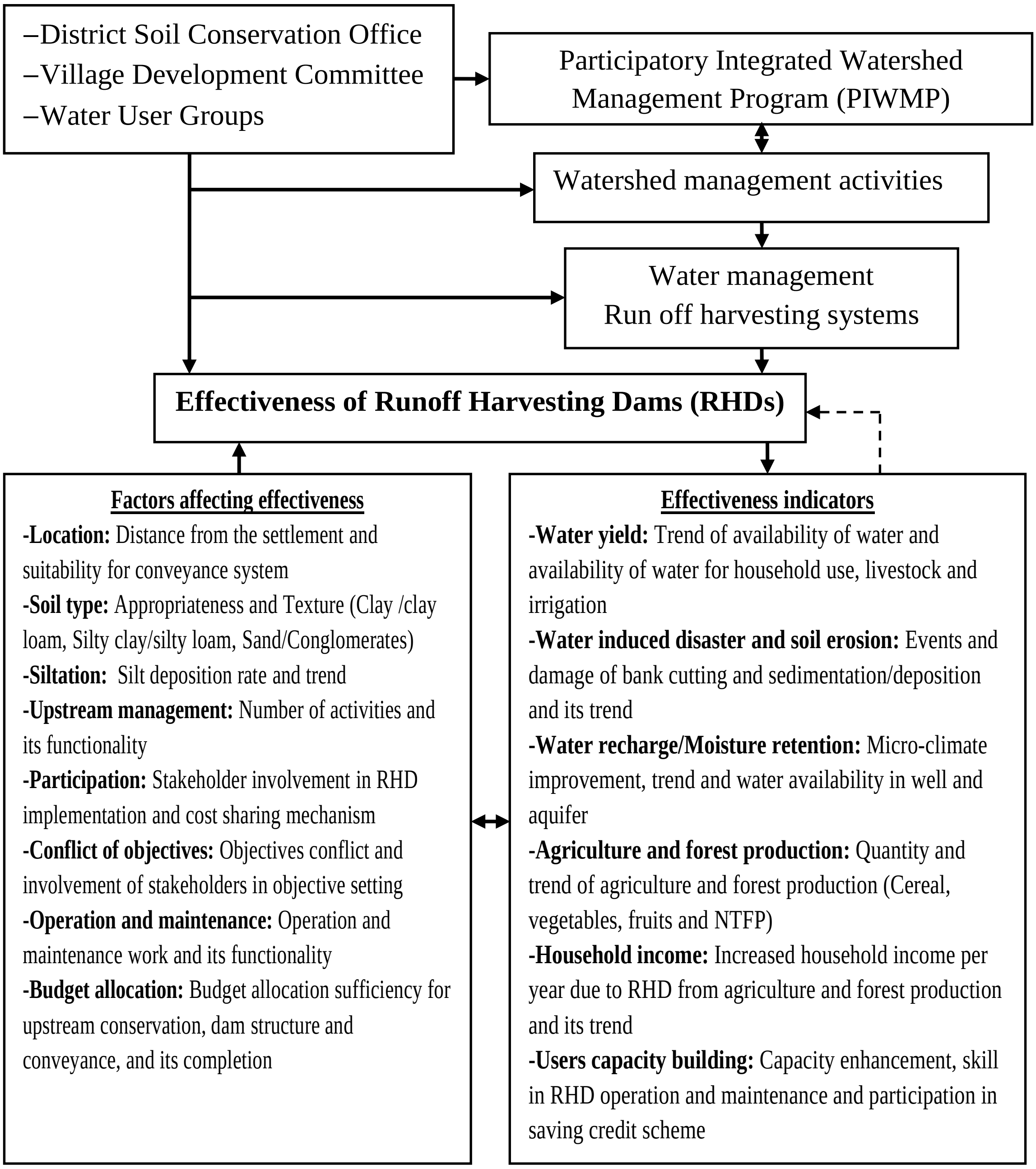
Conservation measures should have been implemented in the catchments. Because of un-willingness of local users for watershed treatment and budget deficit, some RHDs have and some have none of conservation measures. In addition, conflict of interest and objectives of RHDs among user groups and DSCO officials has greatly hampered their effectiveness. Water users and stakeholders have different interest than those of DSCO professionals that may cause negative effect in RHDs operation and maintenance.

There is sometimes and somewhere no proper operation and maintenance of dams, reservoirs, and associated watershed management activities. Due to this, RHDs become ineffective. Besides this, due to lack of budget, not all activities required for upstream conservation, dam and storage reservoir and conveyance system have been completed in one working season. This can cause incompleteness of RHDs.

Effectiveness of a runoff harvesting dam can be measured by availability of water or water yield; reduction in water induced disaster and soil erosion; moisture retention and ground water recharge; increase in production of agriculture and forest crops; increase of household income and capacity building of user groups in terms of knowledge and skill of water harvesting and user group functioning. Effectiveness of RHDs may be contributed by various factors such as those described above and probably many others. So far, there has been no previous systematic study carried out in any aspect of this in Nepal. In order to enhance the effectiveness of RHDs in Nepal, the researcher has identified the effectiveness level of RHDs and analyzes the contributing factors for their effectiveness. Better knowledge and understanding of how RHDs can work more efficiently, will further enhance the implementation of RHDs, soil and water conservation and watershed management in Nepal.

1.3 Conceptual framework

Figure 1.1: Conceptual framework



Factors affecting effectiveness

-**Location:** Distance from the settlement and suitability for conveyance system
-**Soil type:** Appropriateness and Texture (Clay /clay loam, Silty clay/silty loam, Sand/Conglomerates)
-**Siltation:** Silt deposition rate and trend
-**Upstream management:** Number of activities and its functionality
-**Participation:** Stakeholder involvement in RHD implementation and cost sharing mechanism
-**Conflict of objectives:** Objectives conflict and involvement of stakeholders in objective setting
-**Operation and maintenance:** Operation and maintenance work and its functionality
-**Budget allocation:** Budget allocation sufficiency for upstream conservation, dam structure and conveyance, and its completion

Effectiveness indicators

-**Water yield:** Trend of availability of water and availability of water for household use, livestock and irrigation
-**Water induced disaster and soil erosion:** Events and damage of bank cutting and sedimentation/deposition and its trend
-**Water recharge/Moisture retention:** Micro-climate improvement, trend and water availability in well and aquifer
-**Agriculture and forest production:** Quantity and trend of agriculture and forest production (Cereal, vegetables, fruits and NTFP)
-**Household income:** Increased household income per year due to RHD from agriculture and forest production and its trend
-**Users capacity building:** Capacity enhancement, skill in RHD operation and maintenance and participation in saving credit scheme

Department of Soil Conservation and Watershed Management, Nepal, has been implemented Participatory Integrated Watershed Management Program (PIWMP) in watershed scale. These activities have been implemented as an integrated package program taking continuum of watershed (i.e. micro-watershed, sub-watershed, and watershed) into consideration. Target beneficiaries i.e. user groups are in the center of the activities. District Soil Conservation Office on behalf of the

Department of Soil Conservation and Watershed Management of Government of Nepal, local people's representative unit i.e. VDC together with the local user group have been involved for planning and implementing the watershed management activities.

One important activity among various watershed management activities is the runoff harvesting system development under water management heading within which runoff harvesting dam project have been implemented since 1996. This activity is newly introduced and implemented in *Siwalik* and *Bhawar* area of Nepal. There are various indicators identified for effectiveness of RHDs for this study.

A RHD is effective if it gives positive changes in bio-physical and socio-economic conditions. Those conditions are such as increase in the water yield that can be used for irrigation, livestock watering and household consumption in terms of its availability and duration; reduction in water induced disaster in downstream areas like number of flood, bank cutting and sedimentation and deposition events and magnitude of damage; reduction in soil erosion like decreased rate of erosion; increase in moisture around the RHD attributed by moist environment with new growth of forest vegetation and agricultural crops; increase in agricultural production contributed by crop diversity, crop intensity and frequency; increase in forest production like Non Timber Forest Products (NTFPs), grass, fodder, fuel-wood and movement of birds and animals; increase in household income due to increase in agriculture, forest and livestock production and user's capacity building like gaining knowledge and skill on water management, saving credit scheme, participatory learning and action and user group functioning due to RHD project.

These positive changes would be possible when certain situation is met. These are the factors affecting RHDs' effectiveness. These may be numerous but only some of them are taken for this study. They are location; soil type of the site of RHDs; siltation in the reservoir; upstream conservation and management; stakeholder participation; conflict of objectives among stakeholders; operation and maintenance of RHDs and budget allocation in sufficient amount for implementation of RHD project.

A RHD would be effective if soil conservation and watershed management activities are implemented in an integrated fashion in upstream, downstream, dam structure, storage reservoir and conveyance. The assumption is that RHD project can be effective if certain conditions are met. Those conditions are participation of major stakeholders in all stage of project implementation, accessible location of RHD site from the settlement, site suitability for construction of conveyance system. In addition, other conditions are RHD site with clay or silty clay soil or have some soil compaction work on dam and reservoirs' surface, less siltation and/or have system of periodic distillation, consensus decisions among stakeholders for implementation of RHD project, operation and maintenance plan and its implementation, and allocation of required budget for construction of RHD structure, conservation storage, conveyance system and upstream conservation. Thus, all these would contribute to increase in water quantity, reduce in disaster and rate of soil erosion, improve microclimate with increased moisture for growing new vegetation and agricultural crops, and increase in production which contributes to increase user group members' household income and their capability for water management, environmental protection, micro finance and health improvement through group mobilization and strengthening.

1.4 Objectives

The objectives of this study are:

1. To measure the level of effectiveness of runoff harvesting dams in Nepal.
2. To analyze the factors affecting the effectiveness of runoff harvesting dams.

1.5 Research questions

The research questions of this study are:

1. What is the level of effectiveness of runoff harvesting dams?
2. What are the factors affecting the effectiveness of runoff harvesting dams?

1.6 Hypothesis

The hypotheses of this study are:

1. Different RHDs have different levels of effectiveness.

2. Factors affecting the effectiveness of runoff harvesting dams in Nepal are location, soil type, siltation, upstream management, stakeholder participation, conflict of objectives, operation and maintenance and budget allocation.

1.7 Scope of the study

This study will be carried out in *Dhanusha* District of Nepal. This district covers *Siwaik*, *Bhawar* and *Terai* region of Nepal. Twenty-four runoff harvesting dam projects have been implemented after establishment of District Soil Conservation office in this district in 1996. Runoff harvesting dam projects have been considered suitable in *Siwalik* and *Bhawar* area as there are many tertiary waterways, rivulets, sunken valley in ephemeral stream and gullies in the foothill of *Siwalik*. In *Dhanusha,* all of these dams are constructed in *Bhawar* area; this is an area which lies in between *Terai* flat plain and *Siwalik* hill. This area is considered as the water recharge zone for *Terai* region and has too much water in the rainy season and water deficit in the winter. This area is also the source of silt, sediment and debris as the *Siwalik* is the youngest hills among the hills of Nepal and consists of loose earthen material. *Terai* region is an area significant for agricultural production. This area mostly has been using ground water which has been recharged by *Siwalik* and *Bhawar* as a source of irrigation for agriculture production, household consumption including drinking and livestock watering.

The runoff harvesting system of dam type is taken for this study. The associated user groups' settlement of about 35 and 9 VDCs will be covered. There are mainly three key stakeholders i.e. VDC, DSCO and target beneficiaries or local users to plan, implement, operate and maintain the runoff harvesting dam projects which will be consulted during this research process. Water yield; water induced disaster and soil erosion; water recharge and moisture retention; agriculture and forest production; household income and user capacity building are the key indicators for effectiveness of runoff harvesting dams to be analyzed in this study.

Location, soil type, siltation, upstream management, participation of stakeholders, conflict of objectives, budget allocation and operation and maintenance have been analyzed as responsible factors affecting the effectiveness of RHDs in the course of this study.

1.8 Expected outcome

The level of effectiveness of runoff harvesting dams in Nepal and factors that contribute to the effectiveness of RHDs will be better understood. Policy and implementation decisions and guidelines for more effective and efficient implementation of RHDs as an activity of watershed management will be possible.

1.9 Definition of terms

Conservation storage

Water impounded for later release for useful purpose, such as drinking, livestock watering, household consumption, municipal supply, irrigation and power.

-FAO (2000)

Ephemeral stream

A stream that flows only in direct response to precipitation, receiving no water from springs, and no long-continued supply from other sources; its channel is at all times above the water table.

-PCARRD-DOST-DENR-FMB-DA-UPLB-CFNR-FDC/ENFOR (1999)

Integrated Watershed Management

The process of formulating and implementing a course of action involving natural, introduced and human resources of a watershed, taking in to account the social, economic and institutional factors operating within the watershed and the surrounding and other relevant regions to achieve specific objectives.

-PCARRD-DOST-DENR-FMB-DA-UPLB-CFNR-FDC/ENFOR (1999)

Ground water

Water that occurs in zone of saturation, from which springs or open channels are fed; term is sometimes used to include the suspended water as well; also called sub-surface water, underground water or subterranean water.

-PCARRD-DOST-DENR-FMB-DA-UPLB-CFNR-FDC/ENFOR (1999)

Microclimate

The climate within a very small area of the earth’s surface which are different from the outside area such as a small forest patches, a horticulture garden or a corn field etc.

-Brooks, K.N., Ffolliott, P. F.,Gregersen, H.M. and John, L.T. (1990)

Runoff harvesting

Runoff harvesting can be defined as the process of concentrating rainfall as runoff from a larger catchment area to be used in a smaller target area. This process may occur naturally or artificially. The collected runoff water is either directly applied to an adjacent agricultural field (or plot) or stored in some type of (on-farm) storage facility for domestic use and as supplemental irrigation of crops.

- Oweis, T., A. Hachum, and J. Kijne (1999)

Runoff harvesting dam

Small earthen dams; cement stone masonry dams with earthen cover; Reinforced Cement Concrete (RCC) core walls with earthen outer layers constructed based on site requirement across the gullies, deep valleys, ephemeral stream rivulets, and water channel to store excess runoff water during peak monsoon from the catchments for various use. They are household use, livestock watering, small scale irrigation, prevention of water induced disaster and soil erosion and ground water recharge.

-Saini, S. S., (2007)

Soil and water conservation

A field of human endeavor included in the concept of “watershed management” but specifically devoted to the prevention of soil erosion, the preservation of soil fertility, and the effective use of water resources and moisture conservation for human good.

-PCARRD-DOST-DENR-FMB-DA-UPLB-CFNR-FDC/ENFOR (1999)

Watershed

A topographically delineated area of land from which rainwater can drain, as surface runoff via a specific stream or river system to a common outlet points with may be a dam, irrigation system or urban water supply takeoff point, or where the stream discharges in to river, lake or the sea.

-Menon (2008)

Watershed Management

1) The process of guiding and organizing land and other resource uses in a watershed to provide desired goods and services without adversely affecting soil and water resources; 2) the application of business methods and technical principles to the manipulation and control of watershed resources to achieve a desired set of objectives such as maximum supply of useable water, minimization of soil erosion and siltation problems, and reduction of flood and drought occurrences.

-PCARRD-DOST-DENR-FMB-DA-UPLB-CFNR-FDC/ENFOR (1999)

CHAPTER II

LITERATURE REVIEW

This chapter intends to review accessible literature related to runoff harvesting system with reference to watershed management and development. It reviews about watershed management, its importance and activities that can be implemented under it. It also reviews the runoff harvesting system in its scope of background, types, importance and methods with respect to watershed development. It describes various types of runoff harvesting system implemented in Asia and Africa. Moreover, it reviews the runoff harvesting system of dugout type and dam type implemented in Nepal. In addition, it describes the effectiveness indicators and factors of effectiveness of runoff harvesting system. In last, it reviews some of the research findings of runoff harvesting system implemented in various courtiers.

2.1 Watershed management

2.1.1 What is watershed?

According to Brooks et al. (1992), a watershed is a topographically delineated area of land from which rainwater can drain as surface/subsurface runoff, via a specific stream or river system to a common outlet, which could be a dam, irrigation system or domestic/municipal water supply take off point, or where the streams/rivers discharge into large river, lake or the sea. A watershed is a part of a larger system stretched across the earth's surface, with adjacent watershed separated by boundaries or divides. It is a basic hydrologic unit and considered as a biological, physical, economic, and social systems.

Watershed comprises a catchment area (Recharge Zone), a command area (Transition Zone) and a Delta area (Discharge Zone). It is divided by "ridge line" which is a line joining the ridge portions along the boundary of the watershed. A watershed is considered a logical unit for planning and development of its soil, water and biomass resources (Gregersen et al, 2007).

2.1.2 What is watershed management?

According to Shukla, (2004), watershed management is the management of soil, water, and vegetation in watershed line for the sake of people living in the watershed. Watershed management has been done in order to meet the watershed functions in a direction that keeps the watershed in a good condition and safe for life. The watershed functions can be categorized as hydrologic function like collection of water from rainfall, storing it at above and below ground in various amounts and for different times and releasing water as runoff and ecological function like providing sites for geo-chemical reaction and habitat for flora and fauna.

It seeks the integrated approach of resource management for restoring, rehabilitating, and maintenance of ecological systems. The important point of watershed management is the strategy for protecting livelihood of people inhabiting the watershed who have been experiencing soil erosion and moisture stress. The aim has been to ensure availability of drinking water, fuel wood, and fodder and raise the income and employment of people. Watershed management is a part of the broader concept of natural resource management. Thus, watershed management is one of the approaches towards sustainable natural resource management (Loi, 2005).

Sustainable watershed management is crucial. Sustainability involves ensuring a long term supply of adequate quantity and quality of water. At the same time, adverse economic, social, and ecological impacts should be minimized. Equally, it should maintain the structure and function of natural system (Diane, 2002).

According to DeBarry, (2004) sustainable watershed management involves informed decision-making in a complex system of biophysical, social, and economic environment. Decisions involve the allocation of resources, formulation of policies, strategy, and plan, and manipulations of natural resources present in the watershed or hydrological basin. Watershed management requires a multidisciplinary, holistic, and integrated approach. An ecological approach to managing the watersheds recognizes the interconnectedness and relationships of mutual dependence between the ecosystems.

Watershed management is thus strategy to plan and implement activities in a judicial manner so that the optimum balance between use and regeneration of watershed resource can be ensured and well being of the people can be maximized.

2.1.3 Why watershed management is needed?

Satterlund and Adams (1992) have explained watershed management as the holistic approach of natural resource management which includes primarily soil conservation, crop management, fodder development, forest conservation, and water management. Managing watershed may differ as per requirement of place, region, and country; size of the watershed and demands of the people. It is difficult to identify certain common objectives of watershed management. However, it is needed for conservation of moisture in dry and rainfed areas for optimal production; reducing soil erosion and ensuring water conservation; controlling of salinity and alkalinity; improving drainage; preventing floods and siltation in reservoirs; collection of surplus runoff in farm ponds and in ponds of drainage line for recycling, recharging and infiltration that leads to moisture conservation, recharging of ground water and allowing to increase water tables in wells and aquifers; meeting water demands for household use, drinking and cattle feeding; improving farm irrigation systems in order to increase productivity there by generating income and employment through harnessing of improved land and the agro climatic conditions.

According to Gardiner (1994), watershed management is needed for rain water management in order to regulate surface water and ground water that aims at providing quality water in sufficient quantity for different purposes as drinking water, irrigation, power generation, transport management, fishing and coastal resources. Watershed management is necessary for upstream and downstream protection from landslides, soil erosion, land degradation, flood, and sedimentation. Sustainable management of watershed resources can provide livelihood opportunities to the people through watershed goods and services such as water, forestry, agriculture, tourism, and industrial raw materials.

Menon (2008) described the importance of watershed management as “healthy watershed - healthy people”. Watershed management is thus needed in order to enhance quality and quantity of goods and services that watershed provides to the people. These are in the form of quality water in sufficient quantity, good food, good biodiversity, good income, and good health.

2.1.4 What are the activities of watershed management?

Watershed management is an art and techniques of managing watershed resources. Menon (2008) has described three main components of watershed management. They are land management, water management and biomass management. Each has different activities. There are structural, vegetative, production and protection measures applied for land management. Structural measures include activities like contour bunds, compartmental bunds, contour terrace walls and trenches, terracing, field bunds, channel walls, stream bank stabilization, and check dams. Vegetative measures include activities of developing grass cover, shrubs, mulching, vegetative hedges, pasture management, live fencing, and agroforestry. Production measures include mixed cropping, strip cropping, cover cropping, crop rotations, cultivation of shrubs and herbs, contour cultivation, conservation tillage, land leveling, use of improved variety of seeds and horticulture gardening. Protective measures include land slide control, gully plugging, stream, and river bank protection.

Water management involves storage of rainwater, runoff, surface water and ground water. The activities are runoff harvesting system development, development of ground water recharging mechanism and recycling of polluted water. Likewise, biomass management involves activities like eco-preservation; forest regeneration and conservation; plant protection and social forestry and increased productivity of animals. It also includes other complimentary activities such as income and employment generation activities; coordination of health and sanitation programs for better living standards for people; promoting eco-friendly life style and formation of forum of learning community. According to Brooks et al. (1990) described in Gregersen et al. (2007), some of the vegetative and structural measures to meet different objectives are presented in Table 2.1.

Table 2.1: Watershed management objectives and conservation measures.

Management objective	**Measures**	
	Vegetative	Structural
Maintain or increase land productivity	-Agro-forestry Practices -Reforestation or afforestaion -strip cropping, no or minimum tillage cropping, mulching or cover crops -Limiting grazing to sustainable levels	- Terraces (bench, broad based) -Contour ditches and furrows -Gully- control structures and grassed waterways
Assure adequate quantities of usable water	-Encouraging low water consuming species -Using appropriate land use measures to protect reservoirs and channels -Applying vegetative conservation measures in upstream and downstream catchment	-Water harvesting & irrigation facilities (Dam, pond and canal) -Reservoir and water diversion structures -Wells -Encouraging water saving technologies
Assure adequate water quality	-Maintaining or establishing vegetative cover in key areas like stream banks and water source areas - Controlling waste disposal -Using natural forests and wetlands as secondary treatment systems of waste water -Controlling grazing and developing guidelines for riparian systems	-Water treatment facilities -Developing alternate supplies (e.g. wells, water catchments)
Reduce flooding and flood damage	-Re-vegetating or maintaining vegetative cover to enhance infiltration and water consumption by plants -Zoning/regulating flood plain use -Protecting and maintaining wetlands	-Reservoir flood control storage -water diversion structures -Levees -Gully-control structures -Improving structures -Improving channels
Reduce the incidence of landslides	-Reforestation or afforestaion for soil stabilization -Maintaining good vegetative cover to promote infiltration of rainfall -Restricting residence and productive activities on steep unstable slopes	-Bench Terraces -Grassed waterways, drop structures, etc. to control overland flow
Reduce downstream sediment delivery	-Maintain vegetative cover on hill slopes, utilize similar practices to maintain or increase land productivity -Maintain healthy riparian vegetative systems and maintain perennial cover on flood plains	-Use similar structures as above to maintain or increase land productivity -Channel restoration

Source: Gregersen et al. (2007)

According to DSCWM, Nepal (2007), watershed management covers the activities related to land use development planning; community integrated watershed management; nursery establishment and seedling production; community soil conservation and extension, maintenance and operation of conservation activities; monitoring and evaluation of conservation program; user group mobilization, empowerment and strengthening and technology development, study, research and mapping.

The activities related to the land use development planning are sub-watershed prioritization, watershed and sub-watershed management plan preparation and providing technical services for land use development to the watershed people. It aims at making plans for implementation and allowing people for rational utilization and management of watershed resources.

Community integrated watershed management covers the activities related to land productivity conservation, development infrastructure protection, and natural hazard prevention. Main objectives are to improve land productivity status through soil and water conservation and applying land use management on the basis of land capability; to protect and stabilize the basic development infrastructures such as reservoirs, irrigation, roads and trails with the aim at improving the economic life of these infrastructure and ensuring their services; to protect life, land, property and natural resources from natural hazards. The activities are on-farm conservation, terrace improvement, degraded land rehabilitation, applying sloping agricultural land technology (SALT), agroforestry, fruit tree planting, fodder/grass plantation and grazing land management, road slope stabilization, irrigation channel improvement, trail improvement, shelterbelt, greenbelt and buffer strips development such as gully plugging, landslide treatment, torrent control, stream bank protection, water source protection, conservation pond construction and run-off harvesting dam. These are applied in temporal and spatial combination as an integrated package program in a site where watershed management is being carried out.

Nursery establishment and seedling production covers the activities of constructing nursery and associated facilities. It aims at producing appropriate seedlings for soil conservation and watershed development.

Community soil conservation and extension includes the activities of micro-catchment management, demonstration plots establishment and their management, support in rural soil conservation and income generating activities like bee-keeping, private nursery, mushroom, and vegetable growing. These activities are intended to raise the awareness level on soil conservation and watershed management of user group members, develop their knowledge and skills, and motivate them to participate in SCWM activities. In addition, it aims at supporting them for soil conservation and watershed management based income generation opportunities.

Maintenance and operation of conservation activities include the activities related to maintenance and operation of conservation works implemented in the previous year. The main focus is to prepare operation and maintenance plan and its implementation. Activities are based on its damage and operation needs prescribed in operation and maintenance plan. Operation of conservation works focus more on to harness the economic, social, and environmental benefit and sustaining the conservation works.

Monitoring and evaluation of physical conservation activities implemented in the field is on-going process. The activities under this are natural system monitoring; photo point monitoring, progress review meeting and monthly, trimester, half yearly and annual monitoring and evaluation report preparation.

User group mobilization, empowerment, and strengthening aim to mobilize and empower the user group to implement SCWM activities. It includes activities such as user group identification and formation, training/workshop/study tours, conservation education in schools, conservation day celebration and extension material production and distribution.

Technology development, study, research, and mapping include applied research, soil/water sample collection/analysis, mapping, and various types of testing/study/research and report preparation.

In addition, according to Yadav (2005), Soil Conservation and Watershed Management (SCWM) based Income Generating Activities (IGA) as complements to the SCWM program have been practiced in Nepal. They are included as part of integrated package program to contribute to household income of user group. They are vegetable farming, fruit tree plantation, and bamboo/broom grass/*nigalo* plantation, grass plantation, NTFP/herbal/medicinal plant plantation, mulberry plantation, cardamom plantation, ginger/*oal*/turmeric plantation, fodder tree plantation, vegetable farming, farm pond for irrigation and fisheries, mushroom farming, poultry, bee-keeping, rabbit rearing, bamboo craft, handicraft and NTFP processing like rhododendron squash.

As discussed above, watershed management is the integrated management of land, water, and vegetation. Water management is one component of watershed management. It includes the activities to regulate the runoff, stream flow and water source protection. It also includes collection of runoff to create a storage reservoir through damming and digging in order to enhance water use, allow recharge function and decrease water induced disaster. The important activities under water management are development of runoff harvesting system with arrangement of associated structure and conservation measures. DSCWM, Nepal has been implementing these activities under the community integrated watershed management program to meet watershed function of regulating runoff on surface and into the ground, soil, and water conservation and reducing water related disaster. It aims at improving natural environment, increasing forest and agricultural production thereby contributing to household income and employment. DSCWM has launched runoff harvesting dam project in integrated package program constructing the dam, conveyance system and watershed conservation activities in upstream, downstream and nearby watershed including incorporation of various watershed management based IGA as explained above.

2.2 Runoff harvesting system

2.2.1 What is runoff harvesting?

Runoff harvesting refers to the small-scale concentration, collection, storage, and use of rainwater which later become runoff for both domestic and agricultural use (FAO, 2000). This definition implies that the catchment area from which the water is drawn is larger than the command area where it is collected and used. It is a management of runoff water either in small drainage line or in a suitable place of watershed having some structures for collecting runoff and its distribution and structural and vegetative conservation measures in nearby catchment. It is collection and storage of runoff for different uses such as irrigation, household use, livestock watering and recharge. Thus, runoff harvesting system includes mainly 3 components namely catchment, conveyance and conservation storage.

A water harvesting system concentrates water into a storage system like reservoir or pond, or applies water directly to the soil in the cropped area. Thus, a water harvesting system involves a runoff-producing catchment area, a runoff collection scheme, a runoff storage facility, and a cultivated or cropped area. The runoff producing catchment is the most important component in a water harvesting system, since it is responsible for the quantity and quality of runoff water (Oweis et al., 1999 as cited in Abrisqueta et al., 2007). According to FAO (2000), runoff harvesting is defined as

> *the process of collecting and concentrating runoff water from a runoff area into a run-on area, where the collected water is either directly applied to the cropping area and stored in the soil profile for immediate use by the crop, i.e. runoff farming, or stored in an on-farm water reservoir for future productive uses, i.e. domestic use, livestock watering, aquaculture and irrigation. The collected water can also be used for groundwater recharge and storage into the aquifer, i.e. recharge enhancement.*

Thus, it is the collection of runoff through different means for fulfilling various requirements of water for ecological and hydrological improvements.

The runoff harvesting system for this study is defined as collection and storage of runoff from its catchment to pond or reservoir constructed either in water rivulets, deep valleys or some suitable/strategic place in watershed by providing facilities such as a dam for blocking the runoff, conveyance system for water distribution and some conservation measures in upstream, downstream and nearby catchment. The purpose of this system is to enhance the use of runoff water for irrigation, household use, and cattle feeding. In addition, its uses are a measure for soil conservation, downstream water induced disaster prevention and groundwater recharge and moisture conservation. Ultimately, it aims to contribute to local livelihood improvement through production, protection and income enhancement.

2.2.2 Importance of runoff harvesting for watershed management

According to Kerr (2002), runoff harvesting system fulfills the watershed management functions such as reducing incidence of downstream flood, soil and water conservation, ground water recharge, enhancing land productivity contributing to agriculture and forest production and biodiversity enhancement. In addition, it provides water for irrigation, household use, drinking, and cattle feeding. Runoff harvesting system also provides place for recycling of polluted water coming from watershed as non-point source. Ultimately, the runoff harvesting system will contribute to better socio-economic and environmental condition of watershed. The harvesting system significantly reduces peaks of surface runoff. It collects the runoff in storage system, prolonged the time of concentration, and releases it gradually, which reduces erosion hazards and water induced disaster in downstream.

FAO (2000) stated that water harvesting system has been implemented for many years in different areas all over the world to solve the problem of water scarcity in arid and semi-arid areas. Harvested water increases the water availability for garden and farm irrigation, livestock watering, aquaculture and other domestic needs. Water harvesting is a proven technology to increase food security in drought prone areas. Erosion control and recharge of ground water are additional advantages of water harvesting system.

Chapa (2002) explained that runoff harvesting dams have been techniques for holding runoff water to recharge ground water, trapping the debris flow or silt coming from upstream areas and minimizing flood problems at downstream areas, impounding water for irrigation purpose to downstream areas, providing water to wild and domestic animals, raising moisture regime in and around the region especially downstream areas, increasing and maintain bio-diversity and serving recreation purpose such as picnic, fishing and eco-tourism. It implies that runoff harvesting system of various types can help meet the hydrological and ecological functions of watershed thereby enhance the environment and production.

2.2.3 What are methods of runoff harvesting?

Rainwater can be collected from roofs, later on from ground surface as runoff. In addition, it can be collected from seasonal streams, gully, or torrent which is also called flood water runoff harvesting. The harvested runoff is normally collected from its watershed in the form of sheet, rill, and gully and stream flow. This runoff then is stored in pond or a storage reservoir with some structures like tanks, dams. Other storing is directly seeped into the soil or sand. Thus, the methods of runoff harvesting are reservoir system and soil moisture storage system (Agromisa, 1997 cited in Rockstrom, 2000).

According to Hudson (1987), every run off harvesting system has runoff area (i.e. catchment) and run on area (i.e. storage area). Catchment areas are diversified as roof tops, courtyards, streets, public squares; treated or untreated small ground surfaces and slopes of small to large areas and large catchment areas that feed water to seasonal water courses. Similarly, run on areas or storage media are diversified as underground storage in soil, sand, sediments, and cisterns and above ground storage in tanks and jars, ponds and reservoir. Water-harvesting systems work in two ways either concentrates water into a storage reservoir or apply water directly to the soil in the cropped area. Both methods of runoff harvesting can vary in scale from a few square meters benefiting a single household to a few square kilometers serving a larger group of people.

Kerr and Pangare (2001) described a reservoir system of runoff harvesting as the concentration of runoff into a storage reservoir called conservation storage. The reservoir system is in the form of village pond and reservoir in gullies, seasonal stream, and rivulets by providing dam across it. The stored water can be used for a variety of purposes such as household and livestock consumption and irrigation. It also recharges groundwater to a number of local wells. In soil moisture storage system, runoff is channeled directly to the cropped area during rainfall and stored in to the soil profile. Where rainfall is unevenly distributed and soils have high water-holding capacity, this system may store water until the end of the rainy season, when a crop is grown under gradually receding moisture. Where soils are sandier and do not retain moisture for a long time, moisture may be channeled spatially to the location where crops or trees can take advantage of.

Based on the above review, there are two methods of runoff harvesting. They are reservoir type of runoff harvesting and soil storage type of runoff harvesting. In other words, runoff can be harvested and stored in reservoir or in soil profile. Thus, the methods of runoff harvesting can be categorized as reservoir and soil moisture storage type. For this study, the researcher is focusing at runoff harvesting dam which is reservoir type and will analyze the effectiveness indicators in order to measure its level of effectiveness and factors affecting its effectiveness.

2.3 Review of runoff harvesting in Africa and Asia

2.3.1 Background

Worldwide distribution of precipitation is varied. The available precipitation is very little in Sub-Saharan Africa, southern Asia, and north-western China causing the area's most water deficit. Therefore, rain water harvesting in the form of runoff collection has traditionally been used in those areas. The history of water harvesting in Asia can be traced back to about the 9th or 10th Century. The small-scale collection of rainwater from roofs and simple brush dam constructions across the seasonal water courses in order to harvest runoff in the rural areas of South and South-east Asia was common in the past (IFAD 1992).

According to FAO (2000), in Asian countries, run off harvesting was traditionally used in Jordan (since 7000 B.C.), Mesopotamia (since 4500 B.C.), Palestine (since 200 B.C.), Yemen (since 1000 B.C.), Pakistan, India, Sri Lanka and China (since 1200 B.C.). The Asian countries which are still implementing water harvesting system are India, China, Vietnam, Thailand, Myanmar, Philippines, Jordan, Iran, Syria, Saudi Arabia, Oman, Yemen, Afghanistan and Pakistan. African countries like Morocco, Algeria, Egypt, Chad, Mali, Niger, Sudan, Ethiopia, Kenya, Tanzania, and Zambia have been implementing runoff harvesting since long time. Other African countries such as Tunisia used runoff harvesting in the name of *Meskats, Mgoud* and *Jessours;* Somalia used it in the name of *Caag* and *Gawan* system; Sudan used it in the name of *haffire* and *Teras* and Burkina Faso in the name of *Pits.* The areas *Ader, Doutchi* and *Maggia* of Niger of Sub-Saharan African Country has used rock bunds, stalks and earth for water diversion to the cropped field (soil moisture storage). In Burkina Faso, people have used rock bunds (i.e *Mossi*), pits (i.e.*Zay*) and stone terraces as water harvesting structure. In Mali, stone constructions in macro catchments are being used. In *Ouaddai* area of Chad, small check dams have been used. In *Turkana* and *Barringo* area of Kenya, various types of traditional water harvesting system of both soil moisture storage, and reservoir type of runoff harvesting system have been practiced. Water harvesting has high potential in sub-Saharan Africa. Current harvesting is still less than its potential capacity.

In the Middle East, archaeological evidence of water harvesting structures has been found in Jordan, Israel, Palestine, Syria, Iraq, the Negev and the Arabian Peninsula (mainly the Yemen). The oldest was believed to have been constructed over 9,000 years ago (Bruins et al., 1986).

The runoff harvesting systems of soil storage type called runoff farming have been found in the semi-arid to arid *Negev* desert region of Israel. Evidence revealed that simple runoff harvesting structures were used for farming in Southern Mesopotamia as early as in 4,500 BC. In Yemen, small dams for storing runoff for irrigation or rural water supply have been constructed since the beginning of the eighties (Bamatraf, 1994).In Asian region**,** India has a great variety of rain water harvesting techniques developed over the last 2,000 years (Chapa, 2002).

2.3.2 Rainwater harvesting from roof-top

Rainwater harvesting from the house roof is an accepted technology in Asia for getting freshwater. This technique was promoted by government organizations through community involvement in different parts of Asia (Hudson, 1987).

Rainwater collection from the eaves of roofs via simple gutters into traditional jars and pots has been traced back almost 2000 years in Thailand. Both government and household initiatives played key roles in expanding the use of this roof water harvesting technology in water scarce areas. During the 1980s, this was expanded rapidly. More than ten million 2 m^3 ferro-cement rainwater jars were built and many tens of thousands of larger ferro-cement tanks were constructed between 1991 and 1993 and distributed in water scarce areas in northeastern Thailand. There were some problems in early period in the design of jar which were quickly addressed by using metal cover. The jar program for harvesting the roof water was successful because it was affordable thus got high community participation. This was supported not only by the citizens, but also by the government at both local and national levels as well as community based organizations, small-scale enterprises and donor agencies. More than 50,000 tanks were built between 1986 and 1993 only in Thailand (FAO, 2000). The technology is appropriate for dry areas where settlements are located at ridge tops; where to bring water through network of pipes is difficult (Siyal and Sharma, 2002).

Rain water collected from clean roofs and stored in a clean storage can be of better microbiological quality than water collected from untreated household wells and springs. However, rain may contain impurities from the atmosphere and can include lead and arsenic. This is an important issue in industrialized areas and use of rain water should be determined from the quality. Therefore, water quality test is advisable before drinking rain water (WHO, 1997).

2.3.3 Runoff harvesting through flood diversion

A very old flood diversion technique called "*warping*" is found in China's loess area which harvests runoff water as well as sediment into the cropped field (UNEP, 1983).

Water harvesting in streams is done in *wadis* by blocking the flow using stones. Sediments and water are accumulated in upstream of each dike and trees are planted on dike. This system is called “*jessour*” in *Matmata* region of Tunisia where trees such as olives, almonds, figs, pomegranates are grown (Ambani, 1984; Nasri et al., 2004 and Ennabli, 1993 cited in Schiettecatte et al., 2005).

2.3.4 Runoff harvesting tank

In many areas, the "tank" system is traditionally used and it is the backbone of agricultural production. About 40,000 storage tanks also called farm ponds, in a variety of different forms and sizes, were constructed between 1970 and 1974 in order to store rainwater and storm water runoff in China. A thin layer of red clay is generally laid on the bottom of the ponds to minimize seepage loss. Trees, planted at the edges of the ponds, help minimize evaporative loss from the ponds (UNEP, 1983).

The tanks that collect rainwater are constructed either by bunding or by excavating the ground. It is estimated that 4 to 10 hectares of catchment are required to fill one hectare of tank bed. Out of the 46 million hectares under irrigation in India, about 6 million hectares are irrigated by runoff harvested and collected in water tanks or farm ponds (Agarwal and Narain, 1997). In other South Asian regions, concept of pond at low land seems to be common (Chapa, 2002).

2.3.5 Runoff farming

In India, winter rains are uncertain and mostly arrived too late. As per records, the dry spell between September and December 2000 was one of the longest. This long dry spell left a trail of miseries. Most of the rainfed farmers could not sow *rabi* crops. Those who ventured and had sown the seed, the crops completely wilted after germination. However, in those villages where harvested rainwater was available, the farmers could use this water to sow their crops in time as usual and the impact of this long dry spell was not at all felt by these farmers. The only alternative for sustainable crop production in such region, is therefore, “runoff farming.” i.e., harvesting surplus rainwater during monsoon and use it for providing supplemental irrigation as and when needed. (Mittal and Aggarwal, 2001).

According to Kolarkar et al. (1980), in central India, a very old cultivation system based on water harvesting of runoff in the Narmada valley in Madhya Pradesh locally known as *haveli* still exists. It is practiced in areas with black cotton soil. Fields are embanked with one meter height on four sides. Rainwater remains in the field until the beginning of October. A few days before sowing winter crops (*Rabi*), the excess water is drained off. Water is let out slowly and gradually. The cultivators know from long experience which field ought to be drained first. The water from one field enters into another, and then another till it joins the natural drainage or lake. There is a mutual understanding amongst the farmers as to when to release the water.

In West *Rajastan*, India, the place of desert-like condition which has only 167 mm annual precipitation. In this place, large bunds to accumulate runoff were built. These bunds locally called "*Khadin*" created a reservoir which could be emptied at the end of the monsoon season to cultivate wheat and chickpeas with the remaining retained moisture. A similar system locally called "*Ahar*" was developed in the state of Bihar (Kolarkar et al., 1983).

In Baluchistan of Pakistan, two runoff water harvesting techniques were already applied in ancient times: the "*Khuskaba*" system and the "*Sailaba*" system. The first one employs bunds built across the slope of the land to increase infiltration. The latter one utilizes floods in natural water courses which are captured by earthen bunds (UNEP, 1983).

2.3.6 Macro-catchment runoff harvesting

This is suitable in catchment areas of slopes and cultivated areas lying in the drainage bottomlands below the catchments. The ratio of catchment to farm plots varied according to the amount of runoff. The farm plots were constructed with rock dikes across the water courses, thus accumulating and conserving soil inside the plots. The catchment slopes were modified to maximize runoff. Stone conduits were built to carry water to various parts of the bottomland farm plots in needed amounts. The cropping systems varied according to the size of the watershed and its drainage channels. Records showed that varieties of crops were grown, including barley, wheat, legumes, grapes, figs, and dates. This system of runoff harvesting was practiced in Yemen (Bamatraf, 1994).

Macro catchment or long slope water harvesting consists of a hill slope catchment where runoff is brought to a planted area with infiltration basins. In the Tunisian *Bou Hedma* region and *Ben Younes* Mountains, the long slope water harvesting system is called *"tabia*" and the harvesting from an external macro catchment is called *"mgoud"* in *Matmata* region (Ambani, 1984; Nasri et al., 2004 and Ennabli, 1993 cited in Schiettecatte et al., 2005).

2.3.7 Micro-catchment runoff harvesting

In Jordan, earth dam has been constructed to allow infiltration in pasture land since 1964. Rock dams, contour stone bunds, trapezoidal bunds and earth contour bunds were used to increase soil moisture around the trees planted on steep lands. The total area utilized since its inception was estimated to be 6,000 hectares. Contour terraces and ridges were used for run off harvesting in pasture and range improvement and olive tree plantation (Prinz 1996).

According to Ambani(1984); Nasri et al.,(2004) and Ennabli, (1993) cited in Schiettecatte et al.,(2005), micro catchment water harvesting is a practice to collect surface water from a small runoff area for infiltration in a basin where trees or crops are cultivated. Olive trees are planted in micro catchment systems called "*meskat*" in the Tunisian Sahel region.

2.3.8 Runoff harvesting dam

The concept of runoff harvesting dam is age-old practice in South Asia. It is very profound in Sri Lanka and India and recently has been practiced in Nepal (Chapa, 2002).

Small earthen dams; cement stone masonry dams with earthen dams; Reinforced Cement Concrete (RCC), and stone cement masonry core walls based on site requirement with outer layer of earthen dams are constructed across gullies, deep valleys, ephemeral stream rivulets, and water channel to store excess runoff water during peak monsoon from the catchments. It provides life saving irrigation, drinking, and protection of land from erosion due to runoff. In addition, it works for recharging of ground water and improvement of ecology. Use of construction material depends on size of the dam; availability of local construction material for example stone; size of the catchment and rate of annual rainfall and construction site. It varies the use of earthen material, stone, cement, concrete and iron rod depending on the site (Saini, 2007).

Various National and International NGOs and government organizations in *Karnataka*, *Madhyapradesh*, *Andrhapradesh*, *Maharashtra* and *Punjab* states of India have practiced runoff harvesting system of dam type since 1975 in the foothills of *Shivalik* hills locally called *Kandi* area. District Soil Conservation Office of *Terai* and inner *Terai* regions of Nepal namely *Siraha*, *Saptary*, *Udayapur* and *Dhanusha* have practiced RHD project as an activity of watershed management in *Bhawar* area of *Siwalik* foothills since 1995. It was later expanded to other districts of *Terai*, though it was in trial basis (Chapa 2002).

Based on above review, runoff harvesting has been practiced around the world since long time. Water deficit area of Asia and Africa has been benefited by applying various techniques of runoff harvesting of soil moisture storage and reservoir type. They are rainwater harvesting from roof top, flood diversion to cropped area, use of storage tanks or ponds, runoff farming, macro-catchment, micro-catchment and runoff harvesting dams.

2.4 Review of runoff harvesting in Nepal

The Himalayan country, Nepal, most often faces problems of water stress in various parts of the country though it is considered to be one of the richest countries in the world in terms of water resources. The majority of the country's land is steep hill slope. Out of total land area, 76.9% are mountains and hills that are home for more than 52% (about 12 Million) of the total population. This population has been facing with most severe water related stress due to its scarcity. In contrast, 23% of the land area of Nepal covered by *Terai* belt has been facing problems of flooding (Central Bureau of Statistics, 2001). More than 80% of the total rainfall occurs in Monsoon (June -September).Therefore, Nepal observes too much water in four months during monsoon and too little water in rest of the months in a year. More than 80% of the total population depends upon agriculture for their livelihood. On an average, 65% of the total cultivated land is rainfed. About 0.95 million ha (about 24 %) of the land area received irrigation facilities in 2001 (Department of Soil Conservation and Watershed Management, 2002).

Only 3% of the total area of Nepal is covered by water bodies which become the country's largest natural resources. Among 6,000 rivers in Nepal, 1,000 are longer than 11 km and 100 are longer than 160 km. 74% of the annual runoff (4,700 m^3/s) is accounted by the three major snow fed rivers: *Koshi*, *Gandaki* and *Karnali*. The mountain regions of Nepal receive surface and rainfall water, as there are no ground water resources excepting springs and lakes in some parts of the country. Running water is not source of water for the hilly areas for irrigation and household use as it is not feasible due to physical, technical, and financial constraints. Only sources of water for those districts are rainwater, natural springs, and lakes. Therefore, water harvesting is prudent and viable way to increase water availability in rural areas of Nepal (Chapa, 2002).

People have traditionally been using ponds in order to harness water for their livelihood improvement. People have practiced earthen dug out ponds that are simple, cheap, and durable. It was their indigenous knowledge based on trial and error experience to build a pond and supplying water to household use, livestock watering, and home gardening (vegetable farming) in the hilly areas of Nepal. In *Terai* region, ponds were popular for fish farming. After establishment of Department of Soil Conservation and Watershed Management in 1974, runoff harvesting ponds have been implemented to meet watershed functions such as moisture conservation, irrigation, disaster prevention, and biomass production. In addition, it has intended to supply water for household use and cattle feeding. The Department has been trying to make it cheap and simple technology by integrating scientific knowhow and indigenous knowledge so that people can adopt it in their capacity. Some international non-governmental organizations such as ICIMOD, IUCN, and Netherland Development Cooperation (SNV) and national and local NGOs (Water Development Fund Board, Practical Action, Nepal, Alternative Technology Promotion Centre, Nepal, Nepal water Conservation Foundation and Water Aid Nepal etc.) have been involving in implementation of runoff harvesting system research and development. Roof-water harvesting has been practiced and gradually becomes popular among household of rural setting. Some NGOs have been involving with rainwater harvesting from roof top by using home-constructed low cost ferro-cement jars for water collection (ICIMOD, 2007).

Runoff harvesting system has been developed and promoted under soil conservation and watershed management program since establishment of DSCWM in 1974. Realizing the importance of water for people’s livelihood, runoff harvesting system has received high priority. It has been known by various names such as watershed conservation ponds, farm ponds, catchment ponds, multi-purpose runoff harvesting ponds, runoff harvesting dams, water harvesting tanks, and water source protection. They are constructed under same concept differing in construction sites and implementation domain. The sites for construction of runoff harvesting system varied from ephemeral streams, rivulets and gully channel, valley floor, marginal land and farm land (Department of Soil Conservation and Watershed Management, 2002).

Annual progress report of DSCWM, 2002/2003 has shown that 632 runoff harvesting systems have been so far constructed across the country. They are of all sorts of runoff harvesting systems under various names as explained above. Most of the runoff harvesting systems has been implemented in the name of watershed conservation ponds and farm ponds in mid hills of Nepal since the establishment of the Department in 1974. Since 1995, 13 out of 24 District Soil Conservation Offices in *Terai* (i.e. a physiographic region in most southern part of Nepal) have been implementing runoff harvesting systems of dam type. Runoff harvesting systems of dam type, sometimes called runoff harvesting ponds are normally constructed across the stream rivulets and gullies and collect runoff or flood water during rainfall and allow slowly percolating water into the ground. In addition, RHDs slow down the velocity of flowing runoff, increase the time of concentration of flood water and gradually discharge the water. RHDs trap the sediment in one hand and reduce flood damage on the other (Department of Soil Conservation and Watershed Management, 2004).

According to the progress report of District Soil Conservation Offices in *Terai* districts, more than 150 runoff harvesting dams had been completed in *Siraha*, *Saptari*, *Udayapur* and *Dhanusha* districts until 2002/2003. Runoff harvesting dam constructed at *Jandol* of *Saptari* in 1995 was the first one ever constructed in Nepal. This dam is still working for flood control, ground water recharge and moisture retention. The moisture due to this dam allows for *Babio* (*Eulaliopsis binata*) grass cultivation inside the forest. This grass has been used for local paper factory. Forest user group has been gaining income (Department of Soil Conservation and Watershed Management, 2004).

Thus, runoff harvesting system has been developed in Nepal by combining indigenous knowledge with scientific techniques. The runoff harvesting system of dam type is the latest practice in Nepal. It was firstly introduced in Districts of *Terai* region in 1995.

2.5 Effectiveness indicators of runoff harvesting dams

According to Doolette and Magarath (1990) described in Van Dijk (1997), the success of runoff harvesting system could largely be measured through standard economic evaluation, rate of runoff, soil moisture, erosion, sedimentation and crop yield, forest/ NTFPs and land productivity. This implies that these are some indicators indicating the effectiveness of runoff harvesting system.

Rainfall and soil water are fundamental parts of any terrestrial and aquatic ecosystem which supplies goods and services to the human wellbeing. Availability and quality of water determines the agriculture and forest productivity and human health. Rain water/runoff harvesting is the collective term for a wide variety of interventions to use rainfall through collection and storage either in soil or in manmade dam, tanks, pond or container. The effect is increased availability of water for its productive use (Konig and Uberlingen, 2009).

Watershed management interventions through runoff harvesting are often synonymous to soil and water conservation. They act both to harvest rainfall and to conserve soil and water. Due to various runoff harvesting structure like bunding, check dams and small dams, the water induced disaster like stream and gully bank cutting, sedimentation and deposition on productive farm lands will be reduced. Conservation activities implemented in the watershed as part of runoff harvesting system will help in the reduction of siltation in storage reservoir that in turn reduce the need for maintenance. Thus, runoff harvesting dam project acts against water induced disaster and soil erosion (Cortesi, Prasad and Abhiyan, 2009).

Ground water recharge in the watershed management can be induced through various runoff harvesting structure such as dug shallow wells; storage pond and tanks; and small dams and percolation tanks. Moisture in the soil can be enhanced through in-situ and ex-situ runoff harvesting system such as contour furrow, conservation tillage and flood water irrigation and water application to the farm field through conservation storage of the runoff harvesting dam. The soil moisture has been retained in the soil profile which is used by the crops in, around and downstream of the runoff harvesting system (Cortesi, Prasad and Abhiyan, 2009).

The use of harvested water expands the irrigated area and increase the cropping intensity through in-situ and ex-situ rainwater harvesting. The improved water availability in the soil and irrigation has enabled farmer to grow a second crop in the winter season after the usual monsoon season. The additional cash crops, fruits and vegetables can be grown. The moisture retained in the soil of the forest floor allows growing and planting of NTFP and forest stand improvement. This leads the increase in agriculture and forest production (Sharma, 2009).

Runoff harvesting can be an instrumental to decentralized water supply and thereby local food security. It has been proven that the overall increase in crop output from winter crop, homestead garden, timber, NTFP, fodder and grasses bring positive impact in food consumption and economic security. Farmers earn additional income through the sale of surplus agriculture, forest and livestock production (Sharma, 2009).

Involvement of the local community is the key to success the runoff harvesting structures. Their contribution and building up the capacity for operation and maintenance is important. Difference in water user groups either in aspects of gender, ethnicity, economy, can lead to difference in managing and operating the runoff harvesting structures (Saini, 2007). The implementation of runoff harvesting dam project under watershed management seeks community participation which involves largely the target beneficiaries (i.e. user groups). User groups are actively involved through community organization called user group committee. The value of community organization enabled through implementation of runoff harvesting in the watershed has strengthen communities to address other issues in relation to development of health, environment, income and their livelihood. These are the important benefit which can further help individuals and communities to improve both ecosystem management as well as their well being. There is increasing evidence that watershed management with runoff harvesting has strengthened social capital which in turn can have a significant impact on development of other ecosystem services due to enhanced capacity of user groups in terms of knowledge and skill of resource management (Barron, 2009).

Runoff harvesting dams would be effective when they meet hydrological and ecological functions in a sustainable manner thereby support the livelihood and capacity building of the local people. There are effectiveness indicators of runoff harvesting dams in relation with runoff harvesting systems. First and foremost is the increase in water availability that can be used for various purposes. Second is the reduction of water induced disaster and soil erosion. RHDs regulate the water flow, slow down the speed of runoff, prolong the time of concentration and safe release of water, and minimize the water induced disaster and soil erosion. Third is the ground water recharge and moisture retention. The harvested water in the reservoir gradually allows percolating and infiltrating into the ground which contribute to the quantity and quality of ground water available in downstream wells and aquifers. The microclimate around the dams/reservoirs can be improved due to increase in moisture that supports the growth of vegetation, agriculture crops, and biodiversity. Fourth is the increase in agricultural and forest production due to increase in water availability, microclimate improvement and decrease in soil erosion and disasters. Fifth is the increase in household income due to increase in agricultural and forest production. The last indicator is the user group capacity building due to RHD project. As user group members involve in various activities of RHD projects and receive various knowledge and skill development trainings, they will be capacitated in water resource management, operation and maintenance of RHD, carrying out SCWM based IGA, saving /credit and participatory planning, action and learning. User capacity built up is therefore taken as a one effectiveness indicator of RHD project. This study will focus on these 6 indicators in measuring the level of effectiveness of RHDs in Nepal.

2.6 Factors affecting effectiveness of runoff harvesting dams

2.6.1 Location

Location of runoff harvesting structure is very important for collection of runoff water, water distribution, accessibility of users to water, and its maintenance. Location of dam also determines the facilities to be provided for conveyance system. Suitable location of dam contributes to effectiveness of Runoff Harvesting Dams (RHDs), such as dams in the valley type gully collect more water than gully in plain and hill top and also it is cost effective. Some dams are ineffective as they are located far way from settlements. Some have long distance and physical constraint for conveyance system (Chapa, 2002).

According to Khanjani and Busch (1982), storage dam should be at the centre of the farm to minimize the pumping and the conveyance costs for irrigation. On farm storage ponds or dams should be located on low quality or non-productive land as far as possible. A good dam site should provide the maximum storage capacity with the minimum surface area to reduce the loss of productive land and water by evaporation. If the storage facility is located away from the runoff water source, a dugout or ground tank may be used. A natural depression may also be utilized.

The main aim of runoff harvesting is to supplement irrigation in water deficit period. Its proximity to cropping area can be an important point in improving water use efficiency and avoiding field losses. The accessibility of the site has also to be considered for construction of water harvesting structures and distance from village (Prinz and Singh, 2001).

2.6.2 Soil type

Soil type at the site of dam and reservoir determines the strength of the dam and quantity of water holding in the pond. Some ponds are constructed on the sandy soil and conglomerates which have low water holding capacity and so have less water storage volume. The dam filled with these sand and conglomerates have high chance of sliding and eroding due to piping effect caused by water pressure from the pond surface (FAO, 2000).

The suitability of a certain area either as catchment, as cropping area or as storage pond in water harvesting depend strongly on its soil characteristics. They are surface structure which influence the rainfall-runoff process, the infiltration and percolation rate which determine water movement into the soil and within the soil profile, and the soil depth including soil texture which determines the quantity of water which can be stored in the soil and storage pond (Prinz and Singh, 2001).

2.6.3 Siltation

Due to the degraded watershed in upstream area, some RHDs collect more of silt coming from the upstream rather than runoff. After 3-5 years, they have been completely silted up and worked as silt trap dam instead of runoff harvesting dam. Thus, the water quantity and quality decreased. It is basically determined by the land use type, extent of vegetation cover and conservation measure applied in the upstream area (DSCO, *Mahottari*, 2007). Cluff (1981) reported that problems associated with conservation storage include excessive evaporation, seepage loss and siltation. Siltation reduces the water holding capacity of the conservation storage. In a storage pond, where runoff water is collected, erosion in the catchment yielding sediment is a major problem. It implies that siltation is one factor among many that affect on effectiveness of runoff harvesting dams.

2.6.4 Upstream management

Conservation measures should have been implemented in the catchments, upstream drainage line and downstream besides single runoff harvesting structure. Suggested conservation measures include bamboo wattling, fascines, vegetative check dams, forest protection, grass plantation, afforestation and reforestation, gully plugging by gabion, stone and/or masonry check dam and land slide treatment. Some RHDs have these conservation measures but some do not because of un-willingness and negligence of local users for watershed treatment and budget deficit. Because of this, available water quantity due to erosion and siltation has been reduced. All these activities should be incorporated within integrated watershed management and development program (GTZ, Integrated Food Security Project, 2002).

2.6.5 Participation

One of the crucial social aspects for the success and effectiveness of RHD project is the participation of the stakeholders and beneficiaries. All stakeholders have to get involved in planning, designing and implementation of water harvesting structure. A consensus is necessary for operation and maintenance of water harvesting structures. Involvement of local NGOs may also benefit the community for collective action. Participatory management of water resources generated from runoff harvesting ensures effective utilization, maintenance and sustainable operation of the system (Prinz and Singh, 2001).

Worldwide, many projects have failed primarily due to lack of people's participation for mobilizing and utilizing their energies and resources in such programs. The consequences are wastage of public funds invested on construction of these structures, which generally fail after the rains every year and have to be reconstructed. Unless the program stakeholders, i.e. beneficiary and affected people are convinced and own to harvest, store, conserve, repair and maintain the resources by investing their time, energy and money (even partially), water harvesting and conservation projects cannot perform satisfactorily (Samra et al., 2002).

Social mobilization, decentralization and community empowerment are needed and to be included in government policies for success of community based runoff harvesting. Village institutions and local level water users' associations should be involved in the process. Traditional technologies of water harvesting and conservation can be harmonized with modern tools and techniques in order to incorporate local socio-economic and socio-cultural needs. It is suggested that watershed based planning and management of water resources should integrate runoff harvesting system development. Small and micro-water harvesting systems can be an integral part of the water resources development at the regional and national levels. Therefore, it demands the involvement of various stakeholders from planning to implementation and benefit sharing (Khan, 2001).

District Soil Conservation Office (DSCO), Village Development Committee (VDC) and beneficiaries, i.e. User Group (UG) are the main stakeholders of watershed management activities. Some RHDs became ineffective due to lack of proper participation of all stakeholders in site selection, cost sharing, benefit sharing, monitoring, operation, and maintenance (DSCO, *Dhanusha*, 2005).

2.6.6 Conflict of objectives

Soil and water conservation officers and assistants from DSCO aim at reducing water induced disaster like soil erosion and flood and enhancing water recharge for moisture conservation and water availability in the downstream area. Local users are interested in just fulfilling immediate water demand for irrigation and household use. Due to this conflict of interest and objectives of implementing run off harvesting structure, its effectiveness is hampered. Water user and other stakeholders with different in interest may cause negative effect in its operation and maintenance (GTZ, Integrated Food Security Project, 2002).

2.6.7 Operation and maintenance

Some RHDs have no proper operation and maintenance of dams, reservoirs, and associated watershed management activities. Even those that are well planned may not properly operate (Saini, 2007). This is because of lack of budget and ignorance of user groups, VDC and DSCO. Due to this, it becomes ineffective (GTZ, Integrated Food Security Project, 2002). Operation includes distribution of water among water users, its quantity, duration and timing. For this, consensus planning and regulation is necessary. Maintenance includes regular repair of conservation works in the catchment, embankment wall, dam and continuing of inlet, outlet, conveyance and overflow channel. To do all of these, comprehensive operation and maintenance plan is essential and enforced. Thus, regular operation and maintenance is necessary for long life, effectiveness and sustainable use of conservation storage.

2.6.8 Budget allocation

RHDs should be implemented in integrated package program that requires sufficient budget for upstream management, dam, and reservoir construction and conveyance system. Due to lack of budget or allocation of low amount of budget, not all activities have been completed at a time. It is due to lack of advance planning, allocation of required budget and horizontal and vertical communication; and coordination gap between DSCO and DSCWM and district level stakeholders. This causes the incompleteness and time prolonged for completion of RHD project that leads to its ineffectiveness (GTZ, Integrated Food Security Project, 2002).

2.7 Relevant research on runoff harvesting system

Many researches have been done regarding runoff harvesting in Asia, Africa and other continents covering hydrological aspect, crop water relationship, indigenous knowledge of water and energy use, and social, economical, and environmental aspects mainly in context of dry land agriculture. In addition, some research has been done in roof water harvesting in residential and urban areas for household water supply and home gardening. In contrast, very few studies can be found on runoff harvesting in watershed scale covering ecological, social, economical and hydrological functions of watershed. Some research on runoff harvesting system can be found covering different aspects of integrated water resource management applying GIS and remote sensing tools.

According to Nasr (1999), most of the Middle East and North Africa (MENA) countries have used different local techniques of runoff harvesting to manage rainfall to combat desertification. It has been possible, through improving the soil cover and catching rain where it falls, to allow infiltration that increases soil moisture and organic activity in soils. Thus, people in the region considered water harvesting to be an integrated part of agricultural production for fruit trees, grasses and rangeland, controlling soil erosion and conserving soil moisture coupling with appropriate agricultural practices.

Water harvesting is generally feasible in areas with an average annual rainfall of at least 100 mm in winter rains and 250 mm in summer rains. It implies that even if low rainfall areas, it can collect the runoff for various use to counteract water deficit to some extent. The water has mostly been exploited from river water and groundwater and neglected the rainwater and floodwater. However, the availability of rainwater is equally in good amount as of river water. Several studies have shown that by allocating 1 to 5% of the area of the catchments for water harvesting, adequate resources can be generated for meeting the contingent needs of the water deficit communities. In the drought prone areas of India, such as *Deccan Plateau*, central India, the western regions of *Rajasthan* and *Gujarat* and *Tamilnadu*; water harvesting remains an important source of water for agriculture (Kolavalli and Whitaker, 1996).

Nadis /tobas are small to medium sized excavated or embanked village ponds practiced in Gujarat state of India. Pond water is available for periods from two months to a year after rain which depends on the catchment characteristics and amount and intensity of rainfall. The *nadis* range from 1.5 to 12 m in depth, 400 to 700,000 m^3 in capacity and have catchment of various shapes and sizes (8 to 2,000 ha). These *nadis* can also be used for recharging the groundwater through construction of infiltration wells and recharge pits in the bed of the storage area. Under suitable conditions, a recharge pit of 3m x 3m x 3m was sufficient to divert 6,500m^3 / annum water to ground water reservoir. Recharge from a village pond of 2.25 ha and storage capacity of 15,000 m^3 in north Gujarat, India alluvial area, could be induced to create groundwater recharge of 10,000 m^3 in one rainy season (Sharma and Smakhtin, 2001).

A series of check dams can be constructed on a stream to recharge the depleted groundwater aquifers. With the construction of check dams at village *Ujalian,* district *Jodhpur,* India, it was found that static water level in wells in the zone of influence increased from 1.8 – 2.2 m as compared to increase of only 0.5 m in wells located outside the zone of influence. In another study made in *Pali* district of Rajasthan it has been observed that the presence of check dams in series has increased aquifer recharge from 5.2 to 38%. Similarly, construction of two sub-surface barriers across an ephemeral stream within 300 m from the water supply wells has been found to store sufficient water required for a village with a population of 500 persons. Studies were conducted for 3 years (1996-98) at *Kalawas* and *Chauri-Kalan* villages in *Jodhpur* district revealed that with the construction of sub-surface barrier, the annual rate of depletion of groundwater has been reduced from 1.0 m to 0.3 m and from 1.0m to 0.23m respectively (Khan, 2001).

It has been suggested that upper catchments and foothills of several regions provide the greatest scope for rainwater harvesting and groundwater recharge because of favorable hydrological formations and heavy rainfall. Similar water harvesting work has been done in *Kandi* area of Indian *Punjab* foothills as part of an integrated watershed development since last 2 decades. The activities implemented were 19 water harvesting dams, 45,000 ha forest rehabilitation in upper catchments, 7 medium capacity irrigation dams having cultivable command area of 9,606 ha and on farm development. It has now been noticed that there is tremendous increase in ground water table due to water recharge in downstream irrigated area. The water balance has increased from (-) 97,867 ha-m in 1979-80 to (+) 52,075 ha-m during the period 1997-98, thus reversing the falling trend of water table to a rising water table (Khepar 2001). Similar studies undertaken elsewhere suggest that upper catchment of falling water table areas should be taken up on priority basis for watershed management including water conservation/ harvesting structures and low irrigation dams.

The above case is very similar with the case of this study site as *Siwalik* foothills called *Bhawar* area which has been considered as water recharge zone for *Terai* region of Nepal. Therefore, Nepal has been giving a special emphasis on implementation of integrated watershed development program for which runoff harvesting dam construction is taken as an important activity. The realization is that by implementing this activity in upper catchment (i.e. *Bhawar* and *Siwalik*), the availability of ground water for downstream (i.e. *Terai*) irrigation can be ensured and sustainable.

The *Sukhomajri* experience of India has shown that wheat production increased from 40.6 to 63.6 ton/ha, maize production increased from 40.9 to 54.3 ton/ha, grass productivity increased from 0.04 to 3.0 ton/ha, milk production increased from 334 to 579 liter/day and tree density in watershed increased from 13 to 1292/ha after implementation of runoff harvesting system of tank and protection of their upper watershed in order to prevent siltation in the tank storage within 5 years from 1979 to 1984. The annual household income went up from INR 10,000 to INR 15,000. Significant economic and ecological changes have taken place in the village over the years. There has been no migration from the village even during severe droughts. A village level institution, The Hill Resources Management Society that was specifically created to discuss the local problems, manage the local environment and maintain discipline among its members, played a crucial role in this entire exercise (Sharma and Smakhtin, 2001).

Another experience of *Ralegaon Sidhi, Maharastra*, India has shown that a drastic ecological and socio-economic transformation has become possible due to adoption of water harvesting system thereby associated agriculture and forest enterprise within 5 years period. The evolution of village institution in *Ralegaon* has been an important part of its development. It is a village situated in a drought-prone area where the annual rainfall ranges from 450-650 mm/annum. Villagers were not assured of even one regular crop. The village was in grip of chronic poverty, moneylenders and country made liquor. Mr. Anna Hazare, a dedicated retired driver from the army, began work in village by constructing storage ponds, reservoirs and gully plugs. Due to this, the groundwater table began to rise. Simultaneously, governments' social forestry program was utilized to plant about 400,000 trees.

Because of the increased availability of irrigation water, the total area under farming increased from 630 to 950 hectares. The average yield of millets, sorghum and onion increased substantially. Today not a single inhabitant of the village depends upon drought relief. The incomes and prestige have increased substantially (Sharma and Smakhtin, 2001).

The similar experience from *Gopalpura* village of *Rajasthan*, India has shown that there is direct and most dramatic impact of runoff harvesting structures on groundwater as well as surface water availability. Water has increased agricultural productivity of this extremely impoverished land. The people do not migrate during even the worst droughts which they normally used to do. The area is semi-arid and over the years deforestation has left it devoid of any vegetation. Water shortages are common and have a deep impact on the lives of the people and their agriculture. In 1986, the villagers with the help of a local NGO (Tarun Bharat Sangh), built three small earthen rainwater harvesting structures, locally called *johads*, on their fields and village grazing lands to store monsoon rains, irrigate their fields and increase percolation in the ground to recharge wells. The effort of *Gopalpura* has attracted so much attention that within 10 years the communities have been able to build almost 2500 water harvesting structures in over 500 villages of the region. Till 1997-98, water-harvesting structures had cost about USD 3.33 million and the poor villagers in cash or kind contributed more than 73% of this. Their household income now has been increased greatly (Sharma and Smakhtin, 2001).

An impact assessment of runoff harvesting was carried out in *Sahel* region of Niger, West Africa. It was found that 70% grain surpluses were possible after runoff harvesting where as it was deficit by 28% before. Average Sorghum yield in the *Yatenga* province of Burkina Faso increased from 594 kg/ha in the 1984-1988 period to 733kg/ha in the 1995-2001 period as a result of adoption of rain water harvesting as a part of soil and water conservation program. For Millet, the figure were 473kg/ha and 688kg/ha in 1984-1988 period and the 1995-2001 period respectively. Soil fertility parameter also increased after 3 to 5 years. For example, organic matter content increased from 1 to 1.4% and nitrogen increased from 0.05 to 0.8%. Soil structure also improved considerably with an increase in its clay content and decrease in the sand fraction (Reij and Thiombiano, 2003 cited in Barry et al., 2008).

In 1986, villagers of *Raj Samdhiyala*, *North Suarasthtra* of India started building check dams and percolation tanks. They have completed 45 water harvesting structure over an area of 1090 hectare. A study carried out in this area in 2001 shows that there is a greater equity in income distribution among the farmers of the village of rain water harvesting project than that of the control village. The water use efficiency in crop production is enhanced with increased water availability in farm wells. Beneficiary farmers alone were able to grow vegetables during summer since they had water available in their wells. Relatively higher gross cropped area was observed in the case of beneficiary group. Crop yield and return per hectare were found relatively higher for beneficiaries than those for non-beneficiaries groups for all the crops (Tilala and Shiyani, 2005). Findings suggest that water harvesting structures provide multiple benefits to beneficiaries. Increase in yield and net income from various crops, reduction in unit cost of production, efficient utilization of resources and higher labor productivity are some of the benefits which many previous studies on water harvesting also found out. The findings of this study with regard to decline in income inequality and improvement in water use efficiency are important from the policy perspective.

One study reported that the problems associated with conservation storage are evaporation, seepage loss and siltation. It is suggested that reducing the storage surface area decreases the evaporation losses. Floating covers and the application of surface layers can also be done to overcome the problem of evaporation loss. It is also said that potential evaporation can be reduced by making compartment of reservoir tank allowing using each compartment one by one. This helps in reduction of area of reservoir surface when water uses progress. Alternatively, the reservoir can be built with sloping bottom that allows gradual reduction of surface area when water use is progressing. Seepage losses can be reduced by compaction and the application of lining materials. Siltation can be minimized by trapping debris flow on the catchment through erosion control structures such as check dams. A silt-trap pond can be built through which the runoff passes before it flows into the storage reservoir. The accumulated silt in the trap must be removed regularly during the dry season. To avoid silting the conservation storage, the catchment area should be properly vegetated and appropriate soil conservation measures like contour cultivation, on-farm conservation and bioengineering techniques should be adopted (Oweis, Hachum and Kijne, 1999).

Integrated watershed development program can be a solution to mitigate the debris flow. Upstream conservation measures of structural, bio-engineering and forest protection and plantation can be implemented with the construction of runoff harvesting dam. Forest and dense vegetation cover sometime work itself as rainwater harvesting. The area of arid and semi arid zone with low mean annual rainfall (less than 500 mm) may not create the runoff in such a forested and conserved upstream area (Sharma and Smakhtin, 2001).

Detailed case study of *Rajsamadhiyala* watershed in the semi-arid tropical area of Gujarat in India revealed that rainwater harvesting through watershed management doubled the productivity of groundnut and other major crops, increased cropping intensity by 32% in eight years. With improved groundwater availability, diversification with high-value crops like cumin, vegetables and fruits were observed. Food, fodder, fuel sufficiency substantially improved along with the increased incomes, literacy and social development (Sreedevi et al., 2006).

International NGOs working in Nepal have carried out some research on runoff harvesting. For example, ICIMOD and IUCN have worked on indigenous knowledge on water and energy use, analysis of water demand and supply and water budget. Hydrological aspect of watershed and stream and river discharge monitoring and evaluation also has been carried out by ICIMOD. Though Department of Soil Conservation and Watershed Management has been implementing various watershed management activities, it has not carried out any research on runoff harvesting. DSCWM produces annual monitoring report and evaluates SCWM activities including RHDs for next year planning. Supervision is ongoing process during planning and implementation of watershed management activities. Progress report has mostly covered quantitative and qualitative facts and figures about the runoff harvesting dams and their associated conservation structures. They are number of completed dams, conveyance structure and watershed conservation measures; names of those conservation measures implemented in nearby catchment, upstream and downstream; names of SCWM based IGA implemented; cost incurred; information about involved user groups; stakeholder contribution; benefit obtained and problem faced during implementation. In conclusion, there is no systematic research on run off harvesting system in Nepal.

2.8 Conclusion

The aim of this chapter was to review the runoff harvesting system in context of watershed management and development. It looked at the preliminary idea on watershed management, its importance and activities that can be implemented under integrated watershed management and development. It also reviewed the runoff harvesting system, its background, types and importance and methods with respect to watershed development and production system. It described various types of runoff harvesting system implemented in Asia and Africa. Moreover, it reviewed the runoff harvesting system of dugout type and dam type implemented in Nepal. In addition, it reviewed the effectiveness indicators and factors of effectiveness of runoff harvesting dam taking it a type of runoff harvesting system. Chapter then reviewed some of the research findings and experiences of runoff harvesting system of various kinds implemented in different countries.

CHAPTER III

RESEARCH METHODOLOGY

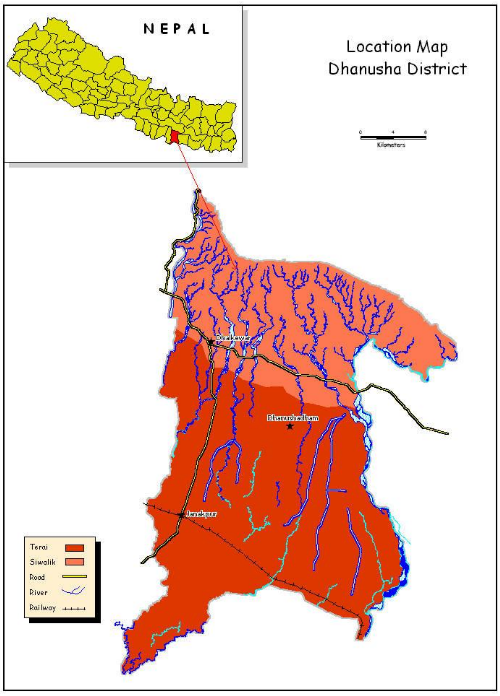
This chapter explains the research methodology of the thesis research entitled “Factors Affecting the Effectiveness of Runoff Harvesting Dams in Nepal”. The study uses a combination of quantitative and qualitative research methods for data collection and analysis. Quantitative method of data collection and analysis consists of household interview and desk review of project books and annual reports and descriptive statistics, cross tab matrix and statistical tests. The qualitative methods of data collection and analysis consist of key informant interview and field observation and descriptive qualitative analysis like compare and contrast, grouping the information in order to find out similarities and differences. Then the chapter gives the details about the study site, research process, data collection methods and scheme, sampling procedure and sample size, selection of key informants and household interviewees and reviewing the documents and data analysis.

3.1 Study area

The study area is *Dhanusha* district of Nepal. The district is one out of 75 districts in Nepal. This district lies in the mid-development region and *Janakpur* zone of Nepal. It lies in *Terai* plain and *Siwalik* regions covering an area of 1,180 sqkm (Central Bureau of Statistics, 2003). Figure 3.1 shows the location of the *Dhanusha* district within Nepal’s map.

Dhanusha district locates between $26^{0}35^{'}$ to $27^{0}05^{'}$north and $85^{0}52^{'}$ to $86^{0}20^{'}$ east. Geographically, the district can be divided into three distinct regions. They are i)*Terai*, the southern plain land, ii) *Siwalik* (i.e. *Churia* hills), the northern most small hills and iii) *Bhawar*, semi-plain land, undulating and the foot hills of *Siwalik* in between *Terai* and *Siwalik* as shown in figure 3.2.

Figure 3.1 Location map of *Dhanusha* district

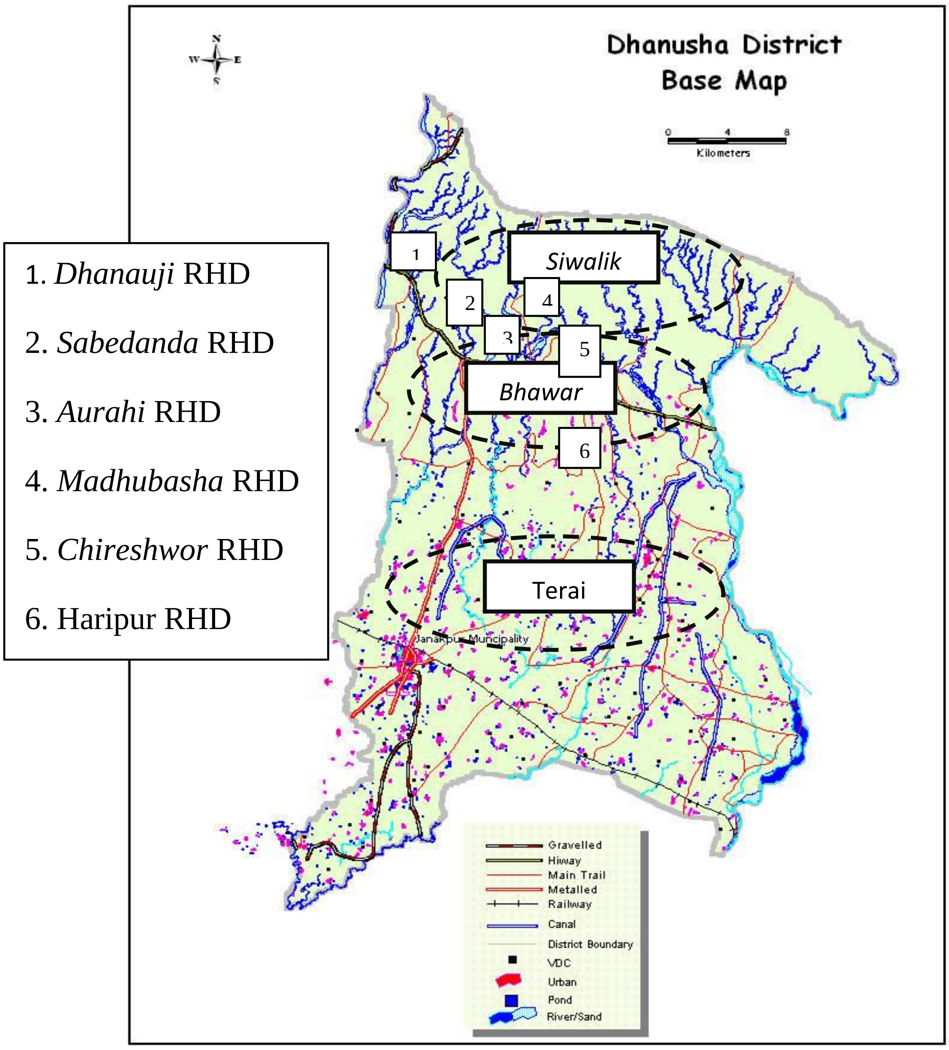


Source: Ministry of Forests and Soil Conservation (MOFSC), (2005).

Out of total area of 1,180 sqkm of the district, 318 sqkm lies in *Siwalik*, 181 sqkm in *Bhawar* and 681 sqkm in *Terai* plain land. In total, 42 percent of the district land areas lie in *Siwalik* and *Bhawar* area which are considered as water recharge zone of *Terai* flat plain, and are important for agricultural production. The elevation ranges between 200-400 feet in *Terai* plain land, 500-1000 feet in *Bhawar* and 1000-2000 feet in *Siwalik* area. Politically, *Dhanusha* district is divided into 6 electoral constituencies, 1 municipality, 101 village development committees (VDCs), and 925 ward committees (District Soil Conservation Office, *Dhanusha*, 2005).

District Soil Conservation Office (DSCO) was established in 1996 with the aim of identifying important watersheds for implementing watershed development activities in order to reduce soil erosion, reduce water induced disaster and enhance water use, conserve and enhance land productivity, protection of development infrastructure and enhance the livelihood of the local people. High priority for conservation and management has been given to *Siwalik* and *Bhawar* region for the enhancement of agricultural productivity in downstream *Terai*. Planning and implementation of different Soil Conservation and Watershed Management (SCWM) activities have been carried out following the principle of Participatory Integrated Watershed Management Program (PIWMP). The *Siwalik* and *Bhawar* areas of the district have been divided into functional sub-watersheds and prioritized on the basis of land use and land system which contribute to erosion and population density. All 6 sampled RHDs were located in *Siwalik* and *Bhawar* region of the district as shown in Figure 3.2.

Figure: 3.2 Base map of *Dhanusha* district showing the *Siwalik*, *Bhawar* and *Terai* and location of studied RHD projects



Source: Adapted from *Dhanusha* District's Forest Sector Plan (DFSP), MOFSC (2005).

3.2 Research process

The research process consists of the following steps:

Step1: Reviewing literature, developing the research proposal with research objectives, research questions, and hypotheses; deciding on research methods (key informant interview, household interview, reviewing documents and field observation) and developing checklist questions for key informant interview and structured questionnaire for household survey, and checklists for collecting secondary data from District Soil Conservation Office (DSCO) and field observations.

Step2: Deciding on target population, sample size and selecting samples.

Step3: Locating respondents, conducting key informant interviews, household interview, and collection of secondary data through reviewing relevant documents from District Soil Conservation Office and observation.

Step4: Data rechecking, data analysis and systematic interpretation.

Step5: Analyzing findings, discussion, conclusion and recommendations, and presenting in the form of thesis research report.

3.3 Research methods and data collection

For the purpose of the study, both qualitative and quantitative methods were used. Qualitative data were collected during key informant interviews and field observations. Quantitative data were collected from household interview and DSCO by reviewing annual reports and project books.

3.3.1 Primary data

The primary data were collected through key informant interviews, household interviews, and site observations.

3.3.1.1 Key informant interview

Four DSCO officials and 6 VDC personnel were chosen as key informants. There was a list of key questions to be used as a research tool to administer with key informants. It enquired and triangulated the data related to effectiveness indicators and factors of effectiveness of RHDs. They were water yield, water induced disaster, rate of soil erosion, moisture enhancement and recharge scenario, forest and agricultural production, household income and user capability to manage the RHD and its water. Checklist questions are put into Appendix I.

3.3.1.2 Household interview

There are 6 user groups with respect to 6 sampled RHDs. Sampled user group members to be interviewed were selected randomly among user group (UG) members of sampled RHD. Generally, UG members are 1 from each household either male or female based on who represents in the UG. The number of households to be interviewed from the user group of sampled RHD is described in 3.5. Structured questionnaire was administered to each sampled user group member of the sampled RHD projects. The structured questionnaire was divided into 4 parts as part A about demographic information, part B about effectiveness indicators, part C about effectiveness factors and part D about some miscellaneous questions related to part B and C. The questions include water yield and its use such as about harvested water and months of availability to irrigation, household consumption and livestock watering; intensity, frequency, and magnitude of damage due to water induced disaster; trend of soil erosion; moisture conservation such as moist or dryness of the area, trend of microclimate improvement, water availability in the downstream wells and aquifer; agriculture and forest production such as introduction of new variety of crops, cropping pattern, frequency of crops, production, NTFPs, grass and fodder; increase in household income per year; capacity built up for RHD operation, accessibility, siltation, budget allocation, cost contribution, coordination and consensuses to implement RHD among DSCO, VDC and user group; activities for watershed management and operation and maintenance plan and its implementation. There were predetermined structured questionnaires. These questionnaires are put in Appendix II.

3.3.1.3 Field observation

Field observations were carried out by the researcher continuously throughout the data collection period in the field. All 6 sampled RHDs, their downstream, upstream and user group settlements were observed. Checklists to be observed are put in Appendix III. Observations made include performance and functioning of RHD such as water in the pond, use of land in downstream area, sign of water induced disaster, water in the downstream wells and aquifers, soil erosion and depositional scar, maintenance and operation of RHD, watershed management activities in nearby catchment. Field observations helped the researcher confirm and triangulate the respondent's view in order to draw the qualitative conclusions.

3.3.2 Secondary data

Secondary data were collected through desk review of RHD project's documents such as project books, annual reports and other relevant documents from DSCO. Data to be collected included the objectives set during RHD project planning, soil type of the RHD site, implementation process followed, technical information, cost invested, achievements, benefit incurred during and after the RHD project, its effect and impact on production, household income, and natural environment. Checklists of data collected are in Appendix IV.

3.4 Sampling procedure

There are 9 sub-watersheds within *Siwalik* and *Bhawar* areas in *Dhanusha* district which are identified as critical sub-watersheds and are prioritized for program implementation. To date, 12 VDCs of 6 sub-watersheds have been implementing watershed management activities since 1996. Total numbers of 24 runoff harvesting dams have been completed in 6 sub-watersheds within the past 11 years. All the runoff harvesting dams are located in the *Bhawar* area of the District as this area is highly water deficit in the winter where as overflow in the rainy season. This area is also the water recharge zone for downstream *Terai*. The lists of the 24 runoff harvesting dams are in Table 3.1.

Table 3.1: List of runoff harvesting dams in *Dhanusha* District

No.	**Name of runoff harvesting dam**	**Location VDC/Ward no.**	**Distance from the settlements**	**Pond area (ha)**	**User group (HH)**			**Age of the dam**
					Male	Female	Total	
1.	*Dhalkebar*	*Dhalkebar* -6	200m	0.12	18	32	50	11
2.	*Tulsi gaun*	*Tulsi*-5	300m	0.12	18	20	38	9
3.	*Bhuchakrapur*	*Bhuchakrapur*-3	500m	0.16	19	20	39	8
4.	*Dhaunauji*	*Bengadabar*-9	200m	0.35	-	41	41	8
5.	*Danda gaun*	*Bengadabar*- 1	600m	0.20	10	30	40	8
6.	*Shanti mahila*	*Shantipur* -1	200m	0.16	-	25	25	7
7.	*Indreni mahila*	*Bengadabar* -8	700m	0.16	-	27	27	5
8.	*Srijana mahila*	*Bengadabar*-9	600m	0.16	-	35	35	4
9.	*Nawa hariyali*	*Bengadabar*-9	300m	0.16	-	27	27	1
10.	*Hariharpur*	*Hariharpur* -1	300m	0.18	15	23	38	10
11	*Basanijhij*	*Pushpwalapur*-1	200m	0.20	-	30	30	8
12	*Dudhamati*	*Mahendranagar*-6	200m	0.16	15	10	25	8
13	*Aurahi*	*Naktajhij*-9	800m	0.20	16	23	39	8
14	*Chireshwar*	*Harihar*-5	200m	0.20	6	35	41	8
15	*Dhalkebar*	*Dhalkebar*-1	700m	0.16	10	25	35	7
16	*Nigure kholsi*	*Naktajhij*-9	900m	0.11	-	23	23	6
17	*Madhubasa*	*Pushpwalapur*-9	600m	0.20	28	34	62	5
18	*Hariharpur*	*Hariharpur*-9	600m	0.20	20	15	35	3
19	*Sabedanda*	*Dhalkebar*-3	500m	0.20	-	39	39	3
20	*Hariyali*	*Pushalapur*- 5	300m	0.20	-	25	25	6
21	*Baghchaur*	*Yagyabhumi*-7	200m	0.15	25	14	40	5
22	*Haripur*	*Umaprempur*-4	300m	0.25	25	35	60	5
23	*Quarter tole*	*Yagyabhumi*- 9	500m	0.20	-	25	25	3
24	*Ratmate*	*Bharatpur*-4	300m	0.20	-	30	30	1

Source: DSCO, *Dhanusha*, 2005, 2009.

A two stage systematic random sampling technique was applied. Based on these runoff harvesting dam projects, samples of RHDs were selected based on the criteria of their distance from the settlements, area of the pond and age of the RHD. It was considered that distance from the settlements, area of the pond or reservoir and age of the dam have equal importance for their effectiveness. RHDs have the distance from settlements ranging from min = 200 to max = 900 m, pond area ranging from min = 0.11 to max = 0.35 ha, and age ranging from min = 1 to max = 11 years. Each criterion divided in to two groups by adding minimum and maximum value and divided by 2. Hence, RHDs were classified into 8 groups as shown in Table 3.2.

Table 3.2: Sample group and underlying runoff harvesting dams

Sample Group number	**RHDs**			**RHD number**
	Distance from the settlements (200+900/2 = 550)	Area of the reservoir (0.11+0.35/2 = 0.23)	Age of the RH (1+ 11/2 = 6)	
1	≤550	≤0.23	≤6	9, 19, 20,21, 23, 24
2	≤550	≤0.23	>6	1,2,3,6,10,11,12,14
3	≤550	>0.23	≤6	22
4	≤550	>0.23	>6	4
5	>550	≤0.23	≤6	7,8, 16,17,18
6	>550	≤0.23	>6	5,13,15
7	>550	>0.23	≤6	-
8	>550	>0.23	>6	-

Selection of sampled RHD was done in such a way that 1 from each sample group should be included. Based on Table 3.2, there is no any RHD in sample group number 7 and 8, so no need to select. In sample group number 3 and 4, there is only one RHD for each group, so they were selected. They were RHD number 4 and 22. For sample group number 1, 2, 5, and 6, researcher chose randomly. By doing so, RHD number 19, 14, 17, and 13 were the sampled RHD respectively. The summary of the sampled RHDs are shown in the following Table 3.3.Thus, 6 out of 24 RHDs were selected as sampled RHDs which overall cover 25 percent of total RHDs.

Table 3.3: Name list of sampled runoff harvesting dams

RHD No.	**Name of Runoff harvesting dam**	**Location VDC/Ward no.**	**Distance from the settlements**	**Pond area (ha)**	**User group (HH)**			**Age of the dam**
					Male	Female	Total	
4	*Dhaunauji*	*Bengadabar*-9	200m	0.20	-	41	41	8
19	*Sabedanda*	*Dhalkebar*-3	500m	0.20	-	39	39	3
13	*Aurahi*	*Naktajhij*-9	800m	0.20	16	23	39	8
17	*Madhubasa*	*Pushpwalapur*-9	600m	0.20	28	34	62	5
14	*Chireshwar*	*Hariharpur*-5	200m	0.35	6	35	41	8
22	*Haripur*	*Umaprempur*-4	300m	0.25	25	35	60	5

3.5 Selection of key informants, household interviewees, and reviewing documents

Sampled households for interviews were identified by applying Bontum (1992) percentage system. Total number of user group households of sampled RHDs was 282. According to this percentage system, for population size of 100 to 900, 25 % of households can be selected. The sampled households of the sampled runoff harvesting dams were calculated and put in to the following Table 3.4.

Table 3.4: Total UG households of Sampled RHDs and their sample size

Name of sampled RHD	**Total UG households**	**Sample size calculation in percentage (25%)**	**Sampled HH**
Dhaunauji	41	41*25/100 = 10.25	10
Aurahi	39	39*25/100 = 9.75	10
Chireshwar	41	41*25/100 = 10.25	10
Madhubasa	62	62*25/100 = 15.50	16
Sabedanda	39	39*25/100 = 9.75	10
Haripur	60	60*25/100 = 15.00	15
Total	282	-	71

Sampled households were selected randomly and household members who are representing in UGs were interviewed.

For key informant interview, VDC chairman and DSCO officials namely District Soil Conservation Officer and Soil Conservation Assistants (SCAs) who have looked after and responsible to plan, implement and facilitate the associated activities of sampled RHD projects were interviewed. There are 6 VDC involved in RHD project, 1 RHD in each VDC. Therefore, 6 VDC chairman were interviewed. There is 1 District Soil Conservation Officer (DSCO) and 3 SCA who were interviewed for this study. These 4 officials are the key personnel involved in planning, implementing, and facilitating the watershed management activities in the district. SCAs normally work as a site in charge for surveying, mapping, drawing, and designing and supervising the individual project during implementation. They also facilitate the user group mobilization, user group training, and workshop. DSCO is in charge of the District Soil Conservation office and see overall planning, implementation and coordination of the SCWM program in the district. Therefore, they have sufficient information about the sampled RHDs.

Desk review of project books, DSCO annual reports and other documents of 6 sampled RHDs were carried out. The summary of key informants, user group members, and documents reviewed are shown in Table 3.5.

Table 3.5: Summary of key informants, household interviewees, and documents

Data collection method	Sources of data	Description
Household interview	User group members	UG members of 6 sampled RHDs i.e. 260 hhs, sample size = 71 hhs
Key informant interview	Key Informants	1 DSCO, 3 SCA, 6 VDC chairman
Desk review	Project books, annual reports and other documents	Project books, annual reports and other documents of 6 RHDs

3.6 Data collection scheme

The data to be collected were mainly related with effectiveness indicators and effectiveness factors. The data of each variable were collected through different tools and different sources as shown in Table 3.6 and Table 3.7.

Table 3.6: Data sources and collection tools of variables of effectiveness indicators

Effectiveness indicators	Variables	Data collection tools	Sources of data
1.Water yield	Average trend of availability of water	1, 2, 3	1, 2, 3, 5
	Water for irrigation (before and after RHD)	1,2, 3	1, 2, 3, 5
	Water for hh use (before and after RHD)	1, 2, 3	1, 2, 3, 5
	Water for livestock (before and after RHD)	1, 2, 3	1, 2, 3, 5
2.Water induced disaster and soil erosion	Decreased	1, 2, 3	1, 2, 3, 5
	Trend of disaster and soil erosion	1, 2, 3	1, 2, 3, 5
	Bank cutting (before and after RHD)	1, 2, 3	1, 2, 3, 5
	Sedimentation/deposition(Before and after RHD)	1, 2, 3	1, 2, 3, 5
3.Water recharge/ moisture retention	Increased	1, 2, 3	1, 2, 3, 5
	Trend	1, 2, 3	1, 2, 3, 5
	Microclimate improvement	1, 2, 3	1, 2, 3, 5
	Water availability in well and aquifer increased	1, 2, 3	1, 2, 3, 5
4.Agriculture and forest production	Increased	1, 2, 3	1, 2, 3, 5
	Average trend of increase in production	1, 2, 3	1, 2, 3, 5
	Agriculture production (before and after RHD)	1, 2, 3	1, 2, 3, 5
	NTFP production (before & after RHD)	1, 2, 3	1, 2, 3, 5
5. Household income	Increased	1, 2, 3	1, 2, 3, 5
	Trend	1, 2, 3	1, 2, 3, 5
	From agricultural production	1, 2, 3	1, 2, 3, 5
	From forest production	1, 2, 3	1, 2, 3, 5
6.User capacity building	Enhanced capacity	1, 2, 3	1, 2, 3, 5
	Skill in operation of RHD	1, 2, 3	1, 2, 3, 5
	Skill in maintenance of RHD	1, 2, 3	1, 2, 3, 5
	Participation in saving credit scheme	1, 2, 3,4	1, 2, 3, 5,6

Table 3.7: Data sources and collection tools of variables of factors of effectiveness

Factor	Variables to be measured	Data collection tools	Source of data
1. Location	-Distance from the household	1	1
	-Suitability for conveyance system	1, 2, 4	1, 2, 3, 6
2. Soil Type	-Appropriateness	1	1
	-Texture	3	4
3.Siltation	-Siltation trend	1, 2,	1, 3, 5
	-Siltation rate	2, 3	3, 5
4. Upstream management	-No of activities	1, 2, 3, 4	1, 3, 4, 5, 6
	-Functionality	1, 2, 3, 4	1, 3, 5, 6
5. Participation	-Involvement of all stakeholders	1, 2, 3	1, 2, 3, 4, 5
	-Cost sharing mechanism	1, 2, 3	1, 2, 3, 4
6. Conflict of objectives	- Objective conflict	1, 2, 3	1, 2, 3
	-Objective setting process	1, 2, 3	1, 2, 3, 4
7. Operation and maintenance	- Operation and maintenance work	1, 2, 3, 4	1, 2, 3, 5, 6
	-Functionality	1, 2, 3, 4	1, 2, 3, 5, 6
8. Budget allocation	-Budget allocation sufficiency	3	4
	- Completion of work	1, 2, 3	1, 2, 3, 4

In above Table 3.6 and Table 3.7, the assigned numbers for data collection tools are symbolized as 1 for household survey, 2 for key informant interview, 3 for desk review, and 4 for field observations. Similarly, for sources of data, 1 for user group members, 2 for VDC chairman, 3 for DSCO officials, 4 for desk review of project books, 5 for desk review of annual reports/other relevant documents, and 6 for field observations.

3.7 Triangulation in data collection

Data collected were verified through multiple data sources and applying various data collection techniques. This was important to avoid bias during investigation process by seeing one form of data through many sources and techniques. Although James (1997) identifies many types of triangulation, triangulation here involved the collection of data from multiple data sources and methods. This research collected the data from key informants, user group members, observation and project books and annual reports. The methods employed were key informant interview, household interview, field observation, and desk review. Some data collected were not found consistence among different methods which were confirmed through repeating the process.

3.8 Data analysis

This research is based on both qualitative and quantitative information collected through household survey, key informant interview, field observation, and desk review. The data were qualitative and quantitative. Hence, both qualitative and quantitative methods were used to analyze the collected data. The data analysis employed descriptive statistics, scoring and ranking, Cross Tab matrix, statistical tests, and systematic description. Microsoft Excel Version 2007 and Statistical Package for Social Survey (SPSS) Version 15.0 were applied.

3.8.1 Measurement of level of effectiveness of runoff harvesting dams

There are 6 effectiveness indicators of RHDs identified for this study. They are water yield (i.e. availability of water); water induced disaster and soil erosion; water recharge and moisture retention; agriculture and forest production; household income and user capacity building. Variables and units of measurement for each effectiveness indicator are presented in Table 3.8.

Table 3.8: Effectiveness indicators and their units of measurement

Indicators	Variables	Unit of measurement
Water yield	Average trend of availability of water	Increased/not increased
	Water for irrigation (before and after RHD)	Area (ha),Duration (months)
	Water for household use (before and after RHD)	Duration (months)
	Water for livestock (before and after RHD)	No., Duration (months)
Water induced disaster and soil erosion	Decreased	Yes/No
	Average decreasing trend of disaster and soil erosion	Increased/not increased
	Bank cutting (before and after RHD)	No of event/yr, Area (ha/yr)
	Sedimentation/deposition(before and after RHD)	No of event/yr, Area (ha/yr)
Water recharge /moisture retention	Increased	Yes/ No
	Increasing trend	Increased/not increased
	Microclimate improvement	Yes/No
	Water availability in well and aquifer increased	Yes/ No
Agriculture and forest production	Increased	Yes/No
	Average trend of increase in production	increased /not increased
	Agriculture production (before and after RHD)	Quintal/ha/year
	Forest production (before & after RHD)	Quintal/ha/year
Household income	Increased	Yes/ No
	Average trend of increase in household income	Increased/not increased
	from agricultural production (before & after RHD)	NRs /yr
	From forest production (before & after RHD)	NRs/yr
User capacity building	Enhanced capacity	Yes/No
	Skill in operation of RHD	Yes/No
	Skill in maintenance of RHD	Yes/No
	Participation in saving credit scheme	Yes/No

Level of effectiveness for each RHD was identified by **scoring and ranking method**. There are 6 effectiveness indicators where each has 4 variables. Each variable was allocated 1 score. Thus, total score were 24. Based on the response of individual respondent during household interview, score was assigned to individual variables which were sum up to get total score. Based on the individual response of the respondents, average score of each RHD project were counted by adding all scores of individual respondents divided by total number of respondents. This provides average score. Effectiveness level of individual sampled RHDs was identified based on their secured average score. The level of effectiveness was classified as:

Level 1: **High**, where 5 to 6 indicators achieved or average scores ≥ 17 to ≤ 24;
Level 2: **Moderate**, where 3 to 4 indicators achieved or average scores ≥ 9 to ≤ 16 and
Level 3: **Low**, where 1 to 2 indicators achieved or average scores ≥ 1 ≤ 8

Each of measured variables of effectiveness indicators were also analyzed through descriptive statistics for systematic description and analysis.

3.8.2 Analysis of factors affecting effectiveness of runoff harvesting dams

There are 8 factors identified for this study that affect the effectiveness of runoff harvesting dams. They are location of RHDs; soil type of the RHDs' site; siltation rate of the reservoir; upstream management by various conservation means; participation of the stakeholders mainly DSCO, VDC and UG in all stage of project planning, implementation, operation and maintenance; conflict on objectives setting of RHD project; post project operation and maintenance and allocation of required budget to complete the dam structure, upstream conservation, and constructing conveyance system. The assumption is that these factors have significant role to be an effective RHD project. Due to the different site specific physical, social, economic, and managerial conditions, the level of factors' influence would be different that contribute to achieve different level of effectiveness. Thus, there would be different level of effectiveness for different RHDs determined by influence of various factors as described above. Level of factors influence would be different for different RHD projects.

The level of factor influence was used as a unit measurement for respective factor for statistical analysis. Measured variables of different factors and their units of measurement are presented in Table 3.9.

Table 3.9: Variables of different factors and their units of measurement

Factors	Measured variables	Unit of measurement
Location	-RHD Distance from the household -Site Suitability for RHD conveyance system	Length (m) Suitable/partially suitable/not suitable
Soil Type	-Soil appropriateness of RHD site for runoff harvesting -Type of soil texture in RHD site	Appropriate/partially appropriate/not appropriate Clay/Clay loam, Silty clay/Silty loam, and sand/conglomerate
Siltation	-Trend of rate of increase in sin RHD reservoir -Siltation rate	Increase in low /medium/high rate Average siltation rate, cm/year
Upstream management	-Number of upstream conservation activities -Functionality	Number: out of gully plugging/forest protection and plantation/bioengineering Well functioned/partially functioned/not functioned
Participation	-No. of stakeholder participated in implementation of RHD project - No. of stakeholder involved in cost contribution for implementation of RHD Project	Users/VDC/DSCO in isolation, 2 or together Users/VDC/DSCO in isolation, 2 or together
Conflict of objectives	- Existence of objective conflict - No. of stakeholder involved in establishment of objectives RHD project	Not conflicted/partially conflicted/ highly conflicted DSCO/VDC/Users in isolation, 2 or together
Operation and maintenance	- Operation and maintenance work done -Functionality of operation and maintenance work	Properly done/partially done/ not done Well functioned/partially functioned/not functioned
Budget allocation	- Sufficiency of allocated budget -Completeness of RHD project in one working season	Sufficient/ partially sufficient/insufficient Completed/partially completed/not completed

These measured variables were also analyzed through percentage of frequencies of respondents and described systematically. The frequency of household interview of each variable was used for Cross Tab matrix analysis.

There were 2 variables for each of 8 factors taken for this study. Each variable were divided in to high, medium, and low level influence on its respective factor which ultimately influence to achieve the certain level of effectiveness of RHD. The criterion for level of influence of each variable was determined based on the literature review, desk review of project books and annual reports and the recommendations of key informants especially from DSCO officials during data collection time in December 2009. These are shown in the following Table 3.10.

Table 3.10: Measured variables and criteria for level of its influence on respective factor

Factors	Measured variables	Level of influence
Location	RHD distance from household (m.)	
	Less than or equal to 300	High
	More than 300 to 600	Moderate
	More than 600	Low
	Site suitability for RHD conveyance system	
	Suitable	High
	Partially suitable	Moderate
	Not suitable	Low
Soil type	Soil appropriateness of RHD site for runoff harvesting	
	Appropriate	High
	Partially appropriate	Moderate
	Not appropriate	Low
	Soil texture	
	Clay/Clay loam	High
	Silty clay/Silty loam,	Moderate
	Sand/Conglomerate	Low
Siltation	Trend of rate of increase in siltation in RHD reservoir	
	Increase in low rate	High
	Increase in medium rate	Moderate
	Increase in high rate	Low
	Siltation rate/year	
	Less than 10 cm	High
	10cm to 20 cm	Moderate
	More than 20 cm	Low
Upstream management	Upstream Conservation activities (no.)	
	All 3 activities from gully plugging/forest protection and plantation/bioengineering	High
	Any 2 activities from gully plugging/forest protection and plantation/bioengineering	Moderate
	Any 1 activity from gully plugging/forest protection and plantation/bioengineering	Low
	Functionality of upstream conservation activities	
	Well functioned	High
	Partially functioned	Moderate
	Not functioned	Low

Table 3.10: Measured variables and criteria for level of its influence on respective factor (Cont.)

Factors	Measured variables	Level of influence
Participation	No. of stakeholder participated in implementation of RHD	
	All 3 stakeholders (DSCO/VDC/UG)	High
	Any 2 stakeholders from DSCO/VDC/UG	Moderate
	Any 1 stakeholder from DSCO/VDC/UG	Low
	No. of stakeholder involved in cost contribution for implementation of RHD project	
	All 3 stakeholders (DSCO/VDC/UG)	High
	Any 2 stakeholders from DSCO/VDC/UG	Moderate
	Any 1 stakeholder from DSCO/VDC/UG	Low
Conflict of objectives	Existence of objective conflict	
	Not conflicted	High
	Partially conflicted	Moderate
	Highly conflicted	Low
	No. of stakeholder involved in establishment of objective	
	All 3 stakeholders (DSCO/VDC/UG)	High
	Any 2 stakeholders from DSCO/VDC/UG	Moderate
	Any 1 stakeholder from DSCO/VDC/UG	Low
Operation and maintenance	Operation and maintenance work done	
	Properly done	High
	Partially done	Moderate
	Not done	Low
	Functionality of operation and maintenance work	
	Well functioned	High
	Partially functioned	Moderate
	Not functioned	Low
Budget allocation	Sufficiency of allocated budget	
	Sufficient	High
	Partially sufficient	Moderate
	Insufficient	Low
	Completeness of RHD project in one working season	
	Completed	High
	Partially completed	Moderate
	Not completed	Low

Household survey data were used to analyze in the factor analysis. The frequency of high, medium, and low level of influence of each variable were used for Cross-Tab Matrix to get level of cumulative influence on respective factor. They were **High**, **Moderate** and **Low** level of factor influence that contributed to certain level of effectiveness. The example for this is shown as follows:

Variable 1

Variable 2

	H (0)	M (2)	L(14)
h (10)	Hh (0)	Mh(20)	(Lh)140
m (6)	Hm(0)	Mm(12)	Lm(84)
l(0)	Hl(0)	Ml(0)	Ll(0)

Cumulative value:

High = Hh+Hm+Mh=0+0+20=20, Moderate = Hl+Mm+Lh=0+12+140 =**152,** and Low = Ml+Lm+Ll=0+84+0=84. Value in the bracket shows the frequency. The frequency of level of influence of one variable is placed in rows and another in column. This follows the rules of Cross Tab matrix to find the product of two different variables and hence, level of influence. Thus, factor influence is moderate as it has highest cumulative value.

3.8.2.1 Dependent and independent variables and their units of measurement

Based on the effectiveness indicator of runoff harvesting dams, the effectiveness level of 6 sampled runoff harvesting dams were identified by analyzing the variables of each of 6 effectiveness indicators as described above in 3.8.1. They are **High**, **Moderate** and **Low**.

There are 8 factors that influence the effectiveness of RHDs. The level of positive influence in order to achieve certain level of effectiveness of each of 8 individual factors was identified based on the analysis of their measured variables. The measured variables of each factor were analyzed by using their frequency through Cross Tab Matrix in order to find out the cumulative level of influence of each factor as described in 3.8.2. They are **High**, **Moderate**, and **Low**. Thus, dependent variable in this study was level of effectiveness of RHD and independent variables were 8 factors that influence the level of effectiveness of RHD. Hence, the dependent variable and independent variables and their units and scales of measurement are given in Table 3.11.

Table 3.11: Dependent and independent variables and their units of measurement

Variables	Scales of measurement	Unit of measurement
Dependent variable:		
1.Levels of effectiveness	Ordinal	High, Moderate and Low (Level 1 to 3)
Independent variables:		
1.Location	Ordinal	High, Moderate and Low (Level 1 to 3)
2.Soil type	Ordinal	High, Moderate and Low (Level 1 to 3)
3.Siltation	Ordinal	High, Moderate and Low (Level 1 to 3)
4.Upstream management	Ordinal	High, Moderate and Low (Level 1 to 3)
5.Participation	Ordinal	High, Moderate and Low (Level 1 to 3)
6.Conflict of objectives	Ordinal	High, Moderate and Low (Level 1 to 3)
7.Operation and maintenance	Ordinal	High, Moderate and Low (Level 1 to 3)
8.Budget allocation	Ordinal	High, Moderate and Low (Level 1 to 3)

It is shown that there were one dependent and more than one independent variable. Based on the above dependent variable and independent variables; and scales and units of measurement, the factor analysis was carried out by using statistical tools of non-parametric rank order Spearman’s correlation. It was because both the dependant and independent variables had small ordinal scale and samples of measurement (Blalock and Jr., 1987); the factor analysis was carried out to find out the significance of effectiveness level of RHDs to the factors of effectiveness.

3.9 Conclusion

This chapter reviewed the research methodology applied in this study. The chapter explained about combination of quantitative and qualitative research methods for data collection and analysis. It described the planning for quantitative method of data collection through household interview and desk review of project books and annual reports and qualitative methods of data collection through key informant interview and field observations. The data analyses included were descriptive statistics, Cross Tab matrix and statistical tests of correlation. It also included the analysis through qualitative and systematic description. Then the chapter gave the details about the study site; research process; data collection methods and its scheme; sampling procedure and sample size; selection of key informant and household interviewees; and reviewing the documents. Chapter also provided information of data analysis using SPSS version15 and Microsoft excel 2007 software package.

CHAPTER IV
RESULTS AND DISCUSSION

This chapter presents the result of the research entitled “Factors Affecting the Effectiveness of Runoff Harvesting Dams in Nepal”. It includes demographic and socio-economic status of the user groups, measurement of level of effectiveness and analysis of effectiveness factors of sampled runoff harvesting dams. The first topic describes the demographic and socio-economic status of the user groups involved in the implementation and operation of their respective runoff harvesting dams. The second topic describes the results of measurement of level of effectiveness of sampled runoff harvesting dams based on the analysis of the measured variables of effectiveness indicators. The third topic describes the outcomes of the analysis of measured variables of effectiveness factors of sampled runoff harvesting dams. In each topic, there is simultaneous discussion over results of the study.

4.1 The demographic and socio-economic status of the user groups

There were 6 sampled runoff harvesting dams taken for this study. The general information of the sampled runoff harvesting dams is as follows:

Table 4.1: Name list and general information of sampled runoff harvesting dams

Name of sampled RHD	**Location VDC/ward number**	**Age of the dam**	**Distance from the settlements (m)**	**Pond area (ha)**	**User group (HH)**			**Sampled HHs**
					Male	**Female**	**Total**	
Dhanauji	*Bengadabar*-9	8	200	0.20	-	41	41	10
Sabedanda	*Dhalkebar*-3	3	500	0.20	-	39	39	10
Aurahi	*Naktajhij*-9	8	800	0.20	16	23	39	10
Madhubasa	*Pushpwalpur*-9	5	600	0.20	28	34	62	16
Chireshwar	*Hariharpur*-5	8	200	0.35	6	35	41	10
Haripur	*Umaprempur*-4	5	300	0.25	25	35	60	15
					Total sampled households			71

The demographic and socio-economic status of user groups represented the sampled households of sampled runoff harvesting dams include household information such as age, gender, education and occupation of the household members; household size; land holding size; agriculture and forest production, collection and use; and livestock and birds rearing.

4.1.1 User group of *Dhanauji* runoff harvesting dam, *Bengadabar*-9

Table 4.2 shows the demographic and basic socio-economic characteristics of household of the user group of *Dhanauji* RHD. The respondents were all female with mean age 38.6 year ranging from 28 to 64. The total population of sampled households was 61 with 54.09% male and 45.91% female. The mean household size was 6 ranging from 5 to 9. Out of total population, 36.05%, 11.48% and 47.50% were involved in agriculture, non-agriculture and education as a major occupation respectively. Likewise, 19.67% and 37.70% were involved in agriculture and non agriculture activities as a minor occupation. Regarding age group, majority of the population (52.46%) were under the age of 21 years, followed by the age group 21 to 40 years (36.05%). Majority of the population had secondary and primary level education, 63.93% and 31.15%, respectively. Very few (4.91%) were illiterate and no one has university level education.

The average land holding size was 0.57 ha ranging from 0.40 to 0.82 ha, out of which 0.21 ha ranging from 0.13 to 0.42 ha was irrigated and 0.36 ha ranging from 0.19 to 0.44 ha was non-irrigated. The average agricultural production (28.7 quintal/year) was seen higher than average consumption (21.80 quintal[1]/year). The average timber production and collection of all household (11.2 0cu.ft/ year) was used up annually. Timber product was mostly used for household purposes and not for sale. The average consumption of NTFP was 2.70 quintal per year while 6.30 quintal /year were produced and collected annually. This shows that surplus agricultural and forest products were sold for cash. The mean number of cow, buffalo and goat were 7 where as birds was 22. All households felt sufficiency in cow, buffalo and goat products, where as only 30% felt sufficiency in bird products.

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[1] A unit of measurement of weight where 100 kg = 1 quintal.

Table 4.2: Demographic and socio-economic characteristics of *Dhanauji* runoff harvesting dam user group, *Bengadabar*-9

Variables	**Observations**	**%**	**Sum**	**Min**	**Max**	**M**	**SD**
Age of the respondent (yr)	10			28	64	38.6	10.596
Gender of the respondent	10	100					
Male	0	0					
Female	10	100					
Household size (no.)	10	100					
Number of household members		100	61				
Male		54.09	33				
Female		45.91	28				
Occupation (Number of people)	61	100					
Major: Agriculture		36.05	22				
Non-agriculture		11.48	7				
Minor: Agriculture		19.67	12				
Non-agriculture		37.70	23				
Involvement in education		47.50	29				
Age group (Number of people)	61						
Less than 21 years		52.46	32				
21 to 40 years		36.05	22				
41 to 60		8.19	5				
More than 60 years		3.28	2				
Education Level	61						
Illiterate		4.91	3				
Primary		31.15	19				
Secondary		63.93	39				
University		0.00	0				
Land holding size in area (ha)	10	100					
Total land holding size		100	5.71	0.40	0.82	0.57	0.138
Irrigated		36.43	2.08	0.13	0.42	0.21	0.103
Non irrigated		63.57	3.63	0.19	0.44	0.36	0.071
Agriculture production (qtl /yr)	10	100					
Total Production		100	287.0	21.0	44.0	28.70	7.103
Total Consumption		75.96	218.0	16.0	35.0	21.80	5.692
Forest product collection							
Timber (Cu.ft /yr)	10	100					
Total collection		100	112.0	8.0	15.0	11.20	2.440
Total Consumption		100	112.0	8.0	15.0	11.20	2.440
Non timber (Quintal /yr)							
Total collection		100	63.0	4.0	10.0	6.30	2.214
Total Consumption		42.86	27.0	1.0	4.0	2.70	0.949
Livestock rearing	10	100					
No. of cow, buffalo and goat		100	67	4	10	6.70	2.263
Sufficiency for consumption							
Yes = 1	10	100					
No = 0	0	0					
No. of birds reared		100	218	12	30	21.80	6.179
Sufficiency for consumption							
Yes = 1	3	30					
No = 0	7	70					

4.1.*2* User group of *Sabedanda* runoff harvesting dam, *Dhalkebarr-3*

Table 4.3 shows the demographic and basic socioeconomic characteristics of the user group.

Table 4.3: Demographic and socio-economic characteristics of *Sabedanda* runoff harvesting dam user group, *Dhalkebar*-3

Variables	**Observations**	**%**	**Sum**	**Min**	**Max**	**M**	**SD**
Age of the respondent (yr)	10	100		35	52	43.80	5.574
Gender of the respondent (no.)	10	100					
Male	7	70					
Female	3	30					
Household size (no.)	10	100					
Number of household members			69				
Male		53.62	37				
Female		46.38	32				
Occupation (Number of people)	69	100					
Major: Agriculture		49.27	34				
Non-agriculture		7.25	5				
Minor: Agriculture		39.13	27				
Non-agriculture		26.09	18				
Involvement in education		33.33	23				
Age group (Number of people)	69	100					
Less than 21		47.83	33				
21 to 40 year		31.88	22				
41 to 60		20.29	14				
More than 60		0.00	0				
Education level (number of people)	69	100					
Illiterate		10.14	7				
Primary		21.74	15				
Secondary		68.12	47				
University		0.00	0				
Land holding in area (ha)	10	100					
Total land holding size		100	5.27	0.40	0.57	0.53	0.053
Irrigated		34.72	1.83	0.08	0.34	0.18	0.073
Non irrigated		65.28	3.44	0.19	0.48	0.34	0.079
Agriculture production (quintal /yr)	10	100					
Total Production		100	205.0	16.00	28.00	20.50	4.378
Total Consumption		-6.83	219.0	17.00	28.00	21.90	3.107
Forest production/collection							
Timber (cu.ft /year)	10	100					
Total collection		100	105.0	7.00	15.00	10.50	2.505
Total Consumption		100	105.0	7.00	15.00	10.50	2.505
Non timber (quintal /year)							
Total collection		100	36.0	2.00	5.00	3.60	1.174
Total Consumption		69.44	25.0	2.00	3.00	2.55	0.497
Livestock rearing (no.)	10	100					
Cow, buffalo and goat		100	83	5	15	8.30	2.908
Sufficiency for consumption							
Yes = 1	10	100					
No = 0	0	0					
Birds reared		100	281	12	55	28.10	14.224
Sufficiency for consumption							
Yes = 1	7	70					
No = 0	3	30					

The average household size of the respondents was 7. Total sampled population was 69 of which 53.62% were male and 46.38% were female. Mean age was 43.8 years. Almost half of the population of respondent households (49.27%) was engaged in agriculture as their major occupation; where as 39.13% and 26.09% were engaged in agriculture and non-agriculture business as a minor occupation, respectively. The 33.33% were involved in school education. It implies that some of those who engaged in non-agriculture and education as a major occupation had adopted agriculture as a minor occupation. Nearly half of the populations were less than 21 years of age. Majority of the sampled population (68.12%) had the secondary level education; whereas 21.74% had primary level education. 10.14% were still illiterate.

Total land holding size was 5.27 ha ranging from 0.40 to 0.57 ha. The average was 0.53ha/household which is less than national average, 0.8 ha/household (Central Bureau of Statistics, 2002). Out of total land, only 34.67% were irrigated. Majority of the cultivated land have not received the irrigation. Agriculture production included cereal, vegetables and fruit crops; with total production of 205 quintal/year where as total consumption was 219. There has been food deficit by 6.83%; and the major deficit on cereal crops. Average production and collection of timber and its use were at the same level, 10.5 cu. ft/year/household. Average collection and production of NTFP was 3.60 quintal/year/household whereas consumption was 2.55. The surplus NTFP have sold for earning cash. All felt sufficiency in cow, buffalo and goat products, with average number of 8 animals /household. 70% households felt sufficiency in bird’s products with mean number of reared, 28.

4.1.3 User group of *Aurahi* runoff harvesting dam, *Naktajhij*-9

Table 4.4 summarizes the demographic and socio-economic characteristics of the sampled household of the user group. 2 male and 8 female respondents participated in the household interview whose mean age was 40.60 years. Total sampled population was 58, 50% male and 50% female. The mean household size was 6.

Table 4.4: Demographic and socio-economic characteristics of *Aurahi* runoff harvesting dam user group, *Naktajhij*-9

Variables	**Observations**	**%**	**Sum**	**Min**	**Max**	**M**	**SD**
Age of the respondent (yr)	10	100		32	48	40.60	5.296
Gender of the respondent (no.)	10	100					
Male	2	20					
Female	8	80					
Household size (no.)	10	100					
Number of household members		100	58				
Male		50.00	29				
Female		50.00	29				
Occupation (Number of people)	58	100					
Major: Agriculture		44.83	26				
Non-agriculture		25.86	15				
Minor: Agriculture		34.48	20				
Non-agriculture		31.03	18				
Involvement in education		24.14	14				
Age group (Number of people)	58	100					
Less than 21		37.93	22				
21 to 40 year		44.83	26				
41 to 60		17.24	10				
More than 60		0.00	0				
Education level (Number of people)	58	100					
Illiterate		15.52	9				
Primary		25.86	15				
Secondary		58.62	34				
University		0.00	0				
Land holding in area (ha)	10	100					
Total land holding size		100	3.91	0.22	0.95	0.39	0.207
Irrigated		37.59	1.47	0.04	0.42	0.15	0.105
Non irrigated		62.41	2.44	0.13	0.53	0.24	0.107
Agriculture production (quintal /yr)	10	100					
Total Production		100	207.0	16.0	35.0	20.70	6.001
Total Consumption		-4.83	217.0	19.0	26.0	21.75	2.574
Forest product collection							
Timber (Cu.ft /yr)	10	100					
Total collection		100	98.0	6.0	15.0	9.80	3.225
Total Consumption		100	98.0	6.0	15.0	9.80	3.225
Non timber (quintal /yr)							
Total collection		100	67.0	5.0	10.0	6.70	1.494
Total Consumption		34.33	23.0	1.0	3.0	2.30	0.675
Livestock rearing (no.)	10	100					
Cow, buffalo and goat		100	58	4	8	5.80	1.751
Sufficiency for consumption							
Yes = 1	6	60					
No = 0	4	40					
Birds reared		100	285	15	49	28.50	11.863
Sufficiency for consumption							
Yes = 1	3	30					
No = 0	7	70					

Out of total population, 44.83% had agriculture as a major occupation. 34.48% and 31.03% had agriculture and non-agriculture business as a minor occupation. Majority of the sampled populations were engaged in agriculture. Nearly half of the population (44.83%) was 21 to 40 years old followed by less than 21 years (37.93%). Majority (58.62%) of the user group population had secondary level education, followed by primary level (25.86%). 15.52% were illiterate and no one had university level education.

Total land holding size was 3.91 ha with an average of 0.39ha per household. Irrigated land was 1.47 ha (37.59%). The average agricultural production per household per year was 20.70 quintal which was less than average consumption (21.7 quintal/hh/yr). The user group was in food deficit condition. This deficit was mainly for cereal rather than fruits and vegetables. Timber was used collected from local forest and from their farm land. The average collected and used amount of timber product was 9.80cu.ft per household per year. However, the average collected amount (6.70quintal/hh/yr) of NTFPs was more than the used amount (2.30quintal/hh/yr). The surplus amount of NTFPs was sold and contributed to sustain their livelihood. Average number of cow, buffalo and goat was 6 and rearing birds were 29 per household. 60% households reported that they were sufficient for consumption of cow, buffalo and goat product, but only 30% reported that they were sufficient of bird's product.

4.1.4 User group of *Madhubasha* runoff harvesting dam *Pushpwalpur*-9

Table 4.5 shows the demographic and socio-economic characteristics of the sampled household of user group of *Madhubasha* RHD. 9 male and 7 female respondents were involved in household interview with mean age of 42.81 years. Average household size of the respondents was 6. Total sampled population was 97 of which 56.70% were male and 43.29% were female. 45.36% had agriculture as a major occupation; where as 28.87% and 45.36% had agriculture and non-agriculture as a minor occupation. Majority of the population belongs to the less than 40 years old. 39.18% was 21 to 40 years old, followed by less than 21 years (37.11%). Likewise majority of the population (51.55%) had secondary level education, followed by 29.89% with primary level education. 18.56% were illiterate and no one had university level education.

Table4.5: Demographic and socio-economic characteristics of *Madhubasha* runoff harvesting dam user group, *Pushpwalpur*-9

Variables	**Observations**	**%**	**Sum**	**Min**	**Max**	**M**	**SD**
Age of the respondent (yr)	16	100		23	61	42.81	11.450
Gender of the respondent (no.)	16	100					
Male	9	56.3					
Female	7	43.8					
Household size (no.)	16	100					
Number of household members		100	97				
Male		56.70	55				
Female		43.29	42				
Occupation (Number of people)	97	100					
Major: Agriculture		45.36	44				
Non-agriculture		24.74	24				
Minor: Agriculture		28.87	28				
Non-agriculture		45.36	44				
Involvement in education		20.62	20				
Age group (Number of people)	97	100					
Less than 21 years		37.11	36				
21 to 40 years		39.18	38				
41 to 60 years		21.65	21				
More than 60 years		2.06	2				
Education level(Number of people)	97	100					
Illiterate		18.56	18				
Primary		29.89	29				
Secondary		51.55	50				
University		0.00	0				
Land holding in area (ha)	16	100					
Total land holding size		100	8.85	0.28	1.47	0.55	0.286
Irrigated		36.05	3.19	0.08	0.63	0.20	0.152
Non irrigated		63.95	5.66	0.16	0.84	0.35	0.162
Agriculture production (quintal /yr)	16	100					
Total Production		100	394.0	14.0	44.0	24.63	8.065
Total Consumption		89.34	352.0	13.0	31.0	22.00	5.112
Forest production/collection	16	100					
Timber (cu.ft./year)							
Total collection		100	141.0	5.0	12.0	8.81	2.228
Total Consumption		100	141.0	5.0	12.0	8.81	2.228
Non timber (quintal /yr)							
Total collection		100	108.0	4.0	10.0	6.75	1.807
Total Consumption		36.57	39.50	2.0	3.0	2.47	0.499
Livestock rearing (no.)	16	100					
Cow, buffalo and goat		100	104	3	10	6.50	2.221
Sufficiency for consumption							
Yes = 1	8	50					
No = 0	8	50					
Birds reared		100	421	12	55	26.31	14.750
Sufficiency for consumption							
Yes = 1	3	18.8					
No = 0	13	81.3					

Total land holding size of the user group was 8.85 ha of which 36.05% were irrigated. The rest was rain fed and had no irrigation facility. Total agricultural production (394 quintal/year) was higher than total consumption (352 quintal/year).

People had tendency to use timber products from natural forest and from their farm land for household use up to the required quantity. The average amount of collected/ produced and used amount of timber were 8.81 cu.ft / year. NTFPs were collected from their farmland and local forest. The mean collection and consumption amount was (6.75 quintal/hh/yr) and 2.47 quintal/hh/yr, respectively. The total collection (108 quintal/year) was more than total consumption (39.50 quintal/year). They sold surplus amount of NTFPs to earn cash income which was contributing to their livelihood. Average number of cow, buffalo and goat per household was 7 ranging from 3 to 10. It 50% household had sufficiency in animal products whereas another 8(50%) not. The mean numbers of birds raised were 26 per household, ranging from 12 to 55. Majority (81.3%) reported that its product was not sufficient for them and they had to buy from outside.

4.1.5 User group of *Chireshwor* runoff harvesting dam, *Hariharpur*-5

Table 4.6 shows demographic and household socio-economic status of user group of *Chireshwor* RHD. 4 male and 6 female respondents were participated in this household interview with mean age of 42.80 years. Average household size was 5. Total population of sampled households was 53 of which 54.72% were male and 45.28% were female. 26.42% and 39.62% were involved in agriculture and non agriculture business as a major occupation. 39.62% and 30.19 were involved in same job as explained above as a minor occupation. Nearly half of the population (45.28%) was less than 20 years old, followed by 21 to 40 years (32.08%). Majority of the population (52.83%) had primary level education, followed by secondary education (37.74%). 9.43% were illiterate; where as none of them had university level education.

Total land holding size was 3.19 ha, ranging from 0.15 to 0.67 ha and mean 0.32 ha. Majority of the land (86.83%) was non-irrigated. The user group had very high food deficit (-86.83%) as the total production was very low (104 quintal/year), compared to the total consumption (193 quintal/year). Total timber production, collection and consumption were same amount (75 cu.ft/year). Timber was not been traded and sold by the user group; they just collected each year up to the required quantity.

Table 4.6: Demographic and socio-economic characteristics of *Chireshwor* runoff harvesting dam user group, *Hariharpur*-5

Variables	**Observations**	**%**	**Sum**	**Min**	**Max**	**M**	**SD**
Age of the respondent (yr)	10	100		26	61	42.80	11.631
Gender of the respondent (no.)	10	100					
Male	4	40					
Female	6	60					
Household size (no.)	10	100					
Number of household members		100	53				
Male		54.72	29				
Female		45.28	24				
Occupation (Number of people)	53	100					
Major: Agriculture		26.42	14				
Non-agriculture		39.62	21				
Minor: Agriculture		39.62	21				
Non-agriculture		30.19	16				
Involvement in education		26.42	14				
Age group (Number of people)	53	100					
Less than 21 years		45.28	24				
21 to 40 years		32.08	17				
41 to 60 years		20.75	11				
More than 60 years		1.89	1				
Education level (no.)	53	100					
Illiterate		9.43	5				
Primary		52.83	28				
Secondary		37.74	20				
University		0	0				
Land holding in area (ha)	10	100					
Total land holding size		100	3.19	0.15	0.67	0.32	0.167
Irrigated		13.17	0.42	0.00	0.17	0.04	0.069
Non irrigated		86.83	2.77	0.15	0.55	0.28	0.134
Agriculture production (qtl/year)	10	100					
Total Production		100	104.0	4.0	24.0	10.40	6.398
Total Consumption		-85.58	193.0	10.0	26.0	19.30	4.900
Forest product collection	10	100					
Timber (cu.ft./year)							
Total collection		100	75.0	5.0	9.0	7.50	1.179
Total Consumption		100	75.0	5.0	9.0	7.50	1.179
Non timber (qtl /year)							
Total collection		100	47.0	2.0	8.0	4.70	2.312
Total Consumption		91.49	43.0	2.0	8.0	4.30	2.214
Livestock rearing (no.)	10	100					
Cow, buffalo and goat		100	63	4	9	6.30	1.889
Sufficiency for consumption							
Yes = 1	9	90					
No = 0	1	10					
Birds reared		100	411	23	65	41.10	13.577
Sufficiency for consumption							
Yes = 1	9	90					
No = 0	1	10					

They collected the NTFPs from the local forest and from their own farm land. Total quantity of NTFPs collected was about 47 quintal/year where as consumption was 43 quintal/year. Small amount of surplus NTFPs was sold to local market to earn cash income. Total number of cow, buffalo and goat was 63 and birds 411. The 90% had sufficiency of livestock and birds production.

4.1.6 User group of *Haripur* runoff harvesting dam, *Umaprempur-4*

The demographic and socio-economic status of the user group of Haripur RHD is summarized in Table 4.7. 15 female respondents with mean age 40.47 years, ranging from 31 to 49 were participated in household interview. Total population of samples households was 90, of which 54.44% were male and 45.56% were female. Average household size was 6 ranging from 4 to 10. 27.78% and 42.22% had agriculture and non-agriculture as a major occupation. 54.44% and 27.77% were involved with agriculture and non-agriculture as a minor occupation. Non-agriculture work included paid labor work in infrastructural development and other farm labor. Majority (54.44%) were less than 21 years old, followed by 21 to 40 years 26.67%). 50% and 42.22% population had got secondary and primary level education respectively. 7.78% were illiterate, no people had got university level education.

Out of total land holding (5.32 ha), only 18.98% were irrigated. Majority of the agriculture land had no irrigation facility and were rainfed. Total agricultural production was 163 quintal/year. This is very high deficit because consumption was 328 quintal/year. People had to go outside of agriculture in search of work to earn money to buy food. They collected and produced 114 cu.ft./year of timber product. All were consumed annually. It was because they collected only up to the required quantity. About 45 quintal and 41 quintal of NTFPs were collected and used annually, respectively. There was some surplus of NTFPs which was sold for their cash income. Average number of cow, buffalo and goat was 8 and bird was 28. 86.7% household had sufficiency in cow, buffalo and goat product for their household consumption. 66.7% replied that the raised bird (i.e. chicken, pigeon and duck) products were sufficient.

Table 4.7: Demographic and socio-economic characteristics of *Haripur* runoff harvesting dam user group, *Umaprempur*-4

Variables	**Observations**	**%**	**Sum**	**Min**	**Max**	**M**	**SD**
Age of the respondent (yr)	15	100		31	49	40.47	5.276
Gender of the respondent (no.)	15	100					
Male	0	0					
Female	15	100					
Household size (no.)	15	100					
Number of household member		100	90				
Male		54.44	49				
Female		45.56	41				
Occupation (Number of people)	90	100					
Major: Agriculture		27.78	25				
Non-agriculture		42.22	38				
Minor: Agriculture		54.44	49				
Non-agriculture		27.77	25				
Involvement in education		22.22	20				
Age group (Number of people)	90	100					
Less than 21 years		54.44	49				
21 to 40 years		26.67	24				
41 to 60		18.89	17				
More than 60 years		0	0				
Education level (no.)	90	100					
Illiterate		7.78	7				
Primary		42.22	38				
Secondary		50.00	45				
University		0.00	0				
Land holding in area (ha)	15	100					
Total land holding size		100	5.32	0.15	0.53	0.35	0.089
Irrigated		18.98	1.01	0.00	0.21	0.07	0.061
Non irrigated		81.02	4.31	0.15	0.40	0.29	0.069
Agriculture production (qtl/yr)	15	100					
Total Production		100	163.0	7.0	19.0	10.87	3.050
Total Consumption		-101.23	328.0	13.5	32.0	21.87	4.816
Forest production / collection							
Timber (cu.ft./year)	15	100					
Total collection		100	114.0	5.0	10.0	7.60	1.549
Total Consumption		100	114.0	5.0	10.0	7.60	1.549
Non timber (quintal /year)							
Total collection		100	45.0	2.0	5.0	3.00	0.845
Total Consumption		91.11	41.0	2.0	5.0	2.77	0.863
Livestock rearing (no.)	15	100					
Cow, buffalo and goat		100	116	3	15	7.73	3.327
Sufficiency for consumption							
Yes = 1	13	86.7					
No = 0	2	13.3					
Birds reared		100	418	12	45	27.87	8.408
Sufficiency for consumption							
Yes = 1	10	66.7					
No = 0	5	33.3					

4.1.7 Comparison of key demographic and socio-economic characteristics of user groups

The key demographic and socio-economic characteristics of all 6 user groups are summarized in the following Table 4.8.

Table 4.8: Demographic and socio-economic characteristics of 6 user group households

Variables	*Dhanauji* RHD	*Sabedanda* RHD	*Aurahi* RHD	*Madhubasha* RHD	*Chireshwor* RHD	*Haripur* RHD
Household size(Number)	6	7	6	6	5	6
Age group (years)						
Less than 21	**52.5%**	**47.8%**	37.9%	37.1%	**45.3%**	**54.4%**
21 to 40	36.1%	31.9%	**44.8%**	**39.2%**	32.1%	26.7%
41 to 60	8.2%	20.3%	17.3%	21.6%	20.7%	18.9%
More than 60	3.3%	0%	0%	2.1%	1.9%	0%
Occupation (Number of people)						
Agriculture	36.1%	**49.3%**	**44.8%**	**45.4%**	26.4%	27.8%
Non-agriculture	11.4%	7.3%	25.9%	24.7%	**39.6%**	**42.2%**
School education	**47.5%**	33.4%	24.2%	20.6%	26.4%	22.2%
Education (Number of people)						
Illiterate	4.9%	10.2%	15.5%	18.6%	9.5%	7.8%
Primary	31.2%	21.7%	25.9%	29.9%	**52.8%**	42.2%
Secondary	**63.9%**	**68.1%**	**58.6%**	**51.5%**	37.7%	**50.0%**
University	0%	0%	0%	0%	0%	0%
Land holding size(ha)						
Total	0.57	0.53	0.39	0.55	0.32	0.35
Irrigated	0.21	0.18	0.15	0.20	0.04	0.07
Non irrigated	**0.36**	**0.34**	**0.24**	**0.35**	**0.28**	**0.29**
Livestock (number)						
Cow/buffalo/goat	7	8	8	**7**	6	8
Bird	**22**	28	**49**	26	41	28
Agricultural production (quintal/year)						
Production	**28.70**	20.50	20.70	**24.63**	10.40	10.87
Consumption	21.80	**21.90**	**21.75**	22.00	**19.30**	**21.87**
Forest production						
Timber (cu. ft./year)						
Collection	11.20	10.50	9.80	8.81	7.50	7.60
Consumption	11.20	10.50	9.80	8.81	7.50	7.60
NTFPs(quintal/year)						
Collection	**6.30**	**3.60**	**6.70**	**6.75**	**4.70**	**3.00**
Consumption	2.70	2.55	2.30	2.47	4.30	2.77

Average household size was 6 which was more than national average (i.e. 5 in rural areas and 4 in urban). 54.4% populations of *Haripur* UG, 52.5% of *Dhanauji*, 47.8% of *Sabedanda* and 45.3% of *Chireshwor* UG were less than 21 years age, respectively. *Dhanauji* and *Haripur* had more population than national average (i.e. 51.1%) in age less than 21 years. 44.8% populations of *Aurahi* UG and 39.2% of Madhubasha were 21 to 40 year. All RHD UG had more population in age group between 21 to 40 years than national average (i.e. 26.6%). It concludes that majority of the population were less than 40 years.

49.3%, 45.4%, 44.8% population had agriculture occupation in *Sabedanda*, *Madhubasha* and *Aurahi* UG, respectively. 42.2% and 39.6% population of *Haripur* and *Chireshwor* UG had non-agriculture occupation, respectively. *Haripur* and *Chireshwor* UG had lower percentage of people involved in agriculture occupation compared to other UGs because they had lower land holding size with more non irrigated farmland. This forced more individual to adopt non agriculture occupation. 47.5% population of *Dhanauji* UG were school going population. Nepal is an agricultural based country; more than 76 % population involve in agriculture business which includes agriculture as both major and minor job. The population of non-agriculture occupation also had agriculture as minor job. Therefore, population of all RHD projects was in line with national figure of occupation. Majority of the population (i.e. 68.1%, 63.9%, 58.6%, 51.5% and 50.0%) of *Sabedanda*, *Dhanauji*, *Aurahi*, *Madhubasha* and *Haripur* UG had secondary level education. 52.8% population of *Chireshwor* UG had primary level education. *Aurahi* and *Madhubasha* UG had 15.5% and 18.6% population illiterate respectively.UG population in all RHD had also primary level education. Illiteracy and low level of education would not be good for technology transfer and UG’s socio-economic development. Even the awareness program and knowledge and skill development training felt hard to impart them.

The average land holding size was ranging from 0.32 to 0.57 ha/hh which were less than national average (0.8ha/hh). Majority of the land were non- irrigated. Due to small land holding size and non-irrigation, the agricultural production could not meet majority of the UG’s food requirements from their own production. This forced them to work other than agriculture such as labor work for their subsistence living. The average number of cow, buffalo and goat were 7 and birds were ranging from 22 to 49. The animal and birds productions were mostly for household consumption that contributed to fulfill their nutritional requirements. Average agricultural production was ranging from 10.40 to 28.7 quintal/hh/year where as consumption was 19.30 to 22.0 quintal/year. *Sabedana*, *Aurahi*, *Chireshwor* and *Haripur* UG consumed more cereals than production. The deficit was heavier for cereals than fruits and vegetables. The households that had insufficient in cereals from their own production would buy from outside. Some of the family members had worked as labors to have extra earnings in order to buy insufficient amount of cereals and expense for other household requirements. Only *Dhanauji* and *Madhubasha* UG had less consumption than production of agriculture products. Timber production, collection and consumption were equal amount for all UG ranging from 7.50 to 11.20 cu.ft./hh/year. UG used timber up to the required quantity and it was not trading. The production and collection of NTFPs were ranging from 3.0 to 6.75 quintal/hh/year where as consumption was 2.30 to 4.30 quintal/year. There were some surpluses of NTFPs in all UGs that supported to have some extra income.

The noticeable fact is that the average land holding size and proportion of irrigated farmland of *Chireshwor* and *Haripur* UG were small compared to other UGs. This agricultural production was also less in these UGs that was not sufficient for their own consumption. This leads them to adopt the occupation other than agriculture heavily such as labor work for their livelihood.

In all user group, it was found that UG members were either migrated from mid-hills' *Brahmin* and *Chhetri* or indigenous and ethnic community like *Mushahar, Dusadh*, *Sada, Kyapchaki-magar,* and *Mahato* who are marginalized and economically poor due to harsh physical environment and low production opportunity.

RHD user groups were survived with subsistence agriculture integrated to livestock and forest. It was characterized by high population growth, low education level, low income, small land holding size with rainfed agriculture and low production. Food production was less than required quantity. However, NTFPs supported them for some income. Some members in every family engaged in labor work to support their livelihood.

4.2 Measurement of the level of effectiveness of runoff harvesting dams

Based on the analysis of effectiveness indicators of sampled runoff harvesting dams, effectiveness was measured and classified in to 3 levels: highly effective (high), moderately effective (moderate) and low effective (low). The detailed outcomes of the measurement of effectiveness of sampled runoff harvesting dams are as follows.

4.2.1 *Dhanauji* runoff harvesting dam, *Bengadabar*- 9, *Dhanusha*

Dhanauji runoff harvesting dam is located in *Bengadabar* Village Development Committee ward no. 9 of *Dhanusha* District. This runoff harvesting dam and its upstream conservation, water storage and conveyance system were built in F.Y. 2001/2002. According to the key informants and project books, the area was devastated because small ephemeral gully carried sediment from upstream and deposited on downstream farm land in the rainy season. The upstream catchment about 20 ha lacked of forest conservation due to illegal cutting of trees and overgrazing. The land around the runoff harvesting dam was degraded due to overgrazing and encroachment. About 10 ha of downstream farm land faced with silt deposition and could hardly be used for agricultural production. About 7 households were displaced in the past due to siltation and deposition. The area and nearby household had water deficit for irrigation, household use and livestock watering.

According to respondents, key informants and project books, this runoff harvesting dam project was implemented with the aim of runoff collection for irrigation, household use and livestock watering, promotion of soil and water conservation based income generating activities, including season vegetable farming, fruit tree plantation, non-timber forest product (NTFP) production, protection of farm land and improving the natural environment through moisture conservation. The conservation activities launched as part of runoff harvesting were plantation and management of upstream forest of 17 ha as a community forest (CF), gully plugging, runoff harvesting dam construction of water storage system and small canal. Various trainings for user group as part of capacity enhancement were launched, including trainings on runoff harvesting system development, operation and maintenance; soil and water conservation based income generating activities; saving credit and participatory learning and actions. The total cost of this RHD project was NRs 530,162.28 to which the District Soil Conservation Office contributed as 422,195.83, VDC 9,280.00 and user group 98,686.45 in the form of labor contribution. Table 4.9 shows the outcome of descriptive statistical analysis of measured variables of effectiveness indicators. The results revealed that there were positive changes in all indicators of effectiveness.

Water availability in the area was increased for irrigation, household use and livestock watering. All respondents (100%) confirmed that the water availability was increased after the construction of RHD. Average area under irrigation increased from 0.15 to 0.21 ha/per household /per year. Duration of irrigation increased from 7 months before runoff harvesting dam construction to 9.6 months after runoff harvesting dam construction. Average duration of water availability for household use increased from 7 to11.60 months. Average number of livestock was increased from 3 to 7 per household and average duration of water for livestock increased from7 to 11.80 months.

All respondents (100%) confirmed that **water induced disaster and soil erosion** was decreased and the decreasing trend increased after implementation of this runoff harvesting dam project. The average number of occurrence of Gully bank cutting and depositional event decreased from 7 to 3 times per year. Consequently, average area of bank cutting was decreased from 0.0065 to 0.0027 ha/year and deposition from 0.126 to 0.0038 ha/year.

All respondents (100%) confirmed that **water recharge and moisture retention** increased with increasing trend, microclimate was improved with moist environment around the runoff harvesting dam, moisture retention in the soil increased, new vegetation came up, and the environment gradually improved. However, all respondents (100 %) did not perceive that the availability and level of water in 5 wells within 1 km of this RHD and nearby aquifers changed or increased. This should be because of only one, this runoff harvesting dam in the area. Other reason might be the location of wells which was being out of zone of influence of runoff harvesting dam.

Table 4.9: Analysis of 6 effectiveness indicators of *Dhanauji* runoff harvesting dam, *Bengadabar*-9

Indicator	Measured Variable	n	%	Min	Max	M	SD
Water Yield	Average trend of availability of	10	100				
	water Increased = 1	10	100				
	Not increased = 0	0	0				
	Water for irrigation	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Area (ha):						
	Before RHD			.08	.42	.1470	.10335
	After RHD			.13	.50	.2142	.12116
	Duration (Month):						
	Before RHD			6	8	7.00	1.054
	After RHD			8	10	9.60	.843
	Water for household use (Month)	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Before RHD			6	8	7.00	1.054
	After RHD			10	12	11.60	.843
	Water for livestock	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Livestock (No):						
	Before RHD			2	6	2.70	1.337
	After RHD			4	10	6.60	2.271
	Duration(Month):						
	Before RHD			6	8	7.00	1.054
	After RHD			10	12	11.80	.632
Water induced disaster and soil erosion	Decreased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Average decreasing trend of water induced disaster and soil erosion	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Bank cutting:	10	100				
	Event (no./yr) :						
	Not increased = 1	4	40				
	Decreased = 0	6	60				
	Before RHD			5	7	5.80	.789
	After RHD			2	3	2.90	.316
	Area (ha/yr) :						
	Not increased = 1	4	40				
	Decreased = 0	6	60				
	Before RHD			.00	.02	.0065	.00782
	After RHD			.00	.01	.0027	.00358

Table 4.9: Analysis of 6 effectiveness indicators of *Dhanauji* runoff harvesting dam, *Bengadabar*-9 (Cont.)

Indicator	Measured Variable	n	%	Min	Max	M	SD
Water induced disaster and soil erosion (Cont.)	Sedimentation/deposition	10					
	Events (no./yr) :						
	Not increased = 1	4	40				
	Decreased = 0	6	60				
	Before RHD			5	7	5.80	.789
	After RHD			2	3	2.90	.316
	Area (ha/yr) :						
	Not increased = 1	4	40				
	Decreased = 0	6	60				
	Before RHD			.00	.04	.0126	.01468
	After RHD			.00	.01	.0038	.00512
Water recharge/ moisture retention	Increased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Increasing trend	10	100				
	Increased =1	10	100				
	Not increased = 0	0	0				
	Microclimate improvement	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Water in well and aquifer increased	10	100				
	Yes = 1	0	0				
	No = 0	10	100				
Agriculture and forest production	Increased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Average trend of increase in production	10	100				
	Increased = 1	7	70				
	Not increased = 0	3	30				
	Agriculture production (quintal/ha/yr)	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Before RHD			15.0	40.0	28.0	6.3246
	After RHD			50.0	65.0	57.0	6.3246
	NTFP production (quintal/ha/yr)						
	Increased = 1	10	100				
	Not increased = 0	10	100				
	Before RHD	0	0				
	After RHD			.00	4.00	.80	1.3984
				2.00	15.00	7.10	3.7845
Household income	Increased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Average trend of increase in household income	10	100				
	Increased = 1	3	30				
	Not increased = 0	7	70				

Table 4.9: Analysis of 6 effectiveness indicators of *Dhanauji* runoff harvesting dam, *Bengadabar*-9 (Cont.)

Indicator	Measured Variable	n	%	Min	Max	M	SD
Household income (Cont.)	Average income from agricultural production (Rs/yr)	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Before RHD			.00	30000	12000	7888.1
	After RHD			20000	50000	36000	8432.7
	Average income from forest production (Rs/yr)	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Before RHD			.00	10000	2250	3809.7
	After RHD			10000	25000	16500	5797.5
User capacity building	Enhanced capacity	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Skill enhanced in operation of RHD	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Skill enhanced in maintenance of RHD	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Participation in saving credit scheme	10	100				
	Yes = 1	10	100				
	No = 0	0	0				

All respondents (100%) confirmed that **agriculture and forest production** was increased due to runoff harvesting dam project. 70% stated that the average trend of increases in production was increased. 30% did not state the trend of increase in production was increased. Average agricultural and NTFP production increased from 28 quintal/ha/year and 0.80 quintal/ha/year to 57 and 7.10, respectively.

All respondents (100%) confirmed that **household income** was increased after implementation of RHD project. However, 70% respondents stated that increasing trend of household income was not higher. Average household income from agricultural and forest production was increased from NRs 12,000/year and 2,250/year to NRs 36,000 and 16,500, respectively.

All respondents (100%) confirmed that **user capacity building** in terms of skill in operation and maintenance of RHD project was enhanced. All of them participated in saving credit scheme.

For *Dhanauji* runoff harvesting dam project, all indicators for effectiveness had positive changes. Water availability for irrigation, household use and livestock increased. Irrigated area and duration of irrigation, number of livestock and duration for livestock watering and household use, increased. These led to increased household income from agriculture and forest production. Water induced disaster and soil erosion decreased. Number of events of gully and stream bank cutting, sedimentation and deposition and damaged area decreased. Moisture retention in the soil increased that brought microclimate improvement in the nearby area and downstream of runoff harvesting dam project. However, water availability in nearby wells and aquifers was not changed. This finding is similar with the findings of Sharma and Smakhtin (2001). Acoording to them, after implementation of runoff harvesting system in *Sukhomajri*, *Ralegaon Sidhi*, *Maharastra* and *Gopalpura* village of *Rajasthan*, India under the watershed management and development project, there was increased in surface water and ground water availability, retained moisture, increased agricultural and forest production and household income.

Based on the above analysis, the overall effectiveness level of *Dhanauji* runoff harvesting dam was measured. The secured score for each indicator were summarized based on the evaluation made by household interviewees in Table 4.10. The effectiveness level of *Dhanauji r*unoff harvesting dam was identified as **high**.

Table 4.10: Evaluation of 6 effectiveness indicators and the level of overall effectiveness of *Dhanauji* runoff harvesting dam, *Bengadabar*-9

Indicator	**Variable**	**Points based on individual response**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Water yield	Average trend of availability of water	1	1	1	1	1	1	1	1	1	1
	Water for irrigation (before and after RHD)	1	1	1	1	1	1	1	1	1	1
	Water for household use (before and after RHD)	1	1	1	1	1	1	1	1	1	1
	Water for livestock (before and after RHD)	1	1	1	1	1	1	1	1	1	1
Water induced disaster and soil erosion	Decreased	1	1	1	1	1	1	1	1	1	1
	Trend of disaster and soil erosion	1	1	1	1	1	1	1	1	1	1
	Bank cutting (before and after RHD)	0	1	0	1	0	1	1	1	1	0
	Sedimentation/deposition(before and after RHD)	0	1	0	1	0	1	1	1	1	0
Water recharge/ moisture retention	Increased	1	1	1	1	1	1	1	1	1	1
	Trend	1	1	1	1	1	1	1	1	1	1
	Microclimate improvement	1	1	1	1	1	1	1	1	1	1
	Water in well and aquifer increased	0	0	0	0	0	0	0	0	0	0
Agriculture and forest production	Increased	1	1	1	1	1	1	1	1	1	1
	Average trend of increase in production	1	1	1	1	0	0	0	1	0	0
	Agriculture production (before and after RHD)	1	1	1	1	1	1	1	1	1	1
	NTFP production (before & after RHD)	1	1	1	1	1	1	1	1	1	1
Household income	Increased	1	1	1	1	1	1	1	1	1	1
	Average trend of increase in household income	1	1	0	0	0	0	0	1	0	0
	From agricultural production (before & after RHD)	1	1	1	1	1	1	1	1	1	1
	From forest production (before & after RHD)	1	1	1	1	1	1	1	1	1	1
User capacity building	Enhanced capacity	1	1	1	1	1	1	1	1	1	1
	Skill in operation of RHD	1	1	1	1	1	1	1	1	1	1
	Skill in maintenance of RHD	1	1	1	1	1	1	1	1	1	1
	Participation in saving credit scheme	1	1	1	1	1	1	1	1	1	1
Total score		21	23	20	22	19	21	21	23	21	19
Grand total score		212									
Average score		210/10 = 21.0									
Effectiveness level		**High**									

4.2.2 *Sabedanda* runoff harvesting dam, *Dhalkebar*-3, *Dhanusha*

Sabedanda runoff harvesting dam is located in *Dhalkebar* VDC ward number 3. The *Sabedanda* small gully passes through village and farmland starting from upstream forest area. The dam across the gully was built erected with spill way and outlet for water conveyance system. The forest area in the upstream area was degraded and became the source of sediment carried down through runoff in the rainy season. This caused for gully widening due to bank cutting. The flowing silt deposited on the downstream farm land. This area faced water deficit in winter and too much water in the rainy season. According to the project books, household interviewees and key informants, the main aim of implementation of this runoff harvesting project is downstream land protection, collection of runoff in summer for household use, livestock watering and irrigation in the winter.

The main conservation activities implemented included management of upstream forest by reforestation as community forest, conservation plantation along the gully side, construction of storage reservoir and dam across the gully with spillway and outlet for conveyance system. Various technical and non technical trainings were launched for user group members in order to enhance the knowledge and skill of soil and water conservation, income generation through soil and water conservation, runoff harvesting system development, operation and maintenance and saving credit. The total cost of this RHD project was NRs 540,413.63 to which District Soil Conservation office contributed as NRs 431,733.11 VDC NRs 33,472.44, and user group NRs 75,208.08 as labor contribution. Table 4.11 shows the output of descriptive statistical analysis of effectiveness indicators for *Sabedanda* runoff harvesting dam.

All respondents (100%) stated that the trend of **availability of water** increased after implementation of runoff harvesting dam project. However, this increased water was mostly for household use and livestock watering. There was a small increase of area and duration of irrigation because there was no suitable conveyance mechanism. The conveyance system did not work. Downstream area was mostly degraded used for afforestation. Very few users (20%) used the water collected from the reservoir of this runoff harvesting dam by using diesel operated water pump. Average areas of irrigation increased from 0.17 ha to 0.18 ha and mean irrigation duration increased from 5.40 to 6.60 months. This change in irrigation was negligible and supplemental. The mean duration of water for household use increased from 5.40 months to 8.40 months and for livestock watering from 5.40 months to 12 months. The number of livestock increased from 4 to 8.

Table 4.11: Analysis of 6 individual effectiveness indicators of *Sabedanda* runoff harvesting dam, *Dhalkebar*-3

Indicators	Measured Variables	Obs.	%	Min	Max.	M	SD
Water Yield	Average trend of availability of water	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Water for irrigation	10	100				
	Increased = 1	1	10				
	Not increased = 0	9	90				
	Area (ha):						
	Before RHD			.00	.34	.1659	.09310
	After RHD			.08	.34	.1827	.07278
	Duration (Month):						
	Before RHD			0	6	5.40	1.897
	After RHD			6	10	6.60	1.350
	Water for household use (Month)	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Before RHD			0	6	5.40	1.897
	After RHD			8	10	8.40	.843
	Water for livestock	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Livestock (No):						
	Before RHD			2	8	3.90	1.969
	After RHD			5	15	8.30	2.908
	Duration(Month):						
	Before RHD			0	6	5.40	1.897
	After RHD			12	12	12.00	.000
Water induced disaster and soil erosion	Decreased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Average decreasing trend of water induced disaster and soil erosion	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Bank cutting:	10					
	Event (no./yr) :						
	Not increased = 1	8	80				
	Decreased = 0	2	20				
	Before RHD			5	6	5.20	.422
	After RHD			2	3	2.60	.516
	Area (ha/yr) :						
	Not increased = 1	8	80				
	Decreased = 0	2	20				
	Before RHD			.00	.02	0.0026	.00548
	After RHD			.00	.01	.0013	.00266

Table 4.11: Analysis of 6 effectiveness indicators of *Sabedanda* runoff harvesting dam, *Dhalkebar*-3 (Cont.)

Indicators	Measured Variables	n	%	Min	Max.	M	SD
Water induced disaster and soil erosion (Cont.)	Sedimentation/deposition	10	100				
	Events (no./yr) :						
	Not increased = 1	3	30				
	Decreased = 0	7	70				
	Before RHD			5	6	5.10	.316
	After RHD			2	3	2.60	.516
	Area (ha/yr) :						
	Not increased = 1	3	30				
	Decreased = 0	7	70				
	Before RHD			.00	.03	.0162	.01298
	After RHD			.00	.01	.0064	.00492
Water recharge/ moisture retention	Increased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Increasing trend	10	100				
	Increased =1	10	100				
	Not increased = 0	0	0				
	Microclimate improvement	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Water in well and aquifer	10	100				
	increased	0	0				
	Yes = 1	10	100				
	No = 0						
Agriculture and forest production	Increased	10	100				
	Yes = 1	2	20				
	No = 0	8	80				
	Average trend of increase in production	10	100				
	Increased = 1	0	0				
	Not increased = 0	10	100				
	Agriculture production (qt/ha/yr)	10	100				
	Increased = 1	2	20				
	Not increased = 0	8	80				
	Before RHD			25.0	35.00	29.30	3.02030
	After RHD			28.0	40.00	32.30	4.52278
	NTFP production (qt/ha/yr)	10	100				
	Increased = 1	0	0				
	Not increased = 0	10	100				
	Before RHD			.00	5.00	3.00	2.30940
	After RHD			.00	5.00	3.00	2.30940
Household income	Increased	10	100				
	Yes = 1	2	20				
	No = 0	8	80				
	Average trend of increase in household income	10	100				
	Increased = 1	0	0				
	Not increased = 0	10	100				

Table 4.11: Analysis of 6 effectiveness indicators of *Sabedanda* runoff harvesting dam, *Dhalkebar*-3 (Cont.)

Indicators	Measured Variables	n	%	Min	Max.	M	SD
Household income (cont.)	Average income from agricultural production (Rs/yr)	10	100				
	Increased = 1	2	20				
	Not increased = 0	8	80				
	Before RHD			.00	.00	.00	.00000
	After RHD			.00	20000	3500	7472.17
	Average income from forest production (Rs/yr)	10	100				
	Increased = 1	0	0				
	Not increased = 0	10	100				
	Before RHD			.00	10000	6100	4581.36
	After RHD			.00	10000	6100	4581.36
User capacity building	Enhanced capacity	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Skill enhanced in operation of RHD	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Skill enhanced in maintenance of RHD	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Participation in saving credit scheme	10	100				
	Yes = 1	10	100				
	No = 0	0	0				

All respondents (100%) confirmed that **Water induced disaster and soil erosion** decreased after implementation of runoff harvesting dam project. The rate of decreasing soil erosion and water induced disaster changed with an increasing trend. The mean number of gully bank cutting decreased from 5 to 3 events per year and the damaged area decreased from 0.0026 to 0.0013 ha/yr. The number of sedimentation and deposition events decreased from 5 to 3 number/year and the area decreased from 0.0162 to 0.0064 ha/year.

All respondents (100%) stated that **moisture retention** increased with increasing trend and microclimate around the runoff harvesting dam increased. However, all respondents (100%) did not perceive water availability in well and aquifer increase. This should be because of only one, this runoff harvesting dam in the area. Other reason might be the location of wells which was being out of zone of influence of runoff harvesting dam.

80% respondents confirmed that **agriculture and forest production** did not increase after implementation of RHD project. All respondents (100 %) stated that the trend of increase in agriculture and forest production did not increase. The mean of agricultural production increased from 29.30 to 32.30 quintal/ha/year. NTFPs production was not increased.

80% respondents confirmed that **household income** was not increased. The mean annual income from agricultural production increased from NRs zero to 3500 per household. The income from forest production was not increased.

All respondents (100%) stated that **user group capacity** for operation and maintenance of RHD enhanced through different technical and non-technical training. All of them participated in saving credit scheme.

For *Sabedanda* RHD project, all indicators except water availability for irrigation, agriculture and forest production and household income had positive changes. The availability of water increased for household use and livestock watering but not for irrigation. Consequently, agricultural and forest production did not increase. This led for not increase in household income. Water induced disaster and soil erosion decreased. The user groups capacity for operation and maintenance of RHD and user group functioning enhanced. Saving and credit scheme helped user group member to borrow money locally.

Based on the above analysis, the overall effectiveness level of *Sabedanda* runoff harvesting dam was measured. The secured score for each indicator were summarized based on the evaluation made by household interviewees in Table 4.12. The effectiveness level of *Sabedanda* runoff harvesting dam was identified as **moderate**.

Table 4.12: Evaluation of 6 effectiveness indicators and the level of overall effectiveness of *Sabedanda* runoff harvesting dam, *Dhalkebar*-3

Indicators	**variables**	**Score based on response of individual respondent**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Water yield	Average trend of availability of water	1	1	1	1	1	1	1	1	1	1
	Water for irrigation (before and after RHD)	0	0	0	0	0	0	1	0	0	1
	Water for hh use (before and after RHD)	1	1	1	1	1	1	1	1	1	1
	Water for livestock (before and after RHD)	1	1	1	1	1	1	1	1	1	1
Water induced disaster and soil erosion	Decreased	1	1	1	1	1	1	1	1	1	1
	Trend of disaster and soil erosion	1	1	1	1	1	1	1	1	1	1
	Bank cutting (before and after RHD)	0	1	0	0	0	0	1	0	0	0
	Sedimentation/deposition(before and after RHD)	1	1	0	0	1	0	1	1	1	1
Water recharge/ moisture retention	Increased	1	1	1	1	1	1	1	1	1	1
	Trend	1	1	1	1	1	1	1	1	1	1
	Microclimate improvement	1	1	1	1	1	1	1	1	1	1
	Water availability in well and aquifer increased	0	0	0	0	0	0	0	0	0	0
Agriculture and forest production	Increased	0	0	0	0	0	0	1	0	0	1
	Average trend of increase in production	0	0	0	0	0	0	0	0	0	0
	Agriculture production (before and after RHD)	0	0	0	0	0	0	1	0	0	1
	NTFP production (before & after RHD)	0	0	0	0	0	0	0	0	0	0
Household income	Increased	0	0	0	0	0	0	1	0	0	1
	Average trend of increase in household income	0	0	0	0	0	0	0	0	0	0
	From agricultural production	0	0	0	0	0	0	1	0	0	1
	From forest production	0	0	0	0	0	0	0	0	0	0
User capacity building	Enhanced capacity	1	1	1	1	1	1	1	1	1	1
	Skill in operation of RHD	1	1	1	1	1	1	1	1	1	1
	Skill in maintenance of RHD	1	1	1	1	1	1	1	1	1	1
	Participation in saving credit scheme	1	1	1	1	1	1	1	1	1	1
Total score		13	14	12	12	13	12	19	13	13	18
Grand total score		139									
Average score		139/10 = 13.9									
Effectiveness level		**Moderate**									

4.2.3 *Aurahi* runoff harvesting dam, *Naktajhij*-9, *Dhanusha*

Aurahi runoff harvesting dam is located in *Naktajhij* Village Development Committee ward number 9 of *Dhanusha* District. According to the key informants, respondents and project books, the area was encroached, overgrazed and overused forest land. The ephemeral gully named *Nigure Kholsi* carried sediment from upstream and deposited in downstream every year. The event of gully bank cutting was common. The area was degraded and water deficit in the winter season.

This runoff harvesting dam and its upstream conservation, water storage and conveyance system were built in F.Y. 2001/2002. Small silt carrying gully was dammed across the gully and runoff was collected. This RHD project was implemented with the aim of collecting runoff water in rainy season for small-scale irrigation, household use and livestock watering in the winter season. The other aim was to promote soil and water conservation based income generating activities including vegetable farming, fruit tree plantation and NTFP production; protection of downstream land from soil erosion and water induced disaster and improvement of local environment through moisture conservation.

The degraded forest of about 45 ha in the upstream catchment was managed as community forest. A conveyance system was built for water distribution. The collected water was used for downstream irrigation for forest plantation, fruit tree growing, cereal and vegetable cropping and NTFP production. Various trainings for user group as part of capacity enhancement were launched, including trainings on runoff harvesting system development, operation and maintenance, soil and water conservation based income generating activities, saving credit and participatory learning and actions. The total cost of the project was NRs 503,203.58 to which the District Soil Conservation Office contributed 418,577.64, VDC 21,645.59 and user group 62,980.35 in the form of labor contribution. Table 4.13 shows the outcome of descriptive statistical analysis of measured variables of effectiveness indicators. The results revealed that there were positive changes in all indicators of effectiveness.

Table 4.13: Analysis of 6 effectiveness indicators of *Aurahi* runoff harvesting dam, *Naktajhij*-9

Indicator	Measured Variables	n	%	Min	Max	M	SD
Water Yield	Average trend of availability of water	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Water for irrigation	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Area (ha):						
	Before RHD			.00	.29	.0420	.09699
	After RHD			.04	.42	.1470	.10523
	Duration (Month):						
	Before RHD			0	6	1.20	2.530
	After RHD			6	9	7.60	.966
	Water for household use (Month)	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Before RHD			0	6	1.20	2.530
	After RHD			6	9	7.90	.876
	Water for livestock	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Livestock (No):						
	Before RHD			0	4	2.20	1.398
	After RHD			4	8	5.80	1.751
	Duration(Month):						
	Before RHD			0	6	1.20	2.530
	After RHD			7	9	8.30	.675
Water induced disaster and soil erosion	Decreased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Average decreasing trend of water induced disaster and soil erosion	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Bank cutting:	10	100				
	Event (no./yr) :						
	Not increased = 1	6	60				
	Decreased = 0	4	40				
	Before RHD			0	5	3.00	1.247
	After RHD			0	3	1.20	1.033
	Area (ha/yr) :						
	Not increased = 1	6	60				
	Decreased = 0	4	40				
	Before RHD			.00	.08	.0197	.03442
	After RHD			.00	.04	.0061	.01322

Table 4.13: Analysis of 6 effectiveness indicators of *Aurahi* runoff harvesting dam, *Naktajhij*-9 (Cont.)

Indicator	**Measured Variables**	**n**	**%**	**Min**	**Max**	**M**	**SD**
Water induced disaster and soil erosion (Cont.)	Sedimentation/deposition	10	100				
	Events (no./yr) :						
	Not increased = 1	2	20				
	Decreased = 0	8	80				
	Before RHD			3	5	3.30	.675
	After RHD			0	3	1.50	.850
	Area (ha/yr) :						
	Not increased = 1	2	20				
	Decreased = 0	8	80				
	Before RHD			.00	.02	.0164	.00873
	After RHD			.00	.04	.0099	.01268
Water recharge/ moisture retention	Increased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Increasing trend	10	100				
	Increased =1	10	100				
	Not increased = 0	0	0				
	Microclimate improvement	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Water in well and aquifer increased	10	100				
	Yes = 1	0	0				
	No = 0	10	100				
Agriculture and forest production	Increased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Average trend of increase in production	10	100				
	Increased = 1	5	50				
	Not increased = 0	5	50				
	Agriculture production (qt/ha/yr)	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Before RHD			20.0	35.0	27.60	6.0221
	After RHD			40.0	61.0	52.0	7.7028
	NTFP production (qt./ha/yr)	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Before RHD			.00	6.0	1.40	2.3664
	After RHD			10.0	20.0	13.60	3.8355
Household income	Increased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Average trend of increase in household income	10	100				
	Increased = 1	4	40				
	Not increased = 0	6	60				

Table 4.13: Analysis of 6 effectiveness indicators of *Aurahi* runoff harvesting dam, *Naktajhij*-9 (Cont.)

Indicator	Measured Variables	n	%	Min	Max	M	SD
Household income (Cont.)	Average income from agricultural production (Rs/yr)	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Before RHD			.00	25000	2500	7905.6
	After RHD			10000	40000	15700	9452.2
	Average income from forest production (Rs/yr)	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Before RHD			.00	15000	2500	4891.1
	After RHD			15000	35000	21500	5797.5
User capacity building	Enhanced capacity	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Skill enhanced in operation of RHD						
	Yes = 1	10	100				
	No = 0	8	80				
		2	20				
	Skill enhanced in maintenance of RHD	10	100				
	Yes = 1	5	50				
	No = 0	5	50				
	Participation in saving credit scheme	10	100				
	Yes = 1	10	100				
	No = 0	0	0				

Water availability in the area was increased for irrigation, household use and livestock watering. All respondents (100%) confirmed that the average trend of availability of water increased after construction of RHD. The average area of irrigation increased from 0.4 to 0.15 ha per household per year. Duration of irrigation increased from 1.20 months before RHD construction to 7.60 months after RHD construction. Average duration of water availability for household use increased from 1.20 to 7.90 months. Average number of livestock increased from 2 to 6 per household and average duration of water availability for livestock increased from 1.20 to 8.30 months.

All respondents (100%) confirmed that **water induced disaster and soil erosion** was decreased and the decreasing trend increased after implementation of this runoff harvesting dam project. Average number of occurrence of gully and stream bank cutting event decreased from 3 to 1 per year and sedimentation and deposition event decreased from 2 to 1 per year. Consequently average area of gully and stream bank cutting decreased from 0.0197 to 0.0061 ha per year and sedimentation and deposition decreased from 0.0164 to 0.0099 ha/year.

All respondents (100%)) confirmed that **water recharge and moisture retention** around the runoff harvesting dam increased with increasing trend. All of them (100%) confirmed that microclimate improved due moisture retention and growing up of new vegetation. However, all respondents (100%) did not perceive that the availability and level of water in local wells changed or increased. This should be because of only one, this runoff harvesting dam in the area. Other reason might be the location of wells which was being out of zone of influence of runoff harvesting dam.

All respondents (100%) confirmed that **agriculture and forest production** increased after construction of this runoff harvesting dam. 50% respondents observed the increasing trend of production. However, another 50% respondents did not observe the increasing trend of production. Average agricultural and NTFP production was increased from 27.60 and 1.40 quintal/ha/year to 52 and 13.60 quintal/ha/year, respectively.

All respondents (100%) confirmed that **household income** increased after implementation of RHD project. However, 60% respondents stated that increasing trend of household income was not increased in higher rate. Average household income from agriculture and forest production increased from NRs 2500 to 15,700/household/year and NRs 21,500/household/year, respectively.

All respondents (100%) confirmed that their **capacity** in terms of skill in operation and maintenance of RHD project was enhanced. However, some user group members who did not get RHD operation and maintenance training have little knowledge and skills on it. All of them participated in saving credit scheme.

For *Aurahi* runoff harvesting dam project, all indicators for effectiveness, except in few variables of some indicators, had positive changes. Water availability for household use, livestock and irrigation increased. Irrigated area and duration of irrigation, number of livestock and duration for livestock watering and household use, increased. These led to increase household income from agriculture and forest production. Water induced disaster and soil erosion decreased. Number of events of gully and stream bank cutting, sedimentation and deposition and damaged area decreased. Moisture retention in the soil increased that brought microclimate improvement in the nearby area and downstream of runoff harvesting dam project. However, water availability in nearby wells and aquifers not changed. User group capacity for operation and maintenance of RHD and user group mobilization enhanced. People were freed from local money lenders due to saving credit scheme.

Based on the above analysis, the overall effectiveness level of *Aurahi* runoff harvesting dam was measured. The secured score for each indicator were summarized based on the evaluation made by household interviewees in Table 4.14. The effectiveness level of *Aurahi* runoff harvesting dam was identified as **high**.

Table 4.14: Evaluation of 6 effectiveness indicators and the level of overall effectiveness of *Aurahi* runoff harvesting dam, *Naktajhij*-9

Indicators	**variables**	**Points based on response of individual respondent**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Water yield	Average trend of availability of water	1	1	1	1	1	1	1	1	1	1
	Water for irrigation (before and after RHD)	1	1	1	1	1	1	1	1	1	1
	Water for household use (before and after RHD)	1	1	1	1	1	1	1	1	1	1
	Water for livestock (before and after RHD)	1	1	1	1	1	1	1	1	1	1
Water induced disaster and soil erosion	Decreased	1	1	1	1	1	1	1	1	1	1
	Trend of disaster and soil erosion	1	1	1	1	1	1	1	1	1	1
	Bank cutting (before and after RHD)	1	0	1	0	0	1	0	0	1	0
	Sedimentation/deposition(before and after RHD)	1	1	1	1	0	0	1	1	1	1
Water recharge/ moisture retention	Increased	1	1	1	1	1	1	1	1	1	1
	Trend	1	1	1	1	1	1	1	1	1	1
	Microclimate improvement	1	1	1	1	1	1	1	1	1	1
	Water availability in well and aquifer increased	0	0	0	0	0	0	0	0	0	0
Agriculture and forest production	Increased	1	1	1	1	1	1	1	1	1	1
	Average trend of increase in production	1	1	1	1	1	0	0	0	0	0
	Agriculture production (before and after RHD)	1	1	1	1	1	1	1	1	1	1
	NTFP production (before & after RHD)	1	1	1	1	1	1	1	1	1	1
Household income	Increased	1	1	1	1	1	1	1	1	1	1
	Average trend of increase in household income	0	1	1	1	1	0	0	0	0	0
	From agricultural production	1	1	1	1	1	1	1	1	1	1
	From forest production	1	1	1	1	1	1	1	1	1	1
User capacity building	Enhanced capacity	1	1	1	1	1	1	1	1	1	1
	Skill in operation of RHD	1	0	0	1	1	1	1	1	1	1
	Skill in maintenance of RHD	1	0	0	0	0	1	1	0	1	1
	Participation in saving credit scheme	1	1	1	1	1	1	1	1	1	1
Total score		22	20	21	21	20	20	20	19	21	20
Grand total score		204									
Average score		204/10 = 20.4									
Effectiveness level		**High**									

4.2.4 *Madhubasha* runoff harvesting dam, *Pushpwalpur*-9, *Dhanusha*

Madhubasha runoff harvesting dam is located in *Pushpwalpur* Village Development Committee ward number 9 of *Dhanusha* District. This RHD project was built in F.Y. 2004/05. According to the key informants, respondents and project books, the area was devastated because a small ephemeral stream carried sediment from upstream and deposited on downstream farm land in rainy season. The upstream forested catchment was degraded because of encroachment, over use and over grazing. The land around the runoff harvesting dam was degraded due to illegal cutting of trees and over grazing. About 15 ha of downstream farm land faced with silt deposition and could hardly be used for agricultural production. The area and nearby households had water deficit for irrigation, household use and livestock watering.

According to the key informants, respondents and project books, the main aim for implementation of this RHD project was collection of runoff in rainy season for downstream irrigation, household use and livestock watering in the winter. The other objectives were protection of downstream farm land from soil erosion and water induced disaster, improvement of local environment through moisture retention and water recharge and promotion of soil and water conservation based income generation through increased agriculture and forest production.

The conservation activities launched as part of runoff harvesting dam project were enrichment plantation and management of upstream forest of 75 ha as community forest; the plugging of stream channel with 9 number of cement masonry and gabion wire check dams in various length and 15 number of brushwood check dam and protection of stream bank with bamboo wattling and bamboo plantation. The runoff harvesting dam of 20 meter length and upper width 2m at the lowermost end of stream was built in order to block the runoff and create the storage reservoir. A small canal was constructed as a conveyance system for water distribution. Various trainings for user group as part of capacity enhancement were launched, including trainings on runoff harvesting system development, operation and maintenance, user group strengthening and mobilization, soil and water conservation based income generating activities, saving credit and participatory learning and actions.

The total cost of the project was NRs 988,521.55 to which DSCO contributed 847,089.20, VDC contributed 43,567.00 and user group contributed as 97,865.35 in the form of labor contribution. The project was completed within two working season (i.e. two fiscal years). Table 4.15 shows the outcome of descriptive statistical analysis of measured variables of effectiveness indicators. The results revealed that there were positive changes in all indicators of effectiveness.

Table 4.15: Analysis of 6 effectiveness indicators of *Madhubasha* runoff harvesting dam, *Pushpwalpur*-9

Indicator	Measured Variables	n	%	Min.	Max.	M	SD
Water Yield	Average trend of availability of water	16	100				
	Increased = 1	16	100				
	Not increased = 0	0	0				
	Water for irrigation	16	100				
	Increased = 1	15	93.75				
	Not increased = 0	1	6.25				
	Area (ha):						
	Before RHD			.00	.50	.1155	.14987
	After RHD			.08	.63	.1997	.15208
	Duration (Month):						
	Before RHD			0	6	3.75	3.0000
	After RHD			5	6	5.94	.250
	Water for household use (Month)	16	100				
	Increased = 1	16	100				
	Not increased = 0	0	0				
	Before RHD			0	6	3.75	3.000
	After RHD			6	12	9.56	1.590
	Water for livestock	16	100				
	Increased = 1	16	100				
	Not increased = 0	0	0				
	Livestock (No):						
	Before RHD			1	4	3.06	1.124
	After RHD			3	10	6.50	2.221
	Duration(Month):						
	Before RHD			0	6	3.75	3.000
	After RHD			10	12	11.88	.500
Water induced disaster and soil erosion	Decreased	16	100				
	Yes = 1	16	100				
	No = 0	0	0				
	Average decreasing trend of water induced disaster and soil erosion	16	100				
	Increased = 1	16	100				
	Not increased = 0	0	0				
	Bank cutting:	16	100				
	Event (no./yr) :						
	Not increased = 1	6	37.5				
	Decreased = 0	10	62.5				
	Before RHD			2	5	3.19	.750
	After RHD			0	2	1.00	.365
	Area (ha/yr) :						
	Not increased = 1	6	37.5				
	Decreased = 0	10	62.5				
	Before RHD			.00	.02	.0134	.00973
	After RHD			.00	.01	.0018	.00398

Table 4.15: Analysis of 6 effectiveness indicators of *Madhubasa* runoff harvesting dam, *Pushpwalpur*-9 (Cont.)

Indicator	Measured Variables	n	%	Min.	Max.	M	SD
Water induced disaster and soil erosion (Cont.)	Sedimentation/deposition	16					
	Events (no./yr) :						
	Not increased = 1	8	50				
	Decreased = 0	8	50				
	Before RHD			0	4	2.94	.929
	After RHD			0	2	.94	.574
	Area (ha/yr) :						
	Not increased = 1	8	50				
	Decreased = 0	8	50				
	Before RHD			.00	.04	.0207	.02002
	After RHD			.00	.02	.0047	.00866
Water recharge/ moisture retention	Increased	16	100				
	Yes = 1	16	100				
	No = 0	0	0				
	Increasing trend	16	100				
	Increased =1	16	100				
	Not increased = 0	0	0				
	Microclimate improvement	16	100				
	Yes = 1	16	100				
	No = 0	0	0				
	Water in well and aquifer increased	16	100				
	Yes = 1	0	0				
	No = 0	16	100				
Agriculture and forest production	Increased	16	100				
	Yes = 1	16	100				
	No = 0	0	0				
	Average trend of increase in production	16	100				
	Increased = 1	7	43.8				
	Not increased = 0	9	56.3				
	Agriculture production (quintal./ha/yr)	16	100				
	Increased = 1	15	93.75				
	Not increased = 0	1	6.25				
	Before RHD			30	42	34.19	3.3310
	After RHD			45	60	50.88	4.2406
	NTFP production (quintal/ha/yr)	16	100				
	Increased = 1	13	81.25				
	Not increased = 0	3	18.75				
	Before RHD			.00	5.00	1.13	2.0615
	After RHD			.00	15.0	9.19	4.8746
Household income	Increased	16	100				
	Yes = 1	16	100				
	No = 0	0	0				
	Average trend of increase in household income	16	100				
	Increased = 1	1	6.25				
	Not increased = 0	15	93.75				

Table 4.15: Analysis of 6 effectiveness indicators of *Madhubasha* runoff harvesting dam, *Pushpwalpur*-9 (Cont.)

Indicator	Measured Variables	n	%	Min.	Max.	M	SD
Household	Average income from						
income	agricultural production	16	100				
(Cont.)	(Rs/yr)	15	93.75				
	Increased = 1	1	6.25				
	Not increased = 0						
	Before RHD			.00	30000	3437.5	8702.25
	After RHD			.00	50000	20375.0	13331.04
	Average income from forest production (Rs/yr)	16	100				
	Increased = 1	14	87.5				
	Not increased = 0	2	12.5				
	Before RHD			.00	10000	2250.0	4074.3
	After RHD			10000	30000	18937.5	6516.3
User capacity building	Enhanced capacity	16	100				
	Yes = 1	16	100				
	No = 0	0	0				
	Skill enhanced in operation of RHD	16	100				
	Yes = 1	13	81.3				
	No = 0	3	18.8				
	Skill enhanced in maintenance of RHD	16	100				
	Yes = 1	11	68.8				
	No = 0	5	31.3				
	Participation in saving credit scheme	16	100				
	Yes = 1	16	100				
	No = 0	0	0				

Water availability in the area was increased for irrigation, household use and livestock watering. All the respondents (100%) confirmed that the water availability was increased after the construction of this RHD. Average area under irrigation increased from 0.12 to 0.20 ha/hh/year. Duration of irrigation increased from 3.75 months before RHD construction to 5.94 months after RHD construction. Average duration of water availability for household use increased from 3.75 months to 9.56 months. Average number of livestock increased from 3 to 7 per household and average duration of water availability for livestock increased from 3.75 months to 11.88 months.

All respondents (100%) confirmed that **water induced disaster and soil erosion** decrease and the decreasing trend increased after implementation of this runoff harvesting dam project. The average number of occurrence of Gully bank cutting and depositional event decreased from 3 to 1 time per year. Consequently, average area of bank cutting was decreased from 0.0134 to 0.0018 ha/year and deposition from 0.0207 to 0.0047 ha/year.

All respondents (100%) confirmed that **water recharge and moisture retention** increased with increasing trend, microclimate was improved with moist environment in downstream and around the RHD, moisture retention in the soil increased, new vegetation came up, existing vegetation grew up, and the environment gradually improved. However, all respondents (100%) did not perceive that the availability and level of water in nearby wells of this RHD changed or increased. It might be because of location of wells. The wells in this case might be located out of zone of influence of RHD that led not to increase the level of water in the wells.

All respondents (100%) confirmed that **agriculture and forest production** increased due to runoff harvesting dam project. However, 56.3% respondents observed that average trend of increase in agriculture and forest production was not in increasing rate. Average agriculture and NTFP production increased from 34.19 and 1.13 quintal/ha/year to 50.88 and 9.19 Quintal/ha/year, respectively.

All respondents (100%) confirmed that **household income** was increased after implementation of RHD project due to increases in agricultural and forest production. However, 93.8% respondents stated that the increasing trend of household income was not higher or increasing rate. The average household income from agricultural and forest production increased from NRs. 3,437.50 and 2,250/household/year to NRs 20,375 and 18,937.50/household/year, respectively.

All respondents (100%) confirmed that their **capacity** in terms of skill in operation and maintenance of RHD project was enhanced. However, very few members of the user group who did not get RHD operation and maintenance training have little knowledge and skills on it. All of them participated in saving credit scheme.

For *Madhubasha* runoff harvesting dam project, all indicators for effectiveness, except in few variables of some indicators, had positive changes. Water availability for household use, livestock and irrigation increased. Irrigated area and duration of irrigation, number of livestock and duration for livestock watering and household use, increased. These led to increase household income from agriculture and forest production. Water induced disaster and soil erosion decreased. Number of events of gully and stream bank cutting, sedimentation and deposition and damaged area decreased. Moisture retention in the soil increased that brought microclimate improvement in the nearby area and downstream of runoff harvesting dam project. However, water availability in nearby wells and aquifers not changed. User group capacity for operation and maintenance of RHD and user group mobilization enhanced. People were economically benefitted and freed from local money lenders due to saving credit scheme.

Based on the above analysis, the overall effectiveness level of *Madhubasha* runoff harvesting dam was measured. The secured score for each indicator were summarized based on the evaluation made by household interviewees in Table 4.16. The effectiveness level of *Madhubasha* runoff harvesting dam was identified as **high.**

Table 4.16: Evaluation of 6 effectiveness indicators and the level of overall effectiveness of *Madhubasha* runoff harvesting dam, *Pushpwalpu*r-9

Indicators	**variables**	**Points based on response of individual respondent**															
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Water yield	Average trend of availability of water	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Water for irrigation (before and after RHD)	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
	Water for household use (before and after RHD)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Water for livestock (before and after RHD)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Water induced disaster and soil erosion	Decreased	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Trend of disaster and soil erosion	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Bank cutting (before and after RHD)	1	1	0	1	1	1	1	1	1	1	0	0	0	0	1	0
	Sedimentation/deposition(before and after RHD)	1	1	1	1	1	0	1	0	0	1	0	0	0	0	1	0
Water recharge/moisture retention	Increased	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Trend	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Microclimate improvement	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Water availability in well and aquifer increased	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture and forest production	Increased	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Average trend of increase in production	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
	Agriculture production (before and after RHD)	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
	NTFP production (before & after RHD)	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1
Household income	Increased	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Average trend of increase in household income	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	From agricultural production	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
	From forest production	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1
User capacity building	Enhanced capacity	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Skill in operation of RHD	1	0	1	1	1	1	1	1	1	0	1	1	1	1	0	1
	Skill in maintenance of RHD	0	0	1	1	1	1	1	1	1	0	1	1	0	1	0	1
	Participation in saving credit scheme	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total score		21	20	17	21	21	20	19	19	18	20	20	20	19	20	20	20
Grand total score		315															
Average score		315/16 = 19.7															
Effectiveness level		**High**															

4.2.5 *Chireshwor* runoff harvesting dam, *Hariharpur*-5, *Dhanusha*

Chireshwor runoff harvesting dam is located in *Hariharpur* Village Development Committee ward number 5 of *Dhanusha* District. This RHD project was implemented in F.Y. 2001/2002. According to key informants, respondents and project books, the area was devastated due to a small ephemeral water ways which carried sediment from upstream catchment and deposited on downstream. The downstream area of about 25 ha was already converted to waste land due to this waterway with deposition of stream bed material such as sand, silt, pebbles, round stones of various sizes and conglomerates which could not be used for agricultural production. The area had water deficit for irrigation, household use and livestock watering. The upper forested catchment was degraded due to over used, over grazed and encroachment.

According to key informants, respondents and project books, this runoff harvesting dam project was implemented with the aim of collecting runoff water in the rainy season for household use, livestock watering, small scale irrigation and fishing in the winter season. Other objectives were downstream protection from soil erosion and deposition, local environment improvement through afforestation and moisture retention. The conservation activities launched as part of runoff harvesting system were enrichment plantation and management of upstream forest of 62 ha as a community forest; storage pond construction in the area of sunken valley and a small earthen dam across the water ways and plantation of 25 ha in the downstream area. Various trainings for user group as part of capacity enhancement were launched, including trainings on runoff harvesting system development, operation and maintenance, user group strengthening and mobilization, soil and water conservation based income generating activities, saving credit and participatory learning and actions.

The total cost of the project was NRs 348,816.98 to which DSCO contributed 255, 367.98, VDC contributed 34, 562.00 and user group contributed 58,887.00 in the form of labor contribution. Table 4.17 shows the outcome of descriptive statistical analysis of measured variables of effectiveness indicators. The results revealed that there were positive changes in all indicators of effectiveness except water availability for irrigation, bank cutting and sedimentation and deposition, agriculture and forest production and household income.

Table 4.17: Analysis of 6 effectiveness indicator of *Chireshwor* runoff harvesting dam, *Hariharpur*-5

Indicator	Measured Variable	n	%	Min	Max	M	SD
Water Yield	Average trend of availability of water	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Water for irrigation	10	100				
	Increased = 1	0	0				
	Not increased = 0	10	100				
	Area (ha):						
	Before RHD			.00	.17	.0420	.06859
	After RHD			.00	.17	.0420	.06859
	Duration (Month):						
	Before RHD			0	6	1.80	2.898
	After RHD			0	6	1.80	2.898
	Water for household use (Month)	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Before RHD			0	6	1.80	2.898
	After RHD			8	10	9.00	1.054
	Water for livestock	10	100				
	Increased = 1	10	100				
	Not increased = 0	0	0				
	Livestock (No):						
	Before RHD			0	4	2.40	1.174
	After RHD			4	9	6.30	1.889
	Duration(Month):						
	Before RHD			0	6	1.80	2.898
	After RHD			10	10	10.00	.000
Water induced disaster and soil erosion	Decreased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Average decreasing trend of water induced disaster and soil erosion	10	100				
	Increased = 1	8	80				
	Not increased = 0	2	20				
	Bank cutting:	10	100				
	Event (no./yr) :						
	Not increased = 1	9	90				
	Decreased = 0	1	10				
	Before RHD			0	4	2.50	1.434
	After RHD			0	3	1.40	.966
	Area (ha/yr) :						
	Not increased = 1	9	90				
	Decreased = 0	1	10				
	Before RHD			.00	.08	.0084	.02656
	After RHD			.00	.00	.0000	.00000

Table 4.17: Analysis of 6 effectiveness indicator of *Chireshwor* runoff harvesting dam, *Hariharpur* 5 (Cont.)

Indicator	Measured Variable	n	%	Min	Max	M	SD
Water induced disaster and soil erosion (Cont.)	Sedimentation/deposition	10	100				
	Events (no./yr) :						
	Not increased = 1	9	90				
	Decreased = 0	1	10				
	Before RHD			2	3	2.80	.422
	After RHD			1	2	1.30	.483
	Area (ha/yr) :						
	Not increased = 1	9	90				
	Decreased = 0	1	10				
	Before RHD			.00	.02	.0021	.00664
	After RHD			.00	.00	.0000	.00000
Water recharge/ moisture retention	Increased	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Increasing trend	10	100				
	Increased =1	8	80				
	Not increased = 0	2	20				
	Microclimate improvement	10	100				
	Yes = 1	2	20				
	No = 0	8	80				
	Water in well and aquifer	10	100				
	increased	0	0				
	Yes = 1	10	100				
	No = 0						
Agriculture and forest production	Increased	10	100				
	Yes = 1	0	0				
	No = 0	10	100				
	Average trend of increase in production	10	10				
	Increased = 1	0	0				
	Not increased = 0	10	100				
	Agriculture production (Qt./ha/yr)	10	100				
	Increased = 1	0	0				
	Not increased = 0	10	100				
	Before RHD			28.00	36.0	31.70	3.0568
	After RHD			28.00	36.0	31.70	3.0568
	NTFP production (Qt./ha/yr)	10	100				
	Increased = 1	0	0				
	Not increased = 0	10	100				
	Before RHD			.00	2.00	.40	.84237
	After RHD			.00	2.00	.40	.84327
Household income	Increased	10	100				
	Yes = 1	0	0				
	No = 0	10	100				
	Average trend of increase in household income	10	100				
	Increased = 1	0	0				
	Not increased = 0	10	100				

Table 4.17: Analysis of 6 effectiveness indicator of *Chireshwor* runoff harvesting dam, *Hariharpur* 5 (Cont.)

Indicator	Measured Variable	n	%	Min	Max	M	SD
Household income (Cont.)	Average income from agricultural production (Rs/yr)	10	100				
	Increased = 1	0	0				
	Not increased = 0	10	100				
	Before RHD			.00	.00	.00	.0000
	After RHD			.00	.00	.00	.0000
	Average income from forest production (Rs/yr)	10	100				
	Increased = 1	0	0				
	Not increased = 0	10	100				
	Before RHD			.00	7000	1400	2951.4
	After RHD			.00	7000	1400	2951.4
User capacity building	Enhanced capacity	10	100				
	Yes = 1	10	100				
	No = 0	0	0				
	Skill enhanced in operation of RHD	10	100				
	Yes = 1	9	90				
	No = 0	1	10				
	Skill enhanced in maintenance of RHD	10	100				
	Yes = 1	9	90				
	No = 0	1	10				
	Participation in saving credit scheme	10	100				
	Yes = 1	10	100				
	No = 0	0	0				

All respondents (100%) confirmed that the **water availability** was increased after the construction of this RHD. However, water availability in the area was increased only for household use and livestock watering but not for irrigation. Average duration of water availability for household use increased from 1.80 months to 9.0 months. Average number of livestock increased from 4 to 9 per household and average duration of water availability for livestock increased from 6 to 10 months.

All respondents (100%) confirmed that **water induced disaster and soil erosion** was decreased after RHD project. However, 80% respondents stated that this decreasing trend of water induced disaster and soil erosion was increased. The average number of occurrence of Gully bank cutting and depositional event decreased from 3 times per year 1 time per year. Consequently, average area of bank cutting was decreased from 0.0084 to 0 ha/year and deposition from 0.002 to 0 ha/year.

All respondents (100%) confirmed that **water recharge and moisture retention** increased. However, 80% respondents observed that this was in increasing trend. 80% respondents observed that microclimate around the area of RHD project was not improved. All respondents (100%) did not perceive that the availability and level of water in nearby wells changed or increased. It might be because of location of wells. The wells in this case might be located out of zone of influence of RHD that led not to increase the level of water in the well.

All respondents (100%) confirmed that **agriculture and forest production** and **household income** did not increase. However, annual report of DSCO shows that user group earned average NRs 10,000/year from fish rearing. This income kept as revolving fund for saving credit scheme. All respondents (100%) confirmed that **user group capacity** in terms of skill in operation and maintenance of RHD project was enhanced. All of them participated in saving credit scheme.

For *Chireshwor* runoff harvesting dam project, only water availability for household use and livestock watering, water induced disaster and soil erosion and user group capacity building indicators had positive changes.

Based on the above analysis, the overall effectiveness level of *Chireshwor* runoff harvesting dam was measured. The secured score for each indicator were summarized based on the evaluation made by household interviewees in Table 4.18. The effectiveness level of *Chireshwor* runoff harvesting dam was identified as **moderate.**

Table 4.18: Evaluation of 6 effectiveness indicators and the level of overall effectiveness of *Chireshwor* runoff harvesting dam**,** *Hariharpur*-5

Indicators	**variables**	**Points based on response of individual respondent**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Water yield	Average trend of availability of water	1	1	1	1	1	1	1	1	1	1
	Water for irrigation (before and after RHD)	0	0	0	0	0	0	0	0	0	0
	Water for household use (before and after RHD)	1	1	1	1	1	1	1	1	1	1
	Water for livestock (before and after RHD)	1	1	1	1	1	1	1	1	1	1
Water induced disaster and soil erosion	Decreased	1	1	1	1	1	1	1	1	1	1
	Trend of disaster and soil erosion	1	1	1	0	0	1	1	1	1	1
	Bank cutting (before and after RHD)	0	0	0	0	0	1	0	0	0	0
	Sedimentation/deposition(before and after RHD)	0	0	0	0	0	1	0	0	0	0
Water recharge/ moisture retention	Increased	1	1	1	1	1	1	1	1	1	1
	Trend	0	1	1	1	1	1	1	1	0	1
	Microclimate improvement	0	0	0	0	1	1	0	0	0	0
	Water availability in well and aquifer increased	0	0	0	0	0	0	0	0	0	0
Agriculture and forest production	Increased	0	0	0	0	0	0	0	0	0	0
	Average trend of increase in production	0	0	0	0	0	0	0	0	0	0
	Agriculture production (before and after RHD)	0	0	0	0	0	0	0	0	0	0
	NTFP production (before & after RHD)	0	0	0	0	0	0	0	0	0	0
Household income	Increased	0	0	0	0	0	0	0	0	0	0
	Average trend of increase in household income	0	0	0	0	0	0	0	0	0	0
	From agricultural production	0	0	0	0	0	0	0	0	0	0
	From forest production	0	0	0	0	0	0	0	0	0	0
User capacity building	Enhanced capacity	1	1	1	1	1	1	1	1	1	1
	Skill in operation of RHD	1	1	1	1	0	1	1	1	1	1
	Skill in maintenance of RHD	1	1	1	1	0	1	1	1	1	1
	Participation in saving credit scheme	1	1	1	1	1	1	1	1	1	1
Total points		10	11	11	10	9	14	11	11	10	11
Grand total points		108									
Average score		108/10 = 10.8									
Effectiveness level		**Moderate**									

4.2.6 *Haripur* runoff harvesting dam, *Umaprempur*-4, *Dhanusha*

Haripur runoff harvesting dam is located in *Umaprempur* Village Development Committee ward number 4 of *Dhanusha* District. This RHD project was implemented in F.Y. 2004/2005. According to key informants, respondents and project books, the area was damaged due to a small ephemeral water ways which carried sediment from upstream catchment and deposited on downstream. The upper catchment was agricultural farm land and horticultural garden which faced problem of gully bank cutting in the rainy season. The downstream area of about 5 ha was already degraded due to gully bank cutting and deposition of silt which could hardly be used for agricultural production. The area had water deficit for irrigation, household use and livestock watering.

According to key informants, respondents and project books, this runoff harvesting dam project was implemented with the aim of collecting runoff water in the rainy season for household use, livestock watering, small scale irrigation and fishing in the winter season. Other objectives were downstream protection from soil erosion, gully bank cutting and deposition, local environment improvement through moisture conservation and greenery promotion. The conservation activities launched as part of runoff harvesting system were bamboo plantation along the both sides of water ways, protection of trees on the farmland and horticultural garden, storage pond construction in the area of sunken valley and a small earthen dam with spill way across the water ways and construction of conveyance canal. Various trainings for user group as part of capacity enhancement were launched, including trainings on runoff harvesting system development, operation and maintenance, user group strengthening and mobilization, soil and water conservation based income generating activities, saving credit and participatory learning and actions.

The total cost of the project was NRs 259,742.86 to which DSCO contributed 184, 555.50, VDC contributed 32, 517.97 and user group contributed 42,669.39 in the form of labor contribution. Table 4.19 shows the outcome of descriptive statistical analysis of measured variables of effectiveness indicators. The results revealed that there were positive changes in all indicators of effectiveness except water availability for irrigation; trend of water induced disaster and soil erosion and bank cutting; agriculture and forest production and household income.

Table 4.19: Analysis of 6 effectiveness indicators of *Haripur* runoff harvesting dam, *maprempur*-4

Indicators	Measured Variables	n	%	Min.	Max.	M	SD
Water Yield	Average trend of availability of water	15	100				
	Increased = 1	15	100				
	Not increased = 0	0	0				
	Water for irrigation	15	100				
	Increased = 1	0	0				
	Not increased = 0	15	100				
	Area (ha):						
	Before RHD			0.00	0.21	0.672	0.061
	After RHD			0.00	0.21	0.672	0.061
	Duration (Month):						
	Before RHD			0	6	4.00	2.928
	After RHD			0	10	4.67	3.086
	Water for household use (Month)	15	100				
	Increased = 1	14	93.3				
	Not increased = 0	0	6.7				
	Before RHD			0	6	4.00	2.928
	After RHD			9	11	10	0.535
	Water for livestock	15	100				
	Increased = 1	15	100				
	Not increased = 0	0	0				
	Livestock (No):						
	Before RHD			0	6	3.20	1.781
	After RHD			3	15	7.67	3.352
	Duration(Month):						
	Before RHD			0	6	4.00	2.928
	After RHD			10	12	11.80	0.561
Water induced disaster and soil erosion	Decreased	15	100				
	Yes = 1	15	100				
	No = 0	0	0				
	Average decreasing trend of water induced disaster and soil erosion	15	100				
	Increased = 1	0	0				
	Not increased = 0	15	100				
	Bank cutting:	15	100				
	Event (no./yr) :						
	Not increased = 1	14	93.3				
	Decreased = 0	1	6.7				
	Before RHD			0	4	0.27	1.033
	After RHD			0	0	0.00	0.000
	Area (ha/yr) :						
	Not increased = 1	14	93.3				
	Decreased = 0	1	6.7				
	Before RHD			0.00	0.01	0.0007	0.0027
	After RHD			0.00	0.00	0.000	0.0000

Table 4.19: Analysis of 6 effectiveness indicators of *Haripur* runoff harvesting dam, *Umaprempur*- 4 (Cont.)

Indicators	Measured Variables	n	%	Min.	Max.	M	SD
Water induced disaster and soil erosion (Cont.)	Sedimentation/deposition	15	100				
	Events (no./yr) :						
	Not increased = 1	3	20				
	Decreased = 0	12	80				
	Before RHD			0	4	3.20	1.65
	After RHD			0	1	0.47	0.51
	Area (ha/yr) :						
	Not increased = 1	3	20				
	Decreased = 0	12	80				
	Before RHD			0.00	0.03	0.0168	0.009
	After RHD			0.00	0.01	0.0048	0.005
Water recharge/ moisture retention	Increased	15	100				
	Yes = 1	15	100				
	No = 0	0	0				
	Increasing trend	15	100				
	Increased =1	10	66.7				
	Not increased = 0	5	33.3				
	Microclimate improvement	15	100				
	Yes = 1	15	100				
	No = 0	0	0				
	Water in well and aquifer	15	100				
	increased	0	0				
	Yes = 1	15	100				
	No = 0						
Agriculture and forest production	Increased	15	100				
	Yes = 1	0	0				
	No = 0	15	100				
	Average trend of increase in production	15	100				
	Increased = 1	0	0				
	Not increased = 0	15	100				
	Agriculture production (Qt./ha/yr)	15	100				
	Increased = 1	0	0				
	Not increased = 0	15	100				
	Before RHD			0.00	40.00	29.933	9.617
	After RHD			0.00	40.00	29.933	9.617
	NTFP production (Qt./ha/yr)	15	100				
	Increased = 1	0	0				
	Not increased = 0	15	100				
	Before RHD			0.00	5.00	1.4667	2.263
	After RHD			0.00	5.00	1.4667	2.263
Household income	Increased	15	100				
	Yes = 1	0	0				
	No = 0	15	100				
	Average trend of increase in household income	15	100				
	Increased = 1	0	0				
	Not increased = 0	15	100				

Table 4.19: Analysis of 6 effectiveness indicators of *Haripur* runoff harvesting dam, *Umaprempur*- 4 (Cont.)

Indicators	Measured Variables	n	%	Min.	Max.	M	SD
Household income (C0nt.)	Average income from agricultural production (Rs/yr)	15	100				
	Increased = 1	0	0				
	Not increased = 0	15	100				
	Before RHD			0.00	0.00	0.0000	0.000
	After RHD			0.00	0.00	0.0000	0.000
	Average income from forest production (Rs/yr)	15	100				
	Increased = 1	0	0				
	Not increased = 0	15	100				
	Before RHD			0.00	5000.	1500.0	2275.6
	After RHD			0.00	5000.	1500.0	2275.6
User capacity building	Enhanced capacity	15	100				
	Yes = 1	15	100				
	No = 0	0	0				
	Skill enhanced in operation of RHD	15	100				
	Yes = 1	11	73.3				
	No = 0	4	26.7				
	Skill enhanced in maintenance of RHD	15	100				
	Yes = 1	9	60				
	No = 0	6	40				
	Participation in saving credit scheme	15	100				
	Yes = 1	12	80				
	No = 0	3	20				

All respondents (100%) confirmed that the **water availability** was increased after the construction of this RHD. However, water availability in the area was increased only for household use and livestock watering but not for irrigation. Average duration of water availability for household use increased from 4 months to 10 months. Average number of livestock increased from 3 to 8 per household and average duration of water availability for livestock increased from 6 to 12 months.

All respondents (100%) confirmed that **water induced disaster and soil erosion** was decreased after RHD project. However, all respondents (100%) respondents stated that this decreasing trend of water induced disaster and soil erosion was not increased. The average number of occurrence of Gully bank cutting and depositional event decreased from 1 and 3 times per year to 0 and 1 time per year, respectively. Consequently, average area of bank cutting was decreased from 0.0007 to 0 ha/year and deposition from 0.0168 to 0.0048 ha/year.

All respondents (100%) confirmed that **water recharge and moisture retention** increased. However, 66.7% respondents observed that this was in increasing trend. All respondents (100%) observed that microclimate around the area of RHD project was improved. All respondents (100%) did not perceive that the availability and level of water in nearby wells changed or increased. It might be because of location of wells. The wells in this case might be located out of zone of influence of RHD that led not to increase the level of water in the wells.

All respondents (100%) confirmed that **agriculture and forest production** and **household income** was not increased. However, annual report of DSCO shows that user group earned average NRs 15,000/year from fish rearing. This income kept as revolving fund for saving credit scheme. All respondents (100%) confirmed that **user group capacity** in terms of skill in operation and maintenance of RHD project was enhanced. Only 80% of them participated in saving credit scheme.

For *Haripur* runoff harvesting dam project, only water availability for household use and livestock watering, water induced disaster and soil erosion, moisture retention and user group capacity building indicators had positive changes.

Based on the above analysis, the overall effectiveness level of *Haripur* runoff harvesting dam was measured. The secured score for each indicator were summarized based on the evaluation made by household interviewees in Table 4.20. The effectiveness level of *Haripur* runoff harvesting dam was identified as **moderate.**

Table 4.20: Evaluation of 6 effectiveness indicators and the level of overall effectiveness of *Haripur* runoff harvesting dam**,** *Umaprempur*-4

Indicators of Effectiveness	**variables**	**Points based on response of individual respondent**														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Water yield	Average trend of availability of water	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Water for irrigation (before and after RHD)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Water for household use (before and after RHD)	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
	Water for livestock (before and after RHD)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Water induced disaster and soil erosion	Decreased	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Average trend of disaster and soil erosion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bank cutting (before and after RHD)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Sedimentation/deposition(before and after RHD)	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0
Water recharge/ moisture retention	Increased	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Trend	1	0	1	0	0	1	0	1	1	0	1	1	1	1	1
	Microclimate improvement	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Water availability in well and aquifer increased	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture and forest production	Increased	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Average trend of increase in production	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Agriculture production (before and after RHD)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	NTFP production (before & after RHD)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Household income	Increased	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Average trend of increase in household income	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	From agricultural production	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	From forest production	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
User capacity building	Enhanced capacity	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Skill in operation of RHD	0	1	1	0	1	0	1	1	1	1	1	1	1	1	0
	Skill in maintenance of RHD	1	1	0	0	1	0	0	1	1	1	1	0	1	1	0
	Participation in saving credit scheme	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Total score		10	10	10	9	11	10	10	11	13	11	12	11	12	11	9
Grand total score		160														
Average score		160/15 = 10.67														
Effectiveness level		**Moderate**														

The effectiveness level of all sampled runoff harvesting dams can be summarized in Table 4.21.

Table 4.21: Level of effectiveness of runoff harvesting dams

Name of runoff harvesting dam	Location	Level of effectiveness
Dhanauji	*Bengadabar-9*	High
Sabedanda	*Dhalkebar-3*	Moderate
Aurahi	*Naktajhij-9*	High
Madhubasha	*Pushpwalpur-9*	High
Chireshwor	*Hariharpur -5*	Moderate
Haripur	*Umaprempur-4*	Moderate

Among 6 sampled RHDs, effectiveness level of 3 RHDs namely *Dhanauji*, *Aurahi* and *Madhubasha* were classified as **high** and 3 RHDs namely *Sabedanda*, *Chireshwor* and *Haripur* were classified as **moderate**. No RHD project was under low effectiveness level.

Those RHD projects which got positive changes in all the indicators were appeared as **highly effective**. Those RHD projects which had positive changes in availability of water for household use and livestock watering, water induced disaster and soil erosion, moisture retention and microclimate improvement and capacity building of the UG but had not positive changes in availability of water for irrigation, agriculture and forest production and household income; therefore appeared as **moderately effective**.

Dhanauji, *Aurahi* and *Madhubasha* RHD projects got positive changes in bio-physical and socio-economic condition after implementation of RHD projects. Before implementation of RHD projects, local users lived with water deficit condition and the upper catchment forest was degraded; the gully bank cutting and deposition was rampant; the area looked very dry; agriculture and forest production was quite low; household income of the people was also low; people had no habit to work in groups; they had no knowledge about runoff harvesting dam and importance of watershed management and community development. After implementation of RHD projects, the area had increased availability of water for irrigation, household use and livestock watering. The area had decreased water induced disaster and soil erosion. It had increased moisture retention and microclimate improvement except no increase in water level in the wells. The area had increased in agriculture and forest production due to moisture conservation, soil conservation and water for irrigation, though *Aurahi* RHD project still had food insufficiency after implementation of the RHD project. However, its contribution to increased food production was found to be significant. There was increased household income due to increase in agriculture and forest production especially from NTFPs and saving credit scheme. The RHD project activities enhanced the capacity for operation and maintenance of RHD projects, group mobilization and saving credit due to various trainings.

Sabedanda, *Chireshwor* and *Haripur* RHD projects brought positive changes in all effectiveness indicators except water availability for irrigation; agriculture and forest production and household income. The areas got water for household use and livestock watering but not for irrigation that did not bring increase in agriculture and forest production thereby in household income. Most of the respondents reported that soil erosion by bank cutting and disaster by deposition was not decreased as expected, though number of event and area of bank cutting and deposition decreased. Therefore, these RHD projects had not brought positive bio-physical and socio-economic changes compared to *Dhanauji*, *Aurahi* and *Madhubasha* RHD projects.

4.3 Analysis of factors affecting the effectiveness of runoff harvesting dams

There are 8 factors taken for this study as factors affecting the effectiveness of runoff harvesting dams. They are location of runoff harvesting dam, soil type of the site where runoff harvesting dam is located, siltation in the reservoir of conservation storage, upstream management i.e. integrated watershed development, participation of stakeholders (i.e. DSCO, VDC and RHD user group), conflict of objectives among stakeholders, post project operation and maintenance, and budget allocation (i.e. sufficiency of budget) for implementation of RHD project. Each factor has 2 variables; each variable has 3 choices to be responded during the interview process. 1 variable each of soil type (i.e. soil texture) and siltation (i.e. siltation rate) was not included in questionnaire of household interview because this data was planned to collect through project books, key informant interview and site observations. It was separately analyzed in order to enter to Cross Tab matrix. Analysis of measured variables related to effectiveness factors of each sampled runoff harvesting dams are presented in the respective Tables and discussed as follows.

4.3.1 Analysis of measured variables related to effectiveness factors of *Dhanauji* runoff harvesting dam, *Bengadabar*-9, *Dhanusha*

Analysis of measured variables related to effectiveness factors of *Dhanauji* runoff harvesting dam is shown in Table 4.22. 60% of respondents responded that their household were less than or equal to 300m far from the RHD site and 40% were within the distance of 301 to 600 m. 90% of respondents indicated that **the location** on site suitability of RHD conveyance system was suitable. None of them realized that it was not suitable. 70% of respondents responded that soil type of the RHD site was appropriate because it could hold the water for long time once it received the runoff. Water seepage and percolation was not perceived as high. 30% stated that it was partially appropriate due to having some portion of conglomerates through which conservation storage could percolate. None of them indicated that the **soil type** of RHD site was not appropriate. 90% respondents stated that **siltation** in the reservoir of conservation storage increased at low rate. Majority of respondents responded that location, soil type and siltation had positive influence on the effectiveness of this RHD.

For **upstream management**, 90% of respondents stated that forest plantation and protection was carried out with gabion check dams for gully protection. The upstream 17 ha forest was managed as a community forest of which the user group of the RHD were general members. 10% of interviewees indicated that, besides there was upstream protection through bioengineering such as bamboo wattling and grass plantation. All respondents (100%) confirmed that these conservation measures worked and functioned well for upstream conservation. Due to this conservation, siltation and sedimentation rate in the conservation storage was low. All respondents (100%), reported that all stakeholders (i.e. DSCO, VDC and user group) were **participated** in planning and implementation of this RHD project; and stated that these stakeholders had contributed financially for its implementation on upstream conservation, conservation storage, dam structure, and conveyance system.

Table 4.22: Analysis of measured variables related to effectiveness factors of *Dhanauji* runoff harvesting dam

Factors	Measured variables	Observations	%
Location	RHD distance from household (m.)	10	100
	Less than or equal to 300	6	60
	301 to 600	4	40
	More than 601	0	0
	Site suitability for RHD conveyance system	10	100
	Suitable	9	90
	Partially suitable	1	10
	Not suitable	0	0
Soil type	Soil appropriateness of RHD site for runoff harvesting	10	100
	Appropriate	7	70
	Partially appropriate	3	30
	Not appropriate	0	0
Siltation	Trend of rate of increase in siltation in RHD reservoir	10	100
	Increase in low rate	9	90
	Increase in medium rate	1	10
	Increase in high rate	0	0
Upstream management	Upstream Conservation activities (no.)	10	100
	All 3 activities from gully plugging/forest protection and plantation/bioengineering	1	90
	Any 2 activities from gully plugging/forest protection and plantation/bioengineering	9	10
	Any 1 activity from gully plugging/forest protection and plantation/bioengineering	0	0
	Functionality of upstream conservation activities	10	100
	Well functioned	10	100
	Partially functioned	0	0
	Not functioned	0	0
Participation	No. of stakeholder participated in implementation	10	100
	All 3 stakeholders (DSCO/VDC/UG)	10	100
	Any 2 stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0
	No. of stakeholder involved in cost contribution	10	100
	All 3 stakeholders (DSCO/VDC/UG)	10	100
	Any 2 stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0

Table 4.22: Analysis of measured variables related to effectiveness factors of *Dhanauji* runoff harvesting dam (Cont.)

Factors	Measured variables	Observations	%
Conflict of objectives	Existence of objective conflict	10	100
	Not conflicted	8	80
	Partially conflicted	2	20
	Highly conflicted	0	0
	No. of stakeholder involved in establishment of objective	10	100
	All 3 stakeholders (DSCO/VDC/UG)	2	20
	Any 2 stakeholders from DSCO/VDC/UG	8	80
	Any 1 stakeholder from DSCO/VDC/UG	0	0
Operation and maintenance	Operation and maintenance work done	10	100
	Properly done	9	90
	Partially done	1	10
	Not done	0	0
	Functionality of operation and maintenance work	10	100
	Well functioned	9	90
	Partially functioned	1	10
	Not functioned	0	0
Budget allocation	Sufficiency of allocated budget	10	100
	Sufficient	10	100
	Partially sufficient	0	0
	Insufficient	0	0
	Completeness of RHD project in one working season	10	100
	Completed	10	100
	Partially completed	0	0
	Not completed	0	0

Regarding **conflict among stakeholders on objectives** of the runoff harvesting dam, 80% of respondents responded that there was no any conflict. 20% indicated that there was some conflict on water distribution and location of dam site, but was resolved through dialogue and consensus among the users which was mediated by DSCO. 80% of respondents mentioned that the objective of this RHD was established by DSCO professionals and user group through series of discussion and meetings. 20% noticed that all stakeholders (i.e. DSCO, VDC and user group) were involved in setting up the objective. According to key informants and project books, DSCO and user group were directly involved in this process of setting up the objectives of the RHD project, where as VDC involved indirectly and accepted the consensus reached by the DSCO and user group. Therefore, VDC agreed on cost contribution. 90% of respondents responded that **operation and maintenance** works were done properly and well functioned. All respondents (100%) indicated that

budget allocation for this project was sufficient. Therefore, the project work was completed within one working season (i.e. one fiscal year).

4.3.2 Analysis of measured variables related to effectiveness factors of *Sabedanda* runoff harvesting dam, *Dhalkebar*-3, *Dhanusha*

Table 4.23 shows the analysis of the measured variables related to effectiveness factors of *Sabedanda* runoff harvesting dam located in *Dhalkebar* 3. Majority of respondents (80%) pointed out that their households were 301 to 600 m far from the site of this runoff harvesting dam. 80% of respondents indicated that **the location** on site suitability of RHD conveyance system was partially suitable. 50% of respondents responded that **soil type** of the RHD site was appropriate because it could hold the water for long time once it received the runoff. Water seepage and percolation was not perceived as high. Another 50% respondents responded that it was partially appropriate due to having some portion of conglomerates through which conservation storage could percolate. None of them indicated that the soil type of RHD site was not appropriate. 70% respondents stated that **siltation** in the reservoir of conservation storage increased at low rate.

For **upstream management**, all (100%) respondents stated that forest plantation and protection was carried out in the upstream area which was managed as a community forest. The user group of the RHD was also general members of this community forest. All respondents (100%) confirmed that forest management and conservation measures partially functioned for upstream conservation. Due to this conservation, siltation and sedimentation rate in the conservation storage was low. All respondents (100%), reported that all stakeholders (i.e. DSCO, VDC and user group) were **participated** in planning and implementation of this RHD project; and stated that these stakeholders had contributed financially for its implementation on upstream conservation, conservation storage, dam structure, and outlet construction.

Table 4.23: Analysis of measured variables related to effectiveness factors of *Sabedanda* runoff harvesting dam

Factors	Measured variables	Observations	%
Location	RHD distance from household (m.)	10	100
	Less than or equal to 300	1	10
	301 to 600	8	80
	More than 600	1	10
	Site suitability for RHD conveyance system	10	100
	Suitable	0	0
	Partially suitable	8	80
	Not suitable	2	20
Soil type	Soil appropriateness of RHD site for runoff harvesting	10	100
	Appropriate	5	50
	Partially appropriate	5	50
	Not appropriate	0	0
Siltation	Trend of rate of increase in siltation in RHD reservoir	10	100
	Increase in low rate	7	70
	Increase in medium rate	3	30
	Increase in high rate	0	0
Upstream management	Upstream Conservation activities (no.)	10	100
	All 3 activities from gully plugging/forest protection and plantation/bioengineering	0	0
	Any 2 activities from gully plugging/forest protection and plantation/bioengineering	0	0
	Any 1 activity from gully plugging/forest protection and plantation/bioengineering	10	100
	Functionality of upstream conservation activities	10	100
	Well functioned	2	20
	Partially functioned	8	80
	Not functioned	0	0
Participation	No. of stakeholder participated in implementation	10	100
	All 3 stakeholders (DSCO/VDC/UG)	10	100
	Any 2 stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0
	No. of stakeholder involved in cost contribution	10	100
	All 3 stakeholders (DSCO/VDC/UG)	10	100
	Any 2 stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0
Conflict of objectives	Existence of objective conflict	10	100
	Not conflicted	8	80
	Partially conflicted	2	20
	Highly conflicted	0	0
	No. of stakeholder involved in establishment of objective	10	100
	All 3 stakeholders (DSCO/VDC/UG)	4	40
	Any 2 stakeholders from DSCO/VDC/UG	6	60
	Any 1 stakeholder from DSCO/VDC/UG	0	0

Table 4.23: Analysis of measured variables related to effectiveness factors of *Sabedanda* runoff harvesting dam (Cont.)

Factors	Measured variables	Observations	%
Operation and maintenance	Operation and maintenance work done	10	100
	Properly done	1	10
	Partially done	9	90
	Not done	0	0
	Functionality of operation and maintenance work	10	100
	Well functioned	1	10
	Partially functioned	9	10
	Not functioned	0	0
Budget allocation	Sufficiency of allocated budget	10	100
	Sufficient	0	0
	Partially sufficient	10	100
	Insufficient	0	0
	Completeness of RHD project in one working season	10	100
	Completed	0	0
	Partially completed	10	100
	Not completed	0	0

Regarding **conflict among stakeholders on objectives** of the runoff harvesting dam, 80% of respondents responded that there was no any conflict. 20% indicated that there was some conflict on income distribution from fishing, but was resolved through dialogue and consensus among the users which was mediated by DSCO. It was decided to use income of the fishing to community school. 60% of respondents mentioned that the objective of this RHD was established by DSCO professionals and user group through series of discussion and meetings. 40% noticed that all stakeholders (i.e. DSCO, VDC and user group) were involved in setting up the objective. According to key informants and project books, DSCO and user group were directly involved in this process of setting up the objectives of the RHD project, where as VDC involved indirectly and accepted the consensus reached by the DSCO and user group. Therefore, VDC agreed on cost contribution. 90% of respondents responded that **operation and maintenance** works were partially done so as to partially function. All respondents (100%) indicated that **budget allocation** for this project was partially sufficient. Therefore, the project work was completed within two working seasons (i.e. two fiscal years).

4.3.3 Analysis of measured variables related to effectiveness factors of *Aurahi* runoff harvesting dam, *Naktajhij*-9, *Dhanusha*

Analysis of measured variables related to effectiveness factors of *Aurahi* runoff harvesting dam is shown in Table 4.24. All respondents (100%) responded that their households were more than 600m far from the RHD site. 90% of respondents indicated that **the location** on site suitability of RHD conveyance system was suitable. None of them realized that it was not suitable. 50% of respondents responded that soil type of the RHD site was appropriate because it could hold the water for long time once it received the runoff. Water seepage and percolation was not perceived as high. 40% stated that it was partially appropriate due to having some portion of silt and conglomerates through which conservation storage could percolate. 10% respondents indicated that the **soil type** of RHD site was not appropriate. 60% respondents stated that **siltation** in the reservoir of conservation storage increased at low rate. 40% respondents perceived that siltation in the reservoir of conservation storage increased at medium rate.

For **upstream management**, 90% of respondents stated that forest plantation and protection was carried out in upstream catchment. This upstream forest was managed as a community forest of which some of the user group members of the RHD were also general members. 10% of interviewees indicated that, besides community forest, there was upstream protection through gully plugging such as loose stone and gabion check dam. 80% respondents confirmed that these conservation measures worked and functioned well for upstream conservation. Due to this conservation, siltation and sedimentation rate in the conservation storage was low. 20% respondents perceived that upstream conservation measures worked and functioned partially. All respondents (100%), reported that all stakeholders (i.e. DSCO, VDC and user group) were **participated** in planning and implementation of this RHD project; and stated that these stakeholders had contributed financially for its implementation on upstream conservation, conservation storage, dam structure, and conveyance system.

Table 4.24: Analysis of measured variables related to effectiveness factors of *Aurahi* runoff harvesting dam

Factors	Measured variables	Observations	%
Location	RHD distance from household (m.)	10	100
	Less than or equal to 300	0	0
	301 to 600	0	0
	More than 600	10	100
	Site suitability for RHD conveyance system	10	100
	Suitable	9	90
	Partially suitable	1	10
	Not suitable	0	0
Soil type	Soil appropriateness of RHD site for runoff harvesting	10	100
	Appropriate	5	50
	Partially appropriate	4	40
	Not appropriate	1	10
Siltation	Trend of rate of increase in siltation in RHD reservoir	10	100
	Increase in low rate	6	60
	Increase in medium rate	4	40
	Increase in high rate	0	0
Upstream management	Upstream Conservation activities (no.)	10	100
	All 3 activities from gully plugging/forest protection and plantation/bioengineering	0	0
	Any 2 activities from gully plugging/forest protection and plantation/bioengineering	1	10
	Any 1 activity from gully plugging/forest protection and plantation/bioengineering	9	90
	Functionality of upstream conservation activities	10	100
	Well functioned	8	80
	Partially functioned	2	20
	Not functioned	0	0
Participation	No. of stakeholder participated in implementation	10	100
	All 3 stakeholders (DSCO/VDC/UG)	10	100
	Any 2 stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0
	No. of stakeholder involved in cost contribution	10	100
	All 3 stakeholders (DSCO/VDC/UG)	10	100
	Any 2 stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0
Conflict of objectives	Existence of objective conflict	10	100
	Not conflicted	2	20
	Partially conflicted	8	80
	Highly conflicted	0	0
	No. of stakeholder involved in establishment of objective	10	100
	All 3 stakeholders (DSCO/VDC/UG)	9	90
	Any 2 stakeholders from DSCO/VDC/UG	1	10
	Any 1 stakeholder from DSCO/VDC/UG	0	0

Table 4.24: Analysis of measured variables related to effectiveness factors of *Aurahi* runoff harvesting dam (Cont.)

Factors	Measured variables	Observations	%
Operation and maintenance	Operation and maintenance work done	10	100
	Properly done	7	70
	Partially done	3	30
	Not done	0	0
	Functionality of operation and maintenance work	10	100
	Well functioned	6	60
	Partially functioned	4	40
	Not functioned	0	0
Budget allocation	Sufficiency of allocated budget	10	100
	Sufficient	10	100
	Partially sufficient	0	0
	Insufficient	0	0
	Completeness of RHD project in one working season	10	100
	Completed	10	100
	Partially completed	0	0
	Not completed	0	0

Regarding **conflict among stakeholders on objectives** of the runoff harvesting dam, 80% of respondents responded that there was partial conflict on water distribution and location of dam site, but was resolved through dialogue and consensus among the users which was mediated by DSCO. 20% indicated that there was not conflict. 90% of respondents mentioned that the objective of this RHD was established by DSCO professionals, VDC and user group through series of discussion and meetings. 10% noticed that 2 stakeholders (i.e. DSCO and user group) were involved in setting up the objective. According to key informants and project books, DSCO and user group were directly involved in this process of setting up the objectives of the RHD project, where as VDC involved indirectly and accepted the consensus reached by the DSCO and user group. Therefore, VDC agreed on cost contribution. 70% of respondents responded that **operation and maintenance** works were properly done and 60% respondents perceived that these works were well functioned. 30% of respondents responded that **operation and maintenance** works were partially done and 40% respondents perceived that these works were partially functioned. All respondents (100%) indicated that **budget allocation** for this project was sufficient. Therefore, the project work was completed within one working season (i.e. one fiscal year).

4.3.4 Analysis of measured variables related to effectiveness factors of *Madhubasha* runoff harvesting dam, *Pushpwalpur*-9, *Dhanusha*

Analysis of measured variables related to effectiveness factors of *Madhubasha* runoff harvesting dam is shown in Table 4.25. 87.5% of respondents responded that their households were more than 600m far from the RHD site. 12.5 5% of respondents indicated that their households were 301 to 600m far from the RHD site. 62.5% of respondents indicated that **the location** on site suitability of RHD conveyance system was suitable. 37.5% of respondents perceived that the location on site suitability of RHD conveyance system was partially suitable. None of them realized that it was not suitable. 81.3% of respondents responded that **soil type** of the RHD site was partially appropriate because it had some portion of silt and conglomerates through which conservation storage could percolate. 18.8% of respondents perceived that soil type of the RHD site was appropriate as it could hold the water for long time once it received the runoff. Water seepage and percolation was not perceived as high. None of them indicated that the **soil type** of RHD site was not appropriate. All respondents (100%) stated that **siltation** in the reservoir of conservation storage increased at low rate.

For **upstream management**, 100% of respondents confirmed upper catchment was managed with the combination of forest plantation and protection, gully plugging with gabion and cement masonry check dams and bioengineering. This upstream forest was managed as a community forest of which some of the user group members of the RHD were also general members. 93.8% respondents perceived that these conservation measures worked and functioned well for upstream conservation. Due to this conservation, siltation and sedimentation rate in the conservation storage was low. All respondents (100%), reported that all stakeholders (i.e. DSCO, VDC and user group) were **participated** in planning and implementation of this RHD project; and stated that these stakeholders had contributed financially for its implementation on upstream conservation, conservation storage, dam structure, and conveyance system.

Table 4.25: Analysis of measured variables related to effectiveness factors of *Madhubasha* runoff harvesting dam

Factors	Measured variables	Observations	%
Location	RHD distance from household (m.)	16	100
	Less than or equal to 300	0	0
	301 to 600	2	12.5
	More than 600	14	87.5
	Site suitability for RHD conveyance system	16	100
	Suitable	10	62.5
	Partially suitable	6	37.5
	Not suitable	0	0
Soil type	Soil appropriateness of RHD site for runoff harvesting	16	100
	Appropriate	3	18.8
	Partially appropriate	13	81.3
	Not appropriate	0	0
Siltation	Trend of rate of increase in siltation in RHD reservoir	16	100
	Increase in low rate	16	100
	Increase in medium rate	0	0
	Increase in high rate	0	0
Upstream management	Upstream Conservation activities (no.)	16	100
	All 3 activities from gully plugging/forest protection and plantation/bioengineering	16	100
	Any 2 activities from gully plugging/forest protection and plantation/bioengineering	0	0
	Any 1 activity from gully plugging/forest protection and plantation/bioengineering	0	0
	Functionality of upstream conservation activities	16	100
	Well functioned	15	93.8
	Partially functioned	1	6.3
	Not functioned	0	0
Participation	No. of stakeholder participated in implementation	16	100
	All 3 stakeholders (DSCO/VDC/UG)	16	100
	Any two stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0
	No. of stakeholder involved in cost contribution	16	100
	All 3 stakeholders (DSCO/VDC/UG)	16	100
	Any two stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0
Conflict of objectives	Existence of objective conflict	16	100
	Not conflicted	7	43.8
	Partially conflicted	9	56.3
	Highly conflicted	0	0
	No. of stakeholder involved in establishment of objectives	16	100
	All 3 stakeholders (DSCO/VDC/UG)	16	100
	Any two stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0

Table 4.25: Analysis of measured variables related to effectiveness factors of *Madhubasha* runoff harvesting dam (Cont.)

Factors	**Measured variables**	**Observations**	**%**
Operation and maintenance	Operation and maintenance work done	16	100
	Properly done	16	100
	Partially done	0	0
	Not done	0	0
	Functionality of operation and maintenance work	16	100
	Well functioned	16	100
	Partially functioned	0	0
	Not functioned	0	0
Budget allocation	Sufficiency of allocated budget	16	100
	Sufficient	0	0
	Partially sufficient	16	100
	Insufficient	0	0
	Completeness of RHD project in one working season	16	100
	Completed	0	0
	Partially completed	16	100
	Not completed	0	0

Regarding **conflict among stakeholders on objectives** of the runoff harvesting dam, 56.3% of respondents responded that there was partial conflict on water for irrigation and fish culture. Some users gave priority to irrigation some to fish culture. It was resolved through dialogue and consensus among the users which was mediated by DSCO. Consensus made as conservation storage will be used both for irrigation and fish culture. 43.8% indicated that there was not conflict as it was already settled with consensus. All respondents (100%) mentioned that the objective of this RHD was established by DSCO professionals, VDC and user group through series of discussion and meetings. According to key informants and project books, DSCO, VDC and user group were actively involved in this process of setting up the objectives of the RHD project. Therefore, all agreed on cost contribution. All respondents (100%) responded that **operation and maintenance** works were properly done and it functioned well. All respondents (100%) indicated that **budget allocation** for this project was partial sufficient. Therefore, the project work was completed within two working season (i.e. two fiscal year).

4.3.5 Analysis of measured variables related to effectiveness factors of *Chireshwor* runoff harvesting dam, *Hariharpur*-5, *Dhanusha*

Table 4.26 shows the analysis of the measured variables related to effectiveness factors of *Chireshwor* runoff harvesting dam located in *Hariharpur* 5. Majority of respondents (90%) pointed out that their households were less than 300m. 10% respondents indicated that their households were 301 to 600 m far from the site of this runoff harvesting dam. 50% of respondents indicated that **the location** on site suitability of RHD conveyance system was partially suitable. 40% of respondents indicated that the location on site suitability of RHD conveyance system was not suitable. 60% of respondents responded that **soil type** of the RHD site was partially appropriate because it had some portion of conglomerates through which conservation storage could percolate. 40% of respondents responded that soil type of the RHD site was not appropriate due to stream bed material such as pebbles, sand and conglomerates remain in the bed of conservation storage. It could not hold the water for long time once it received the runoff. Water seepage and percolation was perceived as high. None of them indicated that the soil type of RHD site was appropriate. 60% respondents stated that **siltation** in the reservoir of conservation storage increased at medium rate and 40% respondents stated that **siltation** in the reservoir of conservation storage increased at low rate.

For **upstream management**, all (100%) respondents stated that forest plantation and protection was carried out in the upstream area which was managed as a community forest. The user group of the RHD was also general members of this community forest. 90% respondents confirmed that forest management and conservation measures were partially functioned for upstream conservation. Due to this conservation, siltation and sedimentation rate in the conservation storage was low. All respondents (100%), reported that all stakeholders (i.e. DSCO, VDC and user group) were **participated** in planning and implementation of this RHD project; and stated that these stakeholders had contributed financially for its implementation on upstream conservation, conservation storage, dam structure, outlet construction and downstream plantation.

Table 4.26: Analysis of measured variables related to effectiveness factors of *Chireshwor* runoff harvesting dam

Factors	Measured variables	Observations	%
Location	RHD distance from household (m.)	10	100
	Less than or equal to 300	9	90
	301 to 600	1	10
	More than 600	0	0
	Site suitability for RHD conveyance system	10	100
	Suitable	1	10
	Partially suitable	5	50
	Not suitable	4	40
Soil type	Soil appropriateness of RHD site for runoff harvesting	10	100
	Appropriate	0	0
	Partially appropriate	6	60
	Not appropriate	4	40
Siltation	Trend of rate of increase in siltation in RHD reservoir	10	100
	Increase in low rate	4	40
	Increase in medium rate	6	60
	Increase in high rate	0	0
Upstream management	Upstream Conservation activities (no.)	10	100
	All 3 activities from gully plugging/forest protection and plantation/bioengineering	0	0
	Any 2 activities from gully plugging/forest protection and plantation/bioengineering	0	0
	Any 1 activity from gully plugging/forest protection and plantation/bioengineering	10	100
	Functionality of upstream conservation activities	10	100
	Well functioned	0	0
	Partially functioned	9	90
	Not functioned	1	10
Participation	No. of stakeholder participated in implementation	10	100
	All 3 stakeholders (DSCO/VDC/UG)	10	100
	Any 2 stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0
	No. of stakeholder involved in cost contribution	10	100
	All 3 stakeholders (DSCO/VDC/UG)	10	100
	Any 2 stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0
Conflict of objectives	Existence of objective conflict	10	100
	Not conflicted	6	60
	Partially conflicted	4	40
	Highly conflicted	0	0
	No. of stakeholder involved in establishment of objective	10	100
	All 3 stakeholders (DSCO/VDC/UG)	4	40
	Any 2 stakeholders from DSCO/VDC/UG	6	60
	Any 1 stakeholder from DSCO/VDC/UG	0	0

Table 4.26: Analysis of measured variables related to effectiveness factors of *Chireshwor* runoff harvesting dam (Cont.)

Factors	Measured variables	Observations	%
Operation and maintenance	Operation and maintenance work done	10	100
	Properly done	0	0
	Partially done	10	100
	Not done	0	0
	Functionality of operation and maintenance work	10	100
	Well functioned	0	0
	Partially functioned	10	100
	Not functioned	0	0
Budget allocation	Sufficiency of allocated budget	10	100
	Sufficient	10	100
	Partially sufficient	0	0
	Insufficient	0	0
	Completeness of RHD project in one working season	10	100
	Completed	10	100
	Partially completed	0	0
	Not completed	0	0

Regarding **conflict among stakeholders on objectives** of the runoff harvesting dam, 60% of respondents responded that there was no any conflict. 40% indicated that there was some conflict on fish culture and its income distribution, but was resolved through dialogue and consensus among the users which was mediated by DSCO. It was decided to do fish culture only for 6 months in the winter and income of the fishing would be used as revolving fund in saving credit scheme. 60% of respondents mentioned that the objective of this RHD was established by DSCO professionals and user group through series of discussion and meetings. 40% noticed that all stakeholders (i.e. DSCO, VDC and user group) were involved in setting up the objective. According to key informants and project books, DSCO and user group were directly involved in this process of setting up the objectives of the RHD project, where as VDC involved indirectly and accepted the consensus reached by the DSCO and user group. Therefore, VDC agreed on cost contribution. All respondents (100%) responded that **operation and maintenance** works were partially done so as to partially function. All respondents (100%) indicated that **budget allocation** for this project was sufficient. Therefore, the project work was completed within one working seasons (i.e. one fiscal years).

4.3.6 Analysis of measured variables related to effectiveness factors of *Haripur* runoff harvesting dam, *Umaprempur*-4, *Dhanusha*

Table 4.27 shows the analysis of the measured variables related to effectiveness factors of *Haripur* runoff harvesting dam located in *Umaprempur* 5 of *Dhanusha* District. 53.3% respondent pointed out that their households were less than 300m far from the site of this RHD project 46.7% respondents indicated that their households were 301 to 600 m far from the site of this runoff harvesting dam. 73.3% of respondents indicated that **the location** on site suitability of RHD conveyance system was suitable. 13.3% of respondents indicated that the location on site suitability of RHD conveyance system was partially suitable. 13.3% of respondents responded that **soil type** of the RHD site was not suitable because it had some portion of conglomerates through which conservation storage could percolate. It could not hold the water for long time once it received the runoff. Water seepage and percolation was perceived as high. 60% respondents indicated that **siltation** in the reservoir of conservation storage increased at high rate. 33.3% respondents stated that siltation in the reservoir of conservation storage increased at medium rate and 6.7 respondents stated that **siltation** in the reservoir of conservation storage increased at low rate.

For **upstream management**, all (100%) respondents stated that bamboo plantation and protection was carried out on the 2 sides of waterways in the upstream area. The trees on farm land horticultural garden were protected. 73.3% respondents confirmed that conservation measures in upstream area were partially functioned for upstream protection. 26.7% respondents indicated that conservation measures in upstream area were not well functioned for upstream protection. Therefore, siltation in the storage reservoir increased. 86.7% respondents reported that all stakeholders (i.e. DSCO, VDC and user group) were **participated** in planning and implementation of this RHD project. 13.3% respondents reported those only DSCO and user groups were **participated** in planning and implementation of this RHD project. All respondents (100%) stated that all stakeholders (i.e. DSCO, VDC and User group) had contributed financially for its implementation of upstream conservation, conservation storage, dam structure, spillway construction and conveyance.

Table 4.27: Analysis of measured variables related to effectiveness factors of *Haripur* runoff harvesting dam

Factors	Measured variables	Observations	%
Location	RHD distance from household (m.)	15	100
	Less than or equal to 300	8	53.3
	301 to 600	7	46.7
	More than 601	0	0
	Site suitability for RHD conveyance system	15	100
	Suitable	11	73.3
	Partially suitable	2	13.3
	Not suitable	2	13.3
Soil type	Soil appropriateness of RHD site for runoff harvesting	15	100
	Appropriate	5	33.3
	Partially appropriate	9	60.0
	Not appropriate	1	6.7
Siltation	Trend of rate of increase in siltation in RHD reservoir	15	100
	Increase in low rate	1	6.7
	Increase in medium rate	5	33.3
	Increase in high rate	9	60
Upstream management	Upstream Conservation activities (no.)	15	100
	All 3 activities from gully plugging/forest protection and plantation/bioengineering	0	0
	Any 2 activities from gully plugging/forest protection and plantation/bioengineering	0	0
	Any 1 activity from gully plugging/forest protection and plantation/bioengineering	15	100
	Functionality of upstream conservation activities	15	100
	Well functioned	0	0
	Partially functioned	11	73.3
	Not functioned	4	26.7
Participation	No. of stakeholder participated in implementation	15	100
	All 3 stakeholders (DSCO/VDC/UG)	13	86.7
	Any 2 stakeholders from DSCO/VDC/UG	2	13.3
	Any 1 stakeholder from DSCO/VDC/UG	0	0
	No. of stakeholder involved in cost contribution	15	100
	All 3 stakeholders (DSCO/VDC/UG)	15	100
	Any 2 stakeholders from DSCO/VDC/UG	0	0
	Any 1 stakeholder from DSCO/VDC/UG	0	0
Conflict of objectives	Existence of objective conflict	15	100
	Not conflicted	0	0
	Partially conflicted	14	93.3
	Highly conflicted	1	6.7
	No. of stakeholder involved in establishment of objective	15	100
	All 3 stakeholders (DSCO/VDC/UG)	9	60
	Any 2 stakeholders from DSCO/VDC/UG	6	40
	Any 1 stakeholder from DSCO/VDC/UG	0	0

Table 4.27: Analysis of measured variables related to effectiveness factors of *Haripur* runoff harvesting dam (Cont.)

Factors	Measured variables	Observations	%
Operation and maintenance	Operation and maintenance work done	15	100
	Properly done	0	0
	Partially done	14	93.3
	Not done	1	6.7
	Functionality of operation and maintenance work	15	100
	Well functioned	0	0
	Partially functioned	14	93.3
	Not functioned	1	6.7
Budget allocation	Sufficiency of allocated budget	15	100
	Sufficient	15	100
	Partially sufficient	0	0
	Insufficient	0	0
	Completeness of RHD project in one working season	15	100
	Completed	15	100
	Partially completed	0	0
	Not completed	0	0

Regarding **conflict among stakeholders on objectives** of the runoff harvesting dam, 93.3% of respondents responded that there was partial conflict on water use and fish culture; but was resolved through dialogue and consensus among the users which was mediated by DSCO. It was decided to do fish culture only for 6 months in the winter and conservation storage will be used both for irrigation and fish culture. 60% of respondents mentioned that the objective of this RHD was established by DSCO professionals, VDC and user group together through discussion and meetings. 40% noticed those only DSCO and user groups were involved in setting up the objective. According to key informants and project books, DSCO and user group were directly involved in this process of setting up the objectives of the RHD project, where as VDC involved indirectly and accepted the consensus reached by the DSCO and user group. Therefore, VDC agreed on cost contribution. 93.3% respondents responded that **operation and maintenance** works were partially done so as to partially function. All respondents (100%) indicated that **budget allocation** for this project was sufficient. Therefore, the project work was completed within one working seasons (i.e. one fiscal years).

4.3.7 Analysis of cumulative influence of effectiveness factor of runoff harvesting dam

There were 8 factors of effectiveness of runoff harvesting dams, each had 2 variables. Each variable was classified in to high, medium and low level of influence on related factors. The frequencies of measured variables, except soil texture and siltation rate, of effectiveness factors of sampled RHD were taken from household interview. The data of soil texture and siltation rate of each of sampled runoff harvesting dam site were collected from project books and annual reports of District Soil Conservation Office, *Dhanusha*. Their levels of influence on respective factors (i.e. soil type and siltation) were taken in frequency only for the purpose of Cross Tab Matrix analysis. These are summarized in Table 4.28. In the table, D1, D2, D3, D4, D5, D6 denote *Dhanauji*, *Sabedanda*, *Aurahi*, *Madhubasha*, *Chireshwor* and *Haripur* runoff harvesting dam, respectively.

Table 4.28: Level of influence of measured variables on effectiveness factors and their frequencies of sampled runoff harvesting Dams

Factors	**Measured Variables**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**
Location	RHD distance from household (m.)	10	10	10	16	10	15
	Less than or equal to 300 (**High**)	6	1	0	0	9	8
	301 to 600 (**Moderate**)	4	8	0	2	1	7
	More than 601 (**Low**)	0	1	10	14	0	0
	Site suitability for RHD conveyance system	10	10	10	16	10	15
	Suitable (**high**)	9	0	9	10	1	11
	Partially suitable (**moderate**)	1	8	1	6	5	2
	Not suitable (**low**)	0	2	0	0	4	2
Soil Type	Soil appropriateness of RHD site	10	10	10	16	10	15
	Appropriate (**High**)	7	5	5	3	0	5
	Partially appropriate (**Moderate**)	3	5	4	13	6	9
	Not appropriate (**Low**)	0	0	1	0	4	1
	Soil texture	10	10	10	16	10	15
	Clay/Clay loam (**high**)	0	10	0	0	0	15
	Silty clay/Silty loam, (**moderate**)	10	0	10	16	0	0
	Sand/Conglomerate (**low**)	0	0	0	0	10	0
Siltation	Trend of rate of increase in siltation	10	10	10	16	10	15
	Increase in low rate (**High**)	9	7	6	16	4	1
	Increase in medium rate(**Moderate**)	1	3	4	0	6	5
	Increase in high rate (**Low**)	0	0	0	0	0	9
	Siltation rate	10	10	10	16	10	15
	Less than 10 cm/year (**high**)	10	0	0	16	0	0
	10cm to 20 cm/year (**moderate**)	0	10	10	0	10	0
	More than 20 cm/year (**low**)	0	0	0	0	0	15

Table 4.28: Level of influence of measured variables on effectiveness factors and their frequencies of sampled runoff harvesting Dams (Cont.)

Factors	**Measured Variables**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**
Upstream management	Upstream Conservation activities (no.)	10	10	10	16	10	15
	All 3 activities (**High**)	1	0	0	16	0	0
	Any 2 activities (**Moderate**)	9	0	1	0	0	0
	Any 1 (**Low**)	0	10	9	0	10	15
	Functionality of upstream conservation	10	10	10	16	10	15
	Well functioned (**high**)	10	2	8	15	0	0
	Partially functioned (**moderate**)	0	8	2	1	9	11
	Not functioned (**low**)	0	0	0	0	1	4
Participation	No. of stakeholder participation	10	10	10	16	10	15
	All 3 stakeholders (**High**)	10	10	10	16	10	13
	Any 2 stakeholders (**Moderate**)	0	0	0	0	0	2
	Any 1 stakeholder (**Low**)	0	0	0	0	0	0
	Involvement in cost contribution	10	10	10	16	10	15
	All 3 stakeholders (**high**)	10	10	10	16	10	15
	Any 2 stakeholders (**moderate**)	0	0	0	0	0	0
	Any 1 stakeholder (**low**)	0	0	0	0	0	0
Conflict of objectives	Existence of objective conflict	10	10	10	16	10	15
	Not conflicted (**High**)	8	8	2	7	6	0
	Partially conflicted(**Moderate**)	2	2	8	9	4	14
	Highly conflicted(**Low**)	0	0	0	0	0	1
	Establishment of objectives of RHD	10	10	10	16	10	15
	All 3 stakeholders (**high**)	2	4	9	16	4	9
	Any 2 stakeholders (**moderate**)	8	6	1	0	6	6
	Any 1 stakeholder from (**low**)	0	0	0	0	0	0
Operation and maintenance	Operation and maintenance work done	10	10	10	16	10	15
	Properly done (**High**)	9	1	7	16	0	0
	Partially done(**Moderate**)	1	9	3	0	10	14
	Not done(**Low**)	0	0	0	0	0	1
	Functionality of operation and maintenance	10	10	10	16	10	15
	Well functioned (**high**)	9	1	6	16	0	0
	Partially functioned(**moderate**)	1	9	4	0	10	14
	Not functioned(**low**)	0	0	0	0	0	1
Budget allocation	Sufficiency of allocated budget	10	10	10	16	10	15
	Sufficient (**High**)	10	0	10	0	10	15
	Partially sufficient (**Moderate**)	0	10	0	16	0	0
	Insufficient (**Low**)	0	0	0	0	0	0
	Completeness of RHD in one working season	10	10	10	16	10	15
	Completed (**high**)	10	0	10	0	10	15
	Partially completed (**moderate**)	0	10	0	16	0	0
	Not completed (**low**)	0	0	0	0	0	0

The frequencies of measured variables were employed in 3×3 cross tab matrix to identify the cumulative influence of their respective factors as follows.

RHD No.: 1 **Name: *Dhanuji*** **Location: *Bengadabar*-9**

1. Location:

High = Hh + Hm + Mh = 54+6+36 = 86

Moderate = Hl + Mm + Lh = 0 + 4 + 0 = 4

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of location is **high**.

Variable 1

Variable 2

	H (6)	M (4)	L(0)
h (9)	54	36	0
m (1)	6	4	0
l(0)	0	0	0

Notes:

Variable 1: Distance from household to RHD indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Site suitability for RHD conveyance system indicated as **high (h), moderate (m) and low (l)**.

2. Soil type:

High = Hh + Hm + Mh = 0+70+0 = 70

Moderate = Hl + Mm + Lh = 0 + 30 + 0 = 30

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of soil type is **high**.

Variable 1

Variable 2

	H (7)	M (3)	L(0)
h (0)	0	0	0
m (10)	70	30	0
l(0)	0	0	0

Notes:

Variable 1: Soil appropriateness of RHD site for runoff harvesting indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Soil suitability of RHD site in terms of soil texture for runoff harvesting indicated as **high (h), moderate (m) and low (l)**.

3. Siltation:

High = Hh + Hm + Mh = 90+0+10 = 100

Moderate = Hl + Mm + Lh = 0 +04 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of siltation is **high**.

Variable 1

Variable 2

	H (9)	M (1)	L(0)
h (10)	90	10	0
m (0)	0	0	0
l (0)	0	0	0

Notes:

Variable 1: Trend of rate of increase in siltation in RHD reservoir indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Average siltation rate in RHD reservoir indicated as **high (h), moderate (m) and low (l)**.

4. Upstream management:

High = Hh + Hm + Mh = 10+0+90 = 100

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of upstream management is **high**.

Variable 1

Variable 2

	H (1)	M (9)	L(0)
h (10)	10	90	0
m (0)	0	0	0
l(0)	0	0	0

Notes:

Variable 1: Number of conservation activities in upstream management of RHD indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of upstream conservation activities of RHD indicated as **high (h), moderate (m) and low (l)**.

5. Participation:

High = Hh + Hm + Mh = 100+0+0 = 100

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of participation is **high**.

Variable 1

Variable 2

	H (10)	M (0)	L(0)
h (10)	100	0	0
m (0)	0	0	0
l(0)	0	0	0

Notes:

Variable 1: Numbers of stakeholders participated in implementation of RHD project indicated as **High (H), Moderate (M) and Low (L**).

Variable 2: Number of stakeholders involved in cost contribution for implementation of RHD project indicated as **high (h), moderate (m) and low (l)**.

6. Conflict of objectives :

High = Hh + Hm + Mh = 16+64+4 = 84

Moderate = Hl + Mm + Lh = 0 + 16 + 0 = 16

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of conflict of objective is **high**.

Variable 1

Variable 2

	H (8)	M (2)	L(0)
h (2)	16	4	0
m (8)	*64*	16	0
l (0)	0	0	0

Notes:

Variable 1: Existence of objective conflict during implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Number of stakeholder involved in establishment of objective of RHD project indicated as **high (h), moderate (m) and low (l)**.

7. Operation and maintenance:

High = Hh + Hm + Mh = 81+9+9 = 99

Moderate = Hl + Mm + Lh = 0 + 1 + 0 = 1

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of operation and maintenance is **high**.

Variable 1

Variable 2

	H (9)	M (1)	L(0)
h (9)	81	9	0
m (1)	9	1	0
l (0)	0	0	0

Notes:

Variable 1: Operation and maintenance efficiency of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of operation and maintenance capacity of RHD project indicated as **high (h), moderate (m) and low (l)**.

8. Budget allocation:

High = Hh + Hm + Mh = 100+0+0 = 100

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of budget allocation is **high**.

Variable 1

Variable 2

	H (10)	M (0)	L(0)
h (10)	100	0	0
m (0)	0	0	0
l(0)	0	0	0

Notes:

Variable 1: Sufficiency of allocated budget for implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Completeness of RHD project in one working season indicated as **high (h), moderate (m) and low (l)**.

RHD No.: 2 **Name:** ***Sabedanda*** **Location:** ***Dhalkebar*-3**

1. Location:

High = Hh + Hm + Mh = 0+8+0 = 8

Moderate = Hl + Mm + Lh = 2+ 64 + 0 = 66

Low = Ml + Lm + Ll = 16 + 8 +2 = 26

Therefore effectiveness of runoff harvesting dam on the basis of location is **Moderate**.

Variable 1

Variable 2

	H (1)	M (8)	L(1)
h (0)	0	0	0
m (8)	8	64	8
l (2)	2	16	2

Notes:

Variable 1: Distance from households to RHD indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Site suitability for RHD conveyance system indicated as **high (h), moderate (m) and low (l)**.

2. Soil type:

High = Hh + Hm + Mh = 50+0+50 = 100

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of soil type is **high**.

Variable 1

Variable 2

	H (5)	M (5)	L(0)
h (10)	50	50	0
m (0)	0	0	0
l(0)	0	0	0

Notes:

Variable 1: Soil appropriateness of RHD site for runoff harvesting indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Soil suitability of RHD site in terms of soil texture for runoff harvesting indicated as **high (h), moderate (m) and low (l)**.

3. Siltation:

High = Hh + Hm + Mh = 0+70+0 = 70

Moderate = Hl + Mm + Lh = 0 +30 + 0 =30

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of siltation is **high**.

Variable 1

Variable 2

	H (7)	M (3)	L(0)
h (0)	0	0	0
m (10)	70	30	0
l (0)	0	0	0

Notes:

Variable 1: Trend of rate of increase in siltation in RHD reservoir indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Average siltation rate in RHD reservoir indicated as **high (h), moderate (m) and low (l)**.

4. Upstream management:

High = Hh + Hm + Mh = 0+0+0 = 0

Moderate = Hl + Mm + Lh = 0 + 0 + 20 = 20

Low = Ml + Lm + Ll = 0 + 80 + 0 = 80

Therefore effectiveness of runoff harvesting dam on the basis of upstream management is **low**.

Variable 1

Variable 2

	H (0)	M (0)	L(10)
h (2)	0	0	20
m (8)	0	0	80
l(0)	0	0	0

Notes:

Variable 1: Number of conservation activities in upstream management of RHD indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of upstream conservation activities of RHD indicated as **high (h), moderate (m) and low (l)**.

5. Participation:

High = Hh + Hm + Mh = 100+0+0 = 100

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of participation is **high**.

Variable 1

Variable 2

	H (10)	M (0)	L(0)
h (10)	100	0	0
m (0)	0	0	0
l(0)	0	0	0

Notes:

Variable 1: Number of stakeholder participated in implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Number of stakeholders involved in cost contribution for implementation of RHD project indicated as **high (h), moderate (m) and low (l)**.

6. Conflict of objectives :

High = Hh + Hm + Mh = 32+48+8 = 88

Moderate = Hl + Mm + Lh = 0 + 12 + 0 = 12

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of conflict of objective is **high**.

Variable 1

Variable 2

	H (8)	M (2)	L(0)
h (4)	32	8	0
m (6)	48	12	0
l (0)	0	0	0

Notes:

Variable 1: Existence of objective conflict during implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Number of stakeholders involved in establishment of objective of RHD project indicated as **high (h), moderate (m) and low (l)**.

7. Operation and maintenance:

High = Hh + Hm + Mh = 1+9+9 = 19

Moderate = Hl + Mm + Lh = 0 + 81 + 0 = 81

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of operation and maintenance is **moderate**.

Variable 1

Variable 2

	H (1)	M (9)	L(0)
h (1)	1	9	0
m (9)	9	81	0
l (0)	0	0	0

Notes:

Variable 1: Operation and maintenance efficiency of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of operation and maintenance capacity of RHD project indicated as **high (h), moderate (m) and low (l)**.

8. Budget allocation:

High = Hh + Hm + Mh = 0+0+0 = 0

Moderate = Hl + Mm + Lh = 0 +100 + 0 = 100

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Variable 1

Variable 2

	H (0)	M (10)	L(0)
h (0)	0	0	0
m (10)	0	100	0
l(0)	0	0	0

Therefore effectiveness of runoff harvesting dam on the basis of budget allocation is **moderate**.

Notes:

Variable 1: Sufficiency of allocated budget for implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Completeness of RHD project in one working season indicated as **high (h), moderate (m) and low (l)**.

RHD No.: 3 **Name:** ***Aurahi*** **Location:** ***Naktajhij*-9**

1. Location:

High = Hh + Hm + Mh = 0+0+0 = 0

Moderate = Hl + Mm + Lh = 0 + 0 + 90 = 90

Low = Ml + Lm + Ll = 0 + 10 + 0 = 10

Variable 1

Variable 2

	H (0)	M (0)	L(10)
h (9)	0	0	90
m (1)	0	0	10
l(0)	0	0	0

Therefore effectiveness of runoff harvesting dam on the basis of location is **moderate**.

Notes:

Variable 1: Distance from households indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Site suitability for RHD conveyance system indicated as **high (h), moderate (m) and low (l)**.

2. Soil type:

High = Hh + Hm + Mh = 0+50+0 = 50

Moderate = Hl + Mm + Lh = 0 + 40 + 0 = 40

Low = Ml + Lm + Ll = 0 + 10 + 0 = 10

Therefore effectiveness of runoff harvesting dam on the basis of soil type is **high**.

Variable 1

Variable 2

	H (5)	M (4)	L(1)
h (0)	0	0	0
m (10)	50	40	10
l(0)	0	0	0

Notes:

Variable 1: Soil appropriateness of RHD site for runoff harvesting indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Soil suitability of RHD site in terms of soil texture for runoff harvesting indicated as **high (h), moderate (m) and low (l)**.

3. Siltation:

High = Hh + Hm + Mh = 0+60+0 = 60

Moderate = Hl + Mm + Lh = 0 + 40 + 0 = 40

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of siltation is **high**.

Variable 1

Variable 2

	H (6)	M (4)	L(0)
h (0)	0	0	0
m (10)	60	40	0
l (0)	0	0	0

Notes:

Variable 1: Trend of rate of increase in siltation in RHD reservoir indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Average siltation rate in RHD reservoir indicated as **high (h), moderate (m) and low (l)**.

4. Upstream management:

High = Hh + Hm + Mh = 0+0+8 = 8

Moderate = Hl + Mm + Lh = 0 + 2 + 72 = 74

Low = Ml + Lm + Ll = 0 + 18 + 0 = 18

Therefore effectiveness of runoff harvesting dam on the basis of upstream management is **moderate**.

Variable 1

Variable 2

	H (0)	M (1)	L(9)
h (8)	0	8	72
m (2)	0	2	18
l(0)	0	0	0

Notes:

Variable 1: Number of conservation activities in upstream management of RHD indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of upstream conservation activities of RHD indicated as **high (h), moderate (m) and low (l)**.

5. Participation:

High = Hh + Hm + Mh = 100+0+0 = 100

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of participation is **high**.

Variable 1

Variable 2

	H (10)	M (0)	L(0)
h (10)	100	0	0
m (0)	0	0	0
l(0)	0	0	0

Notes:

Variable 1: Number of stakeholders participated in implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Number of stakeholders involved in cost contribution for implementation of RHD project indicated as **high (h), moderate (m) and low (l)**.

6. Conflict of objectives :

High = Hh + Hm + Mh = 18 + 2 + 72 = 92

Moderate = Hl + Mm + Lh = 0 + 8 + 0 = 8

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of conflict of objective is **high**.

Variable 1

Variable 2

	H (2)	M (8)	L(0)
h (9)	18	72	0
m (1	*2*	8	0
l (0)	0	0	0

Notes:

Variable 1: Existence of objective conflict during implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Number of stakeholders involved in establishment of objective of RHD project indicated as **high (h), moderate (m) and low (l)**.

7. Operation and maintenance:

High = Hh + Hm + Mh = 42 + 28 + 18 = 88

Moderate = Hl + Mm + Lh = 0 + 12 + 0 = 12

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of operation and maintenance is **high**.

Variable 1

Variable 2

	H (7)	M (3)	L(0)
h (6)	42	18	0
m (4)	28	12	0
l (0)	0	0	0

Notes:

Variable 1: Operation and maintenance efficiency of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of operation and maintenance capacity of RHD project indicated as **high (h), moderate (m) and low (l)**.

8. Budget allocation:

High = Hh + Hm + Mh = 100+0+0 = 100

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of budget allocation is **high**.

Variable 1

Variable 2

	H (10)	M (0)	L(0)
h (10)	100	0	0
m (0)	0	0	0
l(0)	0	0	0

Notes:

Variable 1: Sufficiency of allocated budget for implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Completeness of RHD project in one working season indicated as **high (h), moderate (m) and low (l)**.

RHD No.: 4 **Name:** ***Madhubasa*** **Location:** ***Pushpwalpur*-9**

1. Location:

High = Hh + Hm + Mh = 0 + 0 + 20 = 20

Moderate = Hl + Mm + Lh = 0 + 12 + 14 0 = 152

Low = Ml + Lm + Ll = 0 + 84 + 0 = 84

Therefore effectiveness of runoff harvesting dam on the basis of location is **moderate**.

Variable 1

Variable 2

	H (0)	M (2)	L(14)
h (10)	0	20	140
m (6)	0	12	84
l(0)	0	0	0

Notes:

Variable 1: Distance from households to RHD indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Site suitability for RHD conveyance system indicated as **high (h), moderate (m) and low (l)**.

2. Soil type:

High = Hh + Hm + Mh = 0 + 48 + 0 = 48

Moderate = Hl + Mm + Lh = 0 + 208 + 0 = 208

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of soil type is **moderate**.

Variable 1

Variable 2

	H (3)	M (13)	L(0)
h (0)	0	0	0
m (16)	48	208	0
l(0)	0	0	0

Notes:

Variable 1: Soil appropriateness of RHD site for runoff harvesting indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Soil suitability of RHD site in terms of soil texture for runoff harvesting indicated as **high (h), moderate (m) and low (l)**.

3. Siltation:

High = Hh + Hm + Mh = 256 + 0 + 0 = 256

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of siltation is **high**.

Variable 1

Variable 2

	H (16)	M (0)	L(0)
h (16)	256	0	0
m (0)	0	0	0
l (0)	0	0	0

Notes:

Variable 1: Trend of rate of increase in siltation in RHD reservoir indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Average siltation rate in RHD reservoir indicated as **high (h), moderate (m) and low (l)**.

4. Upstream management:

High = Hh + Hm + Mh = 240 + 16 + 0 = 256

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Variable 1

Variable 2

	H (16)	M (0)	L(0)
h (15)	240	0	0
m (1)	16	0	0
l(0)	0	0	0

Therefore effectiveness of runoff harvesting dam on the basis of upstream management is **high**.

Notes:

Variable 1: Number of conservation activities in upstream management of RHD indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of upstream conservation activities of RHD indicated as **high (h), moderate (m) and low (l)**.

5. Participation:

High = Hh + Hm + Mh = 256 + 0 + 0 = 100

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Variable 1

Variable 2

	H (16)	M (0)	L(0)
h (16)	256	0	0
m (0)	0	0	0
l(0)	0	0	0

Therefore effectiveness of runoff harvesting dam on the basis of participation is **high**.

Notes:

Variable 1: Number of stakeholders participated in implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Number of stakeholders involved in cost contribution for implementation of RHD project indicated as **high (h), moderate (m) and low (l)**.

6. Conflict of objectives :

High = Hh + Hm + Mh = 112 + 0 + 144 = 256

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Variable 1

Variable 2

	H (7)	M (9)	L(0)
h (16)	112	144	0
m (0)	0	0	0
l (0)	0	0	0

Therefore effectiveness of runoff harvesting dam on the basis of conflict of objective is **high**.

Notes:

Variable 1: Existence of objective conflict during implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Number of stakeholders involved in establishment of objective of RHD project indicated as **high (h), moderate (m) and low (l)**.

7. Operation and maintenance:

High = Hh + Hm + Mh = 256 + 0 + 0 = 256

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of operation and maintenance is **high**.

Variable 1

Variable 2

	H (16)	M (0)	L(0)
h (16)	256	0	0
m (0)	0	0	0
l (0)	0	0	0

Notes:

Variable 1: Operation and maintenance efficiency of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of operation and maintenance capacity of RHD project indicated as **high (h), moderate (m) and low (l)**.

8. Budget allocation:

High = Hh + Hm + Mh = 0 + 0 + 0 = 0

Moderate = Hl + Mm + Lh = 0 + 256 + 0 = 256

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of budget allocation is **moderate**.

Variable 1

Variable 2

	H (0)	M (16)	L(0)
h (0)	0	0	0
m (16)	0	256	0
l(0)	0	0	0

Notes:

Variable 1: Sufficiency of allocated budget for implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Completeness of RHD project in one working season indicated as **high (h), moderate (m) and low (l)**.

RHD No.: 5 **Name:** ***Chireshwor*** **Location:** ***Hariharpur*** **-5**

1. Location:

High = Hh + Hm + Mh = 9 + 45 + 1 = 55

Moderate = Hl + Mm + Lh = 36 + 5 + 0 = 41

Low = Ml + Lm + Ll = 4 + 0 + 0 = 4

Therefore effectiveness of runoff harvesting dam on the basis of location is **high**.

Variable 1

Variable 2

	H (9)	M (1)	L(0)
h (1)	9	1	0
m (5)	45	5	0
l(4)	36	4	0

Notes:

Variable 1: Distance from households to RHD indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Site suitability for RHD conveyance system indicated as **high (h), moderate (m) and low (l)**.

2. Soil type:

High = Hh + Hm + Mh = 0 + 0 + 0 = 0

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 60 + 0 + 40 = 100

Therefore effectiveness of runoff harvesting dam on the basis of soil type is **low**.

Variable 1

Variable 2

	H (0)	M (6)	L(4)
h (0)	0	0	0
m (0)	0	0	0
l(10)	0	60	40

Notes:

Variable 1: Soil appropriateness of RHD site for runoff harvesting indicated as **High (H), Moderate (M) and Low (L).**

Variable 2: Soil suitability of RHD site in terms of soil texture for runoff harvesting indicated as **high (h), moderate (m) and low (l)**.

3. Siltation:

High = Hh + Hm + Mh = 0 + 40 +0 = 0

Moderate = Hl + Mm + Lh = 0 + 60 + 0 = 60

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of siltation is **moderate**.

Variable 1

Variable 2

	H (4)	M (6)	L(0)
h (0)	0	0	0
m (10)	40	60	0
l (0)	0	0	0

Notes:

Variable 1: Trend of rate of increase in siltation in RHD reservoir indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Average siltation rate in RHD reservoir indicated as **high (h), moderate (m) and low (l)**.

4. Upstream management:

High = Hh + Hm + Mh = 0 + 0 + 0 = 0

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 90 + 10 = 100

Therefore effectiveness of runoff harvesting dam on the basis of upstream management is **low**.

Variable 1

Variable 2

	H (0)	M (0)	L(10)
h (0)	0	0	0
m (9)	0	0	90
l(1)	0	0	10

Notes:

Variable 1: Number of conservation activities in upstream management of RHD indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of upstream conservation activities of RHD indicated as **high (h), moderate (m) and low (l)**.

5. Participation:

High = Hh + Hm + Mh = 100+0+0 = 100

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of participation is **high**.

Variable 1

Variable 2

	H (10)	M (0)	L(0)
h (10)	100	0	0
m (0)	0	0	0
l(0)	0	0	0

Notes:

Variable 1: Number of stakeholders participated in implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Number of stakeholders involved in cost contribution for implementation of RHD project indicated as **high (h), moderate (m) and low (l)**.

6. Conflict of objectives :

High = Hh + Hm + Mh = 24 + 36+ 16 = 76

Moderate = Hl + Mm + Lh = 0 + 24 + 0 = 24

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of conflict of objective is **high**.

Variable 1

Variable 2

	H (6)	M (4)	L(0)
h (4)	24	16	0
m (6)	36	24	0
l (0)	0	0	0

Notes:

Variable 1: Existence of objective conflict during implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Number of stakeholder involved in establishment of objective of RHD project indicated as **high (h), moderate (m) and low (l)**.

7. Operation and maintenance:

High = Hh + Hm + Mh = 0 + 0 + 0 = 0

Moderate = Hl + Mm + Lh = 0 + 100+ 0 = 100

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of operation and maintenance is **moderate**.

Variable 1

Variable 2

	H (0)	M (10)	L(0)
h (0)	0	0	0
m (10)	0	100	0
l (0)	0	0	0

Notes:

Variable 1: Operation and maintenance efficiency of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of operation and maintenance capacity of RHD project indicated as **high (h), moderate (m) and low (l)**.

8. Budget allocation:

High = Hh + Hm + Mh = 100+0+0 = 100

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of budget allocation is **high**.

Variable 1

Variable 2

	H (10)	M (0)	L(0)
h (10)	100	0	0
m (0)	0	0	0
l(0)	0	0	0

Notes:

Variable 1: Sufficiency of allocated budget for implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Completeness of RHD project in one working season indicated as **high (h), moderate (m) and low (l)**.

RHD No.: 6 **Name: *Umaprempur*** **Location: *Umaprempur*-4**

1. Location:

High = Hh + Hm + Mh = 88 + 16 + 77 = 181

Moderate = Hl + Mm + Lh = 16 + 14 + 0 = 30

Low = Ml + Lm + Ll = 14 + 0 + 0 = 14

Therefore effectiveness of runoff harvesting dam on the basis of location is **high**.

Variable 1

Variable 2

	H (8)	M (7)	L(0)
h (11)	88	77	0
m (2)	16	14	0
l(2)	16	14	0

Notes:

Variable 1: Distance from households to RHD indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Site suitability for RHD conveyance system indicated as **high (h), moderate (m) and low (l)**.

2. Soil type:

High = Hh + Hm + Mh = 75 + 0 + 135 = 210

Moderate = Hl + Mm + Lh = 0 + 0 + 15 = 15

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of soil type is **high**.

Variable 1

Variable 2

	H (5)	M (9)	L(1)
h (15)	75	135	15
m (0)	0	0	0
l(0)	0	0	0

Notes:

Variable 1: Soil appropriateness of RHD site for runoff harvesting indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Soil suitability of RHD site in terms of soil texture for runoff harvesting indicated as **high (h), moderate (m) and low (l)**.

3. Siltation:

High = Hh + Hm + Mh = 0 + 0 + 0 = 0

Moderate = Hl + Mm + Lh = 15 + 0 + 0 = 15

Low = Ml + Lm + Ll = 75 + 0 + 135 = 210

Therefore effectiveness of runoff harvesting dam on the basis of siltation is **low**.

Variable 1

Variable 2

	H (1)	M (5)	L(9)
h (0)	0	0	0
m (0)	0	0	0
l (15)	15	75	135

Notes:

Variable 1: Trend of rate of increase in siltation in RHD reservoir indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Average siltation rate in RHD reservoir indicated as **high (h), moderate (m) and low (l)**.

4. Upstream management:

High = Hh + Hm + Mh = 0 + 0 + 0 = 0

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 165 +60 =225

Therefore effectiveness of runoff harvesting dam on the basis of upstream management is **low**.

Variable 1

Variable 2

	H (0)	M (0)	L(15)
h (0)	0	0	0
m (11)	0	0	165
l(4)	0	0	60

Notes:

Variable 1: Number of conservation activities in upstream management of RHD indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of upstream conservation activities of RHD indicated as **high (h), moderate (m) and low (l)**.

5. Participation:

High = Hh + Hm + Mh = 195 + 30 + 0 = 225

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of participation is **high**.

Variable 1

Variable 2

	H (13)	M (2)	L(0)
h (15)	195	30	0
m (0)	0	0	0
l(0)	0	0	0

Notes:

Variable 1: Number of stakeholders participated in implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Number of stakeholders involved in cost contribution for implementation of RHD project indicated as **high (h), moderate (m) and low (l)**.

6. Conflict of objectives :

High = Hh + Hm + Mh = 0 + 0 + 126 = 126

Moderate = Hl + Mm + Lh = 0 + 84 + 9 = 93

Low = Ml + Lm + Ll = 0 + 6 + 0 = 6

Therefore effectiveness of runoff harvesting dam on the basis of conflict of objective is **high**.

Variable 1

Variable 2

	H (0)	M (14)	L(1)
h (9)	0	126	9
m (6)	0	84	6
l (0)	0	0	0

Notes:

Variable 1: Existence of objective conflict during implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Number of stakeholders involved in establishment of objective of RHD project indicated as **high (h), moderate (m) and low (l)**.

7. Operation and maintenance:

High = Hh + Hm + Mh = 0 + 0 + 0 = 0

Moderate = Hl + Mm + Lh = 0 + 196 + 0 = 196

Low = Ml + Lm + Ll = 14 + 14 + 1 = 29

Therefore effectiveness of runoff harvesting dam on the basis of operation and maintenance is **moderate**.

Variable 1

Variable 2

	H (0)	M (14)	L(1)
h (0)	0	0	0
m (14)	0	196	14
l (1)	0	14	1

Notes:

Variable 1: Operation and maintenance efficiency of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Functionality of operation and maintenance capacity of RHD project indicated as **high (h), moderate (m) and low (l)**.

8. Budget allocation:

Variable 1

	H (15)	M (0)	L(0)
h (15)	225	0	0
m (0)	0	0	0
l(0)	0	0	0

Variable 2

High = Hh + Hm + Mh = 225+0+0 = 225

Moderate = Hl + Mm + Lh = 0 + 0 + 0 = 0

Low = Ml + Lm + Ll = 0 + 0 + 0 = 0

Therefore effectiveness of runoff harvesting dam on the basis of budget allocation is **high**.

Notes:

Variable 1: Sufficiency of allocated budget for implementation of RHD project indicated as **High (H), Moderate (M) and Low (L)**.

Variable 2: Completeness of RHD project in one working season indicated as **high (h), moderate (m) and low (l)**.

The level of influence of 8 effectiveness factors on the effectiveness of 6 sampled runoff dams were calculated through Cross Tab matrix as described above. This level of influence of effectiveness factors are summarized in the following Table 4.29.

Table 4.29: Level of influence of 8 effectiveness factors on effectiveness of 6 sampled runoff harvesting dams

Factors	**Name of runoff harvesting dams**					
	Dhanauji (D1)	*Sabedanda* (D2)	*Aurahi* (D3)	*Madhubasha* (D4)	*Chireshwor* (D5)	*Haripur* (D6)
Location	High	Moderate	Moderate	Moderate	High	High
Soil type	High	High	High	Moderate	Low	High
Siltation	High	High	High	High	Moderate	Low
Upstream management	High	Low	Moderate	High	Low	Low
Participation	High	High	High	High	High	High
Conflict of objectives	High	High	High	High	High	High
Operation and maintenance	High	Moderate	High	High	Moderate	Moderate
Budget allocation	High	Moderate	High	Moderate	High	High

The level of influence of all factors towards the effectiveness of ***Dhanauji* RHD project** were high. Location and soil type of RHD site; siltation of conservation storage; upstream conservation; stakeholder involvement for implementation, cost contribution and objective setting of RHD project; conflict of objectives; post project operation and maintenance and budget allocation for completion of all associated activities of RHD project had high level of influence towards effectiveness of this RHD project. All had contributed positively towards its effectiveness. For ***Sabedanda RHD***, the levels of influence of factors of effectiveness towards its effectiveness were found mixed. 4 factors had high, 3 had moderate and 1 had low level of influence. Soil type, siltation, stakeholder participation and conflict of objective had high level of influence. Location, operation and maintenance and budget allocation had moderate level of influence. Upstream management had low level of influence.

For ***Aurahi*** **RHD project**, 6 factors had high level of influence and 2 factors had moderate level of influence towards its effectiveness. Soil type, siltation, stakeholder participation, conflict of objectives, operation and maintenance and budget allocation had high level of influence. Location and upstream management had moderate level of influence. For ***Madhubasha*** **RHD project**, 5 factors had high level of influence and 3 factors had moderate level of influence towards its effectiveness. Siltation, upstream management, participation of stakeholders, conflict of objectives, operation and maintenance had high level of influence. Location, soil type and budget allocation had moderate level of influence.

For ***Chireshwor*** **RHD project**, 4 factors had high level of influence, 2 factors had moderate level of influence and 2 factors had low level of influence towards its effectiveness. Location, participation of stakeholders, conflict of objectives and budget allocation had high level of influence. Siltation and operation and maintenance had moderate level of influence. Soil type and upstream management had low level of influence. For ***Haripur*** **RHD project**, 5 factors had high level of influence, 1 factor had moderate level of influence and 2 factors had low level of influence towards its effectiveness. Location, soil type, participation of stakeholders, conflict of objectives and budget allocation had high level of influence. Operation and maintenance had moderate level of influence. Siltation and upstream management had low level of influence.

Location had high influence towards effectiveness of *Dhanauji*, *Chireshwor*, and *Haripur* RHD projects because these were near from the user group's households (i.e. within 300m) and site is suitable for construction of conveyance system. But it had moderate influence on *Sabedanda*, *Aurahi* and *Madhubasha* RHD project because these sites were more than 500m far from the majority of the user group's household. The location of *Aurahi* RHD project was even more far, more than 800m, among these 3 RHD projects. The location of *Sabedanda* RHD project was also not suitable for construction of conveyance system as most of the farm land were upper than RHD site and downstream land were not suitable for farming so used for afforestation. Khanjani and Busch (1982) indicated that the dam and storage reservoir should be in a place where water distribution can be done conveniently. It should be at the centre of the farm to minimize the cost and to have easy accessibility. Similar idea has been given by Prinz and Singh (2001) and stated that its proximity to household and cropping area can be an important point in improving water use efficiency and avoiding field losses. The accessibility of the site has also to be considered for construction of water harvesting structures and distance from village. These findings are consistent to the findings of the location factor influence to the effectiveness of *Dhanauji*, *Chireshwor*, and *Haripur* RHD projects.

Soil type had high level of influence on effectiveness of *Dhanauji*, *Sabedanda*, *Aurahi* and *Haripur* RHD project. *Sabedanda* and *Haripur* RHD had clay and clay loam type of soil which could hold runoff water for long time. *Dhanauji* and *Aurahi* had silty clay soil which also can hold the water but not that much of clay soil. Household interviewee indicated that the water holding capacity of the storage reservoir had increased in the later years because of clogging the soil pores due to deposition of clay carried out through runoff. It had moderate influence on effectiveness of *Madhubasha* RHD project. This site had silty clay soil which had moderate level of water holding capacity. In addition, household interviewee indicated that some seepage loss had occurred on storage pond of *Madhubasha* RHD. It had low level of influence on effectiveness of *Chireshwor* runoff harvesting dam as it had sand, conglomerates and pebbles deposition of stream bed material. Though respondents indicated some clogging the soil pores and gradual improvement in water holding, there was still low water holding in storage reservoir due to percolation and seepage loss. FAO (2000) recommended that clay and clay loam soil are suitable for water harvesting as it can hold more water than sand and conglomerates soil. The soil with low water holding capacity if deposited with clay soil can also hold water which may take 3-4 years of construction of harvesting system in order to fill the soil pore and reduce the seepage. This is in consistence with the findings of this study.

Siltation had high level of influence on effectiveness of *Dhanauji*, *Sabedanda*, *Aurahi and Madhubasha* RHD project. Majority of respondents of these RHD projects indicated that trend of siltation in storage reservoir was not increased in higher rate. According to the annual report of the DSCO *Dhanusha*, rate of siltation in *Dhanauji* and *Madhubasha* RHD had less than 10 cm/year and *Sabedanda* and *Aurahi* had 10 to 20 cm/year which was thought to be highly and moderately influence to be the low rate of siltation. Low rate of siltation helped towards highly effective RHD project. It had moderate level of influence on effectiveness of *Chireshwor* RHD project. For this project, majority of respondents indicated that siltation in storage reservoir was increased medium rate. According to annual reports, siltation rate of *Chireshwor* RHD had 10 to 20 cm/year which contributed moderately to the rate of siltation. It had low influence on effectiveness of *Haripur* RHD project. It showed that there should be greater problem of siltation. Majority of respondents indicated that trend of siltation in the storage reservoir of this RHD was increased in higher rate. According to annual report, the rate of siltation of this RHD was more that 20cm/year which was thought to be high rate of siltation. All of these contributed the low level of influence of siltation towards effectiveness of *Haripur* RHD project.

Upstream management had high level of influence on effectiveness of *Dhanauji and Madhubasha* RHD project. Upstream area of *Dhanauji* RHD project was managed with plantation and protection of forest and gully plugging by gabion check dams but not implemented bioengineering works. Upstream area of *Madhubasha* RHD project was managed by integrating all 3 activities such as plantation and protection of forest; gully plugging by masonry and gabion check dams and gully bank protection by bioengineering works. The forest of upstream area of above RHD projects were managed as CF. Majority of respondents indicated that these conservation activities were functioned well. The flow of sediment and debris became low due to upstream conservation and development. It had moderate level of influence on effectiveness of *Aurahi* RHD project. The forest of upstream area was managed with only plantation and protection and declared as CF. But there were no other conservation activities applied for the conservation and management of upstream areas. Majority of respondent indicated the management of forest development works functioned well for protection of upper catchment. It had low level of influence on effectiveness of *Sabedanda, Chireswor* and *Haripur* RHD project. The upstream area of *Sabedanda* and *Chireshwor* RHD projects were managed only thorough an activity of plantation and protection of forest. The area was declared as CF. The upstream area of *Haripur* RHD projects were managed through plantation of bamboo tree along the bank of stream line. There were no application of other gully plugging and bioengineering measures in all three RHD projects. Majority of the respondents indicated that this conservation measure was partially functioned.

Sharma and Smakhtin (2001) indicated that integrated watershed development program can be a solution to mitigate the debris flow. Upstream conservation measures of structural, bio-engineering and forest protection and plantation can be implemented with the construction of runoff harvesting dam. Forest and dense vegetation cover can help upstream protection and minimize the siltation. This shows the consistent fact with siltation and upstream management factor of this study.

Participation had high level of influence on effectiveness of all 6 RHD (i.e. *Dhanauji, Sabedanda, Aurahi, Madhubasha, Chireshwor and Haripur*) projects. All stakeholders (i.e. DSCO, VDC and UGs) were participated for overall planning and implementation of these RHD projects. Almost all respondents confirmed that the cost of RHD projects was contributed by all stakeholders in all RHD projects.

Conflict of objectives had high level of influence on effectiveness of all 6 RHD projects. High level of influence means less conflict on objectives of the project among stakeholders that support the project to be more effective. Majority of respondents confirmed that there was no any conflict in *Dhanauji*, *Sabedanda* and *Chireshwor* RHD projects. Likewise, majority of respondents confirmed that there was partial conflict in *Aurahi*, *Madhubasha* and *Haripur* RHD projects which was resolved through mutual discussion during project planning and implementation. Majority of the stakeholders confirmed that all 3 stakeholders (i.e. DSCO, VDC and UGs) were involved to set up the objectives of RHD project in *Aurahi, Madhubasha* and *Haripur* and 2 stakeholders (i.e. DSCO and UGs) in *Dhanauji*, *Sabedanda* and *Chireshwor*.

According to Prinz and Singh, 2001, all stakeholders have to get involved in planning, designing and implementation of water harvesting structure. A consensus is necessary for operation and maintenance of water harvesting structures. Similarly, Samra et al.(2002) explained that unless the program stakeholders, i.e. beneficiary and affected people were convinced and had willing to harvest, store, conserve, repair and maintain the resources by investing their time, energy and money (even partially), water harvesting and conservation projects could not perform satisfactorily. In this study, all beneficiary user groups, DSCO and VDC have involved in planning and implementation and cost sharing of the project which ensured the participation and reduced the conflict over objectives of RHD projects. Thus, participation and conflict of objectives had high level of influence towards effectiveness of all RHD projects.

Operation and maintenance had high level of influence on effectiveness of *Dhanauji*, *Aurahi* and *Madhubasha* RHD projects. Majority of respondents confirmed that these RHD projects had operation and maintenance plan; operation and maintenance work were propropely done as per plan and functioned well. It had moderate level of influence on *Sabedanda*, *Chireshwor* and *Haripur* RHD projects. Majority of respondents confirmed that these RHD projects had no operation and maintenance plan; operation and maintenance work were partially done and partially functioned. These RHD project did not provide the irrigation to the user group. Therefore they are reluctant to maintain it. They replied that much work was not needed to get water for household use and livestock watering, whatever operation and maintenance work they have done was considered to be sufficient.

Budget allocation had high level of influence on effectiveness of *Dhanauji*, *Aurahi*, *Chireshwor* and *Haripur* RHD projects. Majority of respondents confirmed that the allocated budget were sufficient to complete the planned activities of these RHD projects and completed within one working season (i.e. one fiscal year). It had moderate level of influence on *Sabedanda* and *Madhubasha* RHD projects. Majority of respondents confirmed that the allocated budget were partially sufficient to complete the planned activities. It took two working seasons (i.e. two fiscal years) to complete the work of upstream conservation, storage reservoir, dam structure and spill way/outlet.

According to GTZ, Integrated Food Security Project (2002), some RHDs had no proper operation and maintenance of dams, reservoirs, and associated watershed management activities. Even those that were well planned might not properly operate. This was because of lack of budget and ignorance of user groups, VDC and DSCO. RHDs should be implemented in integrated package program that requires sufficient budget for upstream management, dam, and reservoir construction and conveyance system. Due to lack of budget or allocation of low amount of budget, not all activities have been completed at a time. These ideas are in line with the findings of this study of operation and maintenance and budget allocation factor.

4.3.8 Correlation analysis of level of effectiveness and factors of effectiveness of runoff harvesting dams

Table 4.30 shows the frequencies of 1 dependent (i.e. effectiveness level) and 8 independent variables (i.e. 8 effectiveness factors). The assumption was that the effectiveness of runoff harvesting depends on various factors. Among them were location, soil type of the RHD site, siltation in the storage reservoir, upstream management through integrated watershed development, stakeholder participation for implementation of RHD projects, conflict of objectives among stakeholders, operation and maintenance of the RHD project, and allocation of sufficient budget.

Both dependent and independent variables were ordinal scale and units of measurement are high, moderate and low (i.e. rank order). The qualitative and quantitative information of all 6 effectiveness indicators were used to calculate the level of effectiveness (i.e. order/ordinal scale). Likewise, the frequencies of qualitative information of all, 8, factors were converted through Cross-Tab matrix to ranks (i.e. order/ordinal scale). The sample size was very small (i.e. 6 RHDs). If both the variables (i.e. dependent and independent) are ordinal, non-parametric Spearman’s rank order correlation can be applied. It measures the linear relationship between two ordinal variables. It is the associations of two ordinal variables (i.e. 1 effectiveness level and 8 factors of effectiveness of 6 sampled RHDs). The greater the association between variables, the more we can accurately predict the outcome of the events.

Total observations were 6 (i.e. 6 sampled runoff harvesting dams). The effectiveness level of 3 RHD projects were identified as high and another 3 RHD projects were identified as moderate. Thus, the frequencies of dependent variables were shown 3 for high and 3 for moderate and zero for low. For independent variables, the location factor had high level of influence on 3 RHD projects and moderate level of influence on 3 RHD projects. The soil factor had high level of influence on 4 RHD projects, moderate level of influence on 1 RHD project and low level of influence on 1 RHD project. Likewise, the siltation factor had high level of influence on 4 RHD projects, moderate level of influence on 1 RHD project and low level of influence on 1 RHD project. The upstream management factor had high level of influence on 2 RHD projects, moderate level of influence on 1 RHD project and low level of influence on 3 RHD projects. The participation factor had high level of influence on all, 6, RHD projects. Likewise, conflict of objective factor had high level of influence on all, 6, RHD projects. The operation and maintenance factor had high level of influence on 3 RHD projects and moderate level of influence on 3 RHD projects. Lastly, the budget allocation factor had high level of influence on 4 RHD projects and moderate level of influence on 2 RHD projects. These frequencies of effectiveness factors are shown as independent variables in the column of the same Table 4.30.

Table 4.30: Summary of frequencies of dependent and independent variables of sampled runoff harvesting dams

S.N.	**Variables**	**Observations**			
		Total	High(1)	Moderate(2)	Low (3)
1	**Dependent variable**				
1.1	Level of Effectiveness of RHDs	6	3	3	0
2	**Independent variables**				
2.1	Location	6	3	3	0
2.2	Soil type	6	4	1	1
2.3	Siltation	6	4	1	1
2.4	Upstream management	6	2	1	3
2.5	Participation	6	6	0	0
2.6	Conflict of objectives	6	6	0	0
2.7	Operation and maintenance	6	3	3	0
2.8	Budget allocation	6	4	2	0

The data of Table 4.30 were fed in SPSS version 15 for Spearman’s rank order correlation. The outputs are shown in Appendix-V. The test shows that the level of effectiveness of sampled RHD projects were significant with the factors upstream management and operation and maintenance at the 0.01 level where as it was insignificant with the factors location, soil type, siltation, participation of stakeholder, conflict of objective and budget allocation. Thus, the level of effectiveness of RHD projects is greatly influenced by upstream management and operation and maintenance factor.

Upstream area is responsible for producing debris flow and silts that ultimately, if flow to the conservation storage, reduces the volume of water and life of the dam structures. Operation and maintenance is very essential for sustainable use of RHD, continuation of water productivity and longevity of the overall system (i.e. catchment, conveyance and storage) of runoff harvesting dam projects. According to Sharma and Smakhtin (2001), integrated watershed development program can be a solution to mitigate the debris flow. Upstream conservation measures of structural, bio-engineering and forest protection and plantation can be implemented with the construction of runoff harvesting dam. In this study, it was found that those RHD projects which had combination of more than two conservation measures applied in upstream management had high level of influence. Those that had only one activity and not properly maintained had low level of influence on its effectiveness. It clearly indicated the need for the integrated watershed development program i.e. integrating various conservation activities in combination in a watershed area with the RHD projects.

Upstream management had high level of influence on effectiveness of *Dhanauji and Madhubasha* RHD project. Upstream area of *Dhanauji* RHD project was managed with plantation and protection of forest and gully plugging by gabion check dams but not implemented bioengineering works. Upstream area of *Madhubasha* RHD project was managed by integrating all 3 activities such as plantation and protection of forest; gully plugging by masonry and gabion check dams and gully bank protection by bioengineering works. The flow of sediment and debris became low due to upstream conservation and development. It had moderate level of influence on effectiveness of *Aurahi* RHD project. The forest of upstream area was managed with only plantation and protection and declared as CF. But there were no other conservation activities applied for the conservation and management of upstream areas. It had low level of influence on effectiveness of *Sabedanda, Chireswor* and *Haripur* RHD projects. The upstream area of *Sabedanda* and *Chireshwor* RHD projects were managed only an activity of plantation and protection of forest. The upstream area of *Haripur* RHD project was managed through plantation of bamboo tree along the bank of stream line. There were no application of other gully plugging and bioengineering measures in all three RHD projects.

To be effective RHD projects, there should be operation and maintenance plan; operation and maintenance work should be properly done as per plan and allowed to function well. Operation and maintenance had high level of influence on effectiveness of *Dhanauji*, *Aurahi* and *Madhubasha* RHD projects that had met above criteria. *Sabedanda*, *Chireshwor* and *Haripur* RHD projects had moderate level of influence on their effectiveness that did not meet the above criteria. Majority of respondents confirmed that these RHD projects had no operation and maintenance plan; operation and maintenance work were partially done and partially functioned. These RHD projects did not provide the irrigation to the user groups. Therefore they were reluctant to maintain the RHDs. It was general belief among UG that operation and maintenance work was not needed to get water for household use and livestock watering. Therefore operation and maintenance work was become insufficient and the levels of effectiveness of these RHD projects were moderate.

Other remaining factors i.e. location, soil type, siltation, participation, conflict of objectives and budget allocation did not significantly affect the effectiveness of RHD projects as they had high and moderate levels of influence on effectiveness of majority of the RHD projects. Location of majority of RHD projects were near from the user group's households (i.e. within 300m and 500 m) and site was suitable for construction of conveyance system. Soil type was clay to clay loam and silty clay to silty loam and siltation rate was low to medium rate in the majority of RHD projects. Participation of all stakeholders existed in all level of planning and implementation of all RHD projects that prevented the conflict of objectives among stakeholders. Budget allocation was sufficient for majority of the RHD projects for implementation of upstream conservation, conveyance and dam structural work.

4.4 Conclusion

This chapter described the results of demographic and socio-economic status of the user groups involved in planning, implementation, operation, and use of runoff harvesting dams; the level of effectiveness; and the factors of effectiveness of sampled runoff harvesting dams.

The user use group households involved in the management of RHD projects was characterized by larger household size, low education, low income, subsistence agriculture with small land holding size, rainfed and low productivity. Except *Dhanauji* and *Madhubasha*, all have lack of food sufficiency and have to depend on non-agriculture businesses too such as labor works for their livelihood.

The ***Dhanauji*, *Aurahi* and *Madhubasha* RHD projects were highly effective** as they have increased water availability for irrigation, household use and livestock watering; decreased soil erosion and disaster; improved moisture retention and microclimate improvement; increased agricultural production and household income and enhanced UG capacity for runoff harvesting dam management and UG functioning. The ***Sabedanda*, *Chireshwor* and *Haripur* RHD project were moderately effective** as they have increased in water availability for household use and livestock, improved microclimate and moisture retention and enhanced capacity of user groups for RHD project management and user group functioning. In contrast, they have not increased water availability for irrigation due to which there was no increase in agriculture and forest production and household income. There was still some soil erosion by bank cutting and disaster by deposition, though number of event and area of bank cutting and deposition per year was decreased after implementation of RHD projects.

The level of influence of all, 8, factors on effectiveness of *Dhanauji* RHD project were high that supported this RHD project as highly effective. 4 factors had high, 3 had moderate and 1 had low level of influence on effectiveness of *Sabedanda* RHD project that supported this RHD project as moderately effective. 6 factors had high and 2 factors had moderate level of influence on effectiveness of *Aurahi* RHD project that supported this RHD project as highly effective. 5 factors had high and 3 factors had moderate level of influence on effectiveness of *Madhubasha* RHD project that supported this RHD project as highly effective. 4 factors had high, 2 factors had moderate and 2 factors had low level of influence on effectiveness of *Chireshwor* RHD project that supported this RHD project as moderately effective. 5 factors had high 1 factor had moderate and 2 factors had low level of influence on effectiveness of *Haripur* RHD project that supported this RHD project as moderately effective.

The levels of effectiveness of RHD projects were significantly correlated with the factors **upstream management** and **operation and maintenance** where as other factors such as **location, soil type, siltation, participation of stakeholder, conflict of objective and budget allocation** had not statistically significant correlation with the effectiveness of RHD projects. Thus, the levels of effectiveness of RHD projects were greatly limited by upstream management and operation and maintenance factor. They were positively influenced and contributed by the factors location, soil type, siltation, participation of stakeholder, conflict of objective and budget allocation to achieve highly effective runoff harvesting dam project.

CHAPTER V
CONCLUSION AND RECOMMENDATIONS

This chapter summarizes the major findings of the research and put forward the recommendations based on the results. Key findings of the socio-economic and demographic status of the user group, effectiveness of runoff harvesting dams, and factors affecting the effectiveness of runoff harvesting dams in Nepal are concluded. Chapter ends with explaining the limitations and constraints of the study.

The core idea of this study was to understand the level of effectiveness of runoff harvesting dams which was considered to be determined by various factors. A RHD project would be effective if soil conservation and watershed management activities are implemented in an integrated fashion in upstream catchment; downstream areas; and properly construction of dam structure, storage reservoir and conveyance. Hence, the assumption was that RHD project could be effective if certain conditions were met. Although those conditions might be numerous, for this study, they were taken as accessible location of RHD site and its suitability for construction of conveyance system; appropriate soil type in RHD site such as clay or silty clay soil or had some soil compaction work on dam and reservoirs' surface; less siltation in the conservation storage; upstream conservation through integrated watershed development; participation of major stakeholders in all stage of project planning and implementation; timely settlement of conflict on objectives and other disputes; operation and maintenance; and allocation of required budget for construction of RHD structure, conservation storage, conveyance system, upstream conservation and downstream development for production enhancement.

Effective RHD projects could be realized by various indications. For this study, they were taken as increased water availability, reduced water induced disasters and rate of soil erosion, improved microclimate with increased moisture for growing new vegetation and agricultural crops, and increased production which contributes to increase user group members' household income and their capability for water management, environmental protection, micro finance and other community development such as infrastructure and health condition through group mobilization and strengthening. This chapter includes conclusion of these effectiveness indicators and factors of effectiveness of runoff harvesting dam projects.

5.1 Socio-economic status of the runoff harvesting dam user groups

The user groups involved in the implementation and operation of the RHD projects are mostly subsistence farmer. Their farm businesses are integrated with livestock and forest. Average household sizes (i.e. 6) are greater than national average (i.e.5) and land holding sizes are below the national average (0.8ha/hh). The education level is mostly secondary school and primary school level. Illiteracy is still remaining among the UG member, though it is small population. They have no opportunity to get university level education. Average income level is low and hard to provide basic food, health and shelter.

In every household, some members are involved in labor work besides agriculture occupation to earn additional cash income to contribute to fulfill basic needs. User group member are either migrated from mid-hills' *Brahmin* and *Chhetri* or indigenous and ethnic community like *Mushahar*, *Dusadh*, *Sada, Kyapchaki-magar*, and *Mahato* who are economically poor. They mostly have cereals deficit, but have some surpluses in NTFPs. They live in harsh physical environment, land of low productivity, erosion and disaster prone, rain fed area. After involving in watershed development and other community development programme, they have capacitated by some skills and knowledge for production and income generation.

5.2 Effectiveness level of Runoff harvesting dams

Out of 6 sampled runoff harvesting dams, 3 are highly effective and 3 are moderately effective. The ***Dhanauji, Aurahi*** **and** ***Madhubasha*** **RHD projects are highly effective** as they have increased availability of water for irrigation, household use and livestock watering; decreased soil erosion and disaster; improved moisture retention and microclimate improvement; increased agricultural production and household income and enhanced UG capacity after implementation of RHD projects. The ***Sabedanda*, *Chireshwor* and *Haripur* RHD project are moderately effective** as they have increased in water availability for household use and livestock, improved microclimate and moisture retention and enhanced capacity of user groups. But, they have not increased water availability for irrigation due to which there is no increase in agriculture and forest production and household income. There is still some soil erosion by bank cutting and disaster by deposition, though number of event and area of damage is decreased after implementation of RHD projects.

Due to the RHD project activities, user group capacity has been enhanced for group mobilization, saving credit, handling of community development activities, RHD project management, operation and maintenance and raising health issues through participatory learning and action. Besides this, all user groups earn some extra income from fishing that went to the group revolving fund to run the saving and credit scheme.

All runoff harvesting dams have been implemented and operated with the aim of collecting summer rainfall for winter use; for household consumption, livestock watering and irrigation; protecting the downstream land from soil erosion and water induced disasters; improving natural environment through moisture retention, water recharge and microclimate improvements; and enhancing household income through soil and water conservation based income generation and production.

Although the main function of runoff harvesting dam is water recharge, there is no perceived change in water availability and increase in water level in nearby wells after implementation of RHD projects. This might be because of location of wells which is being out of zone of influence of RHD reservoir.

5.3 Factors affecting the effectiveness of runoff harvesting dams

Location of RHD site in terms of distance from the users household and site suitability for RHD conveyance; **type of soil** in RHD site that contribute to hold water in storage reservoir; **siltation** that determines the volume of water in the storage pond; **upstream management** and development programme through various integrated watershed conservation activities; **participation of stakeholders** from the beginning to end to plan and implement the RHD projects; existence of **objective conflicts** and stakeholder involvement to resolve it and other dispute; proper **operation and maintenance** of RHD projects to get maximum goods and services of water and strengthen its service life and sufficient **budget allocation** to complete the whole component of the RHD projects are taken as factors of effectiveness for this study.

The level of influence of all eight factors towards effectiveness of *Dhanauji* RHD project were high that supported this RHD project as highly effective. 4 factors (i.e. soil type, siltation, participation and conflict of objectives) had high, 3 (i.e. location, operation and maintenance) had moderate and 1(i.e. upstream management) had low level of influence towards effectiveness of *Sabedanda* RHD project that supported this RHD project as moderately effective. 6 factors (i.e. soil type, siltation, participation, conflict of objective, operation and maintenance and budget allocation) had high and 2 factors (i.e. location and upstream management) had moderate level of influence towards effectiveness of *Aurahi* RHD project that supported this RHD project as highly effective. 5 factors (i.e. siltation, upstream management, participation, conflict of objectives and operation and maintenance) had high and 3 factors (i.e. location, soil type and budget allocation) had moderate level of influence towards effectiveness of *Madhubasha* RHD project that supported this RHD project as highly effective. 4 factors (i.e. location, participation, conflict of objective and budget allocation) had high, 2 factors (i.e. siltation and operation and maintenance) had moderate and 2 factors (i.e. soil type and upstream management) had low level of influence towards effectiveness of *Chireshwor* RHD project that supported this RHD project as moderately effective. 5 factors (i.e. location, soil type, participation, conflict of objectives and budget allocation) had high 1 factor (i.e. operation and maintenance) had moderate and 2 factors (i.e. siltation and upstream management) had low level of influence towards effectiveness of *Haripur* RHD project that supported this RHD project as moderately effective.

The levels of effectiveness of RHD projects are significantly correlated with the factors upstream management and operation and maintenance. Other factors such as location, soil type, siltation, participation of stakeholder, conflict of objective and budget allocation have no statistically significant correlation with the effectiveness of RHD projects. Thus, RHD projects are positively influenced and contributed by the factors of location, soil type, siltation, participation of stakeholder, conflict of objective and budget allocation to achieve highly effective runoff harvesting dam project and greatly limited or negatively influenced by upstream management and operation and maintenance factor. It is concluded that if good operation and maintenance and good upstream management are done, the level of effectiveness of RGD project can be enhanced. While keeping other factors continuing, care should be given to upstream management and operation and maintenance in the planning and implementation of RHD projects so that level of effectiveness of RHD projects can be increased.

5.4 Recommendations

The effectiveness of RHDs can be made effective in Nepal through better operation and maintenance of the RHD projects and upstream management. In order to ensure proper operation and maintenance, there should be provision of preparing an operation and maintenance plan before completing the project. There should be strong procedural, financial and institutional mechanism for strict implementation of this plan. To do this, the water user committee should divide the works and responsibilities among the user group to ensure the implementation of the operation and maintenance plan.

Like highly effective runoff harvesting dams, moderately effective runoff harvesting dams provided water for household use and livestock watering. In contrast, it did not provide water for irrigation, though one objective among others for implementing these RHD projects was irrigation. It was because the outlet and conveyance system was little higher than level of conservation storage. The effect was it could not provide water for winter irrigation. To overcome this situation, the level of outlet surface should be decreased so that water can be distributed conveniently. It can be done as part of routine operation and maintenance work.

Due to lack of sufficient budget and user group capability to complete the upstream management, conservation storage, dam construction and conveyance system in one fiscal year or one working season, the effective RHD project can not be materialized. To overcome this problem, the watershed development and RHD structural and non structural components can be integrated in to multiyear plan. The principle of integrated watershed development can be applied to work from the top to down of the catchment. First year, upstream management and development can be done. Second year, conservation work in drainage line, stream and gully can be implemented. Last or third year, small dam with storage reservoir and conveyance system can be built. User group mobilization, strengthening and capacity building trainings can be launched during the plan period. This will decrease the work load to the user group and DSCO in one hand and solve the problem of budget insufficiency. Other land management and agricultural and forestry services and inputs can intensively be launched with RHD project in the downstream area as the land is degraded and socio-economic condition of the UG households mostly are poor in the rural watershed. Thus, it is strongly recommended that DSCWM should formulate a guideline having provision of multi-year (at least 3 years) plan of RHD project planning and implementation that can be followed by DSCO of *Terai* and *Siwalik* physiographic region to overcome the budget constraint, user group capacity mobilization, and component integration (i.e. catchment, conservation storage and conveyance; and agriculture and forest production).

This study was mostly depended on participant’s response, general field observation and annual progress report of District Soil Conservation Office. The topic is very much technical requiring the integrated knowledge of hydrology, hydrogeology, watershed management and development, geomorphology and sociology which require multidisciplinary team of professionals and rigorous evaluation based on long term assessment and monitoring of data. Thus, it is recommended that this research can be further strengthened, confirmed and verified through a long term study for its wider application. Such research should be launched and coordinated by Department of Soil Conservation and Watershed Management (DSCWM).

It is perceived that the study and scientific research on runoff harvesting dam in Nepal is very weak. Though it burdens the extra work load for DSCO, action research can be carried out during annual implementation of RHD projects by DSCO so that systematic data base can be established and evaluated. Long time monitoring and evaluation of function of upstream conservation and downstream protection, rainfall-runoff pattern, siltation on storage reservoir and production pattern and trend can be studied.

5.5 Limitations and constraints

No study has been done in this topic of runoff harvesting system in Nepal. This situation provided this work a new avenue but various difficulties. There was no availability of printed information on RHDs specific to Nepal. This study was mostly depending on participant's responses and field observation. Study experienced limitation of time for data collection and field work. There were 6 RHD sites to be visited, and research method was mix of qualitative and quantitative. Generally, this requires more time. Iterative process to check or verification of information is indispensable but for this study, time did not permit to do so.

REFERENCES

Abrisqueta, J., Plana V., Mounzer, O., Mendez, J. and Ruiz-Sanchez, M. (2007). Effects of soil tillage on runoff generation in a Mediterranean apricot orchard. *Journal of Agricultural Water Management, Vol.93*, 11-18.

Agrawal, A., and Narain, S. (1997). Dying wisdom: State of India's Environment No. 4, Centre for Scienc and Environment, New Delhi, India.

Awwad, A. and Shatanaw M. (1997). Water harvesting and infiltration in arid areas affected by surface crust: examples from Jordan. Journal of Arid Environment (1997) 37: 443-452.

Bamatraf, A. (1994). Water Harvesting and Conservation Systems in Yemen. In: FAO, Water Harvesting for Improved Agricultural Production. FAO, Rome.

Barron, J. (2009). Introduction: Rainwater Harvesting as a Way to Support Ecosystem Services and Human well-being. In: UNEP/SEI, Rainwater Harvesting: A Lifeline for Human Well-being. A report prepared for UNEP by Stockholm Environment Institute, Stockholm, Sweden.

Barry, B., Olaleye, A. O., Zougmore, R., Fatondji, D. (2008). Rainwater harvesting technologies in the Sahelian zone of West Africa and the potential for outscaling. IWMI Working Paper 126. International Water Management Institute. Colombo, Sri Lanka.

Blalock, H.M and Jr. (1987). Social Statistics. (2nd ed.): Tokyo: McGraw-Hill, Kogakusha, Ltd.

Bontum, K. (1992). Research Methodology of Social Sciences. (6th Edition) : Bangkok : Pranakorn Printing.

Bruins, H. J., Evenari, M. and Nessler, U. 1986. Rainwater-harvesting for Food Production inArid Zones. Applied Geography 6, 13-32.

Brooks, K.N., Ffolliott, P. F.,Gregersen, H.M. and John, L.T. (1992). Hydrology and the Management of Watershed. Iowa State University Press, Ames-IOWA, 392.

Central Bureau of Statistics (2001). Statistical Year Book, 2001, His Majesty's Government of Nepal, Central Bureau of Statistics, Central Office, Kathmandu, Nepal.

Central Bureau of Statistics (2003). Statistical Year Book, 2001, His Majesty's Government of Nepal, Central Bureau of Statistics, Central Office, Kathmandu, Nepal.

Chapa, D.R. (2002). Siwalik Range (Churia Hills) Rehabilitation Plan, Specially prepared for 10th Plan (2002 –2006).His Majesty's Government, National Planning Commission, Nepal.

Cluff, C. B., (1981). Surface Storage for Water Harvesting Agri-systems. In: Rainfall Collection for Agriculture in Arid and Semiarid Regions. Proceedings of a Workshop, (ed. G. R. Dutt, C.F. Hutchinson, and M. A. Garduno), University of Arizona,USA.

Cortesi, L.,Prasad, E. and Abhiyan, M.P. (2009). Rainwater Harvesting for Management of Watershed Ecosystem. In: UNEP/SEI, Rainwater Harvesting: A Lifeline for Human Well-being. A report prepared for UNEP by Stockholm Environment Institute, Stockholm, Sweden.

Department of Soil Conservation and Watershed Management (2004). Annual Progress Report F.Y. 2002/2003, in Nepali. Department of Soil Conservation and watershed Management, Kathmandu, Nepal.

Department of Soil Conservation and Watershed Management (2002). Upper Terai – Chure Integrated Watershed Management Program (Proposal). Department of Soil Conservation and Watershed Management, Babarmahal, Kathmandu, Nepal.

Department of Soil Conservation and Watershed Management (2007). Soil Conservation and Watershed Management Program. [online]. Available from http://www.dscwm.gov.np/sc&w_Management_Programs.html [Accessed 12 April 2009].

DeBarry, P.A. (2004). Watersheds: Processes, Assessment, and Management, Wiley, John Wiley and Sons, Inc., Hoboken, New Jersey, USA.

Diane, M. (2002). Community Approaches to Watershed Management. Centre for rural studies and Enrichment. St. Peter's College, Muenster, Canada.

Dillaha,T., Ferraro, P., Huang, M., Southgate, D., Upadhyaya, S. and Wunder, S. (2007). Payment for Watershed Services, Regional Syntheses, USAID.

District Soil Conservation Office, Dhanusha (2005). Annual Progress Report of F.Y. 2004/2005.District Soil Conservation Office Dhanusha, Nepal.

District Soil Conservation Office, Mahottari (2007). Annual Progress Report of F.Y. 2006/2007.District Soil Conservation Office Mahottari, Nepal.

FAO (2000). Water Harvesting, Water Resources Development and management Services. [Online]. Available from http://www.fao.org/ag/agl/aglw/wharv.htm [Accessed 8 May, 2008].

Gardiner,J.L. (1994). Sustainable Development for River Catchments. Journal of Water and Environmental Management, Vol. 8.pp 308-319.

Gregersen, H. M., Ffolliott, P.F. and Brooks, K. N. (2007).Integrated Watershed Management: Connecting People to their Land and Water. Cambridge University Press, Cambridge, UK.

GTZ-Integrated Food Security Project (2002). Experience sharing workshop of Integrated Food Security Project, Cluster 4, Lahan, Siraha. German Development Cooperation, Integrated Food Security Project, Kathmandu, Nepal.

Hudson, N. W. (1987). Soil and Water Conservation in Semi Arid Areas, Soil Resources Management and Conservation Services, FAO Land and Water Development Division, Rome, Italy. [Online]. Available from http://www.fao.org/docrep/t0321e/t0321e00.htm [Accessed 18 April, 2008].

ICIMOD (2007).Good Practices in Watershed Management: Lesson Learned in the Mid Hills of Nepal, International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

IFAD (1992). Soil and water Conservation in Sub-Saharan Africa: Issues and Options, IFAD, Rome.

James, P.K. (1997). Research design in occupational education. Oklahoma State University.

Kerr, J. and Pangare, G. (2001). Water Harvesting and Watershed Management. [Online]. Available from http://www.ifpri.org/2020/focus/focus09 /focus09_09.htm [Accessed 9th April, 2009].

Kerr, J. (2002). Watershed Development, Environmental Services, and Poverty Alleviation in India. World Development 30 (8).

Khan, M.A. (2001). Traditional and improved techniques for groundwater recharge and storage in arid regions. Proceedings ICAR-IWMI Policy Dialogue on Ground Water Management (Eds. Sharma B. R. & Tushar Shah), CSSRI, Karnal, India.

Khanjani, M. J. and Busch, J. R. (1982).Optimal irrigation distribution systems with internal storage. Transactions of the American Society of Agricultural Engineer 25:743-747.

Khepar, S.D. (2001). Strategies for ensuring hydrological sustainability of rice wheat cropping system in Punjab. Proceeding ICAR-IWMI Policy Dialogue on Ground Water Management (Eds: Sharma, B.R. and Tushar Shah), CSSRI, Karnal, India.

Kolarkar, A., Murthy, K. and Singh, N. (1980). Water Harvesting and Runoff Farming in Arid Rajasthan. Indian Journal of Soil Conservation 8 (2).

Kolarkar, A., Murthy, K. and Singh, N. (1983). Khadin-a method of harvesting water for agriculture in the Thar desert. Arid Environment 6:59-66.

Kolavalli, S., and Whitaker, M.L. (1996). Institutional aspects of water harvesting: Khadins in Western Rajasthan, India. Proceedings of the 6th Annual Conference of the International Assocation for the Study of Common Property, June 1996, Berkley, California.

Konig, K.W. and Uberlingen, G. (2009). Rainwater Harvesting for Water Security in Rural and Urban Areas. In: UNEP/SEI, Rainwater Harvesting: A Lifeline for Human Well-being. A report prepared for UNEP by Stockholm Environment Institute, Stockholm, Sweden.

Loi, N. K. (2005). Decision Support System (DSS) for Sustainable Watershed Management in Dong Nai Watershed-Vietnam. Doctor of Philosophy (Forestry), Dissertation. Graduate School, Kasetsart University, Bangkok.

Menon, S. (2008). Watershed Management: Global and Indian Perspectives. In watershed Management, Concepts and Experiences. The Icfai University Press 52, Nagarjuna Hills, Hyderabad, India.

Millennium Ecosystem Assessment (2005). Current State and Trends, chapter 22, Dry land Systems, A report of the Millennium Ecosystem Assessment, World Resource Institute. [Online]. Available from http://www.millenniumassessment.org/documents/documents.291.aspx.pdf [Accessed 7th April 2009].

Mittal, P. and Aggarwal, R. (2001). Rainwater Harvesting Need of the Hour. The Tribune,Agriculture Tribune, Chandigarh, India.

Ministry of Forests and Soil Conservation (2005). District Forest Sector Plan of Dhanusha District. Biodiversity Sector Support program for Siwalik and Terai, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

Nasr, M. (1999). Assessing Desertification and Water Harvesting in the Middle East and North Africa: Policy Implications, ZEF – Discussion Papers on Development Policy No. 10, Center for Development Research, Bonn.

Nasri, S., Albergel,J., Cudennec, C. and Berndtsson, J. (2004). Hydrological processes in macro-catchment water harvesting in the arid region of Tunisia: the traditional system of tabias. Journal of Hydrological Sciences, Volume 49, No. 2 pp. 261- 272.

National Planning Commission (2004). A Concept Paper for Co-operation for Conservation and Development of Churia Region of Nepal. National Planning Commission, Kathmandu, Nepal.

Oweis, T., A. Hachum, and J. Kijne (1999). Water harvesting and Supplementary Irigation for Improved water use efficiency in dry areas. SWIM paper 7. International Water Management Institute. Colombo, Sri Lanka.

PCARRD-DOST-DENR-FMB-DA-UPLB-CFNR-FDC/ENFOR (1999). Guidelines for watershed management and development in the Philippines, Los Banos, Laguna: PCARRD-DOST-DENR-FMB-DA-UPLB-CFNR-FDC/ENFOR. 241pp.

Prinz, D. and Singh A. (2001). Technological Potential for Improvements of Water Harvesting. Paper prepared for Thematic Review IV.2: Assessment of

Irrigation Options. Institute of Water Resource Management, Hydraulic and Rural Engineering (IWK), University of Karlsruhe, Germany.

Prinz, D. (1996). Water Harvesting: Past and Future. In: Pereira L. S. (ed.), Sustainability of Irrigated Agriculture. Proceedings, NATO Advanced Research Workshop, Vimeiro, 21-26, 03. 1996, Balkema, Rotterdam.

Rockstrom J. (2000). Water Resource Management in smallholder Farms in Eastern and Southern Africa: An Overview. Phys. Chem. Earth (B), Vol. 25, No.3, pp.275-283.

Saini, S.S. (2007). Rain Water Harvesting in Punjab-An experience. Department of Soil and Water Conservation, Punjab, India.

Samra, J. S., Sharda, V.N. and Sikka, A.K. (2002). Water Harvesting and Recycling: Indian Experiences. Central Soil & Water Conservation & Training Institute, Dehradun, India.

Satterlund, D.R. and Adams, P.W. (1992). Wildland Watershed Management. Second edition, John Wiley and Sons, Inc., New York, USA. 436p.

Schiettecatte, W., Ouessar, M., Gabriels, D., Tanghe, S., and Abdelli, F. (2005). Impact of water harvesting techniques on soil and water conservation: a case study on micro catchment in southeastern Tunisia. Journal of Arid Environment (2005) 61: 297-313.

Sekar, I. and Randhir, T. (2007). Spatial assessment of conjunctive water harvesting potential in watershed systems. Journal of Hydrology (2007)334:39-52.

Shukla S. (2004).Watershed- Functions and Management, Institute of Food and Agricultural Sciences, University of Florida, USA.

Sharma, B. and Smakhtin, V. (2001). Potential of Water Harvesting as a Strategic Tool for Drought Mitigation. International Water Management Institute, Colombo, Sri Lanka.

Sharma, B. (2009). Rainwater Harvesting in the Management of Agro-ecosystems. In: UNEP/SEI, Rainwater Harvesting: A Lifeline for Human Well-being. A report prepared for UNEP by Stockholm Environment Institute, Stockholm, Sweden.

Siyal, S. A. and Shrama, C. (2002). Rooftop water harvesting for women and health, unpublished report prepared for International Centre for Integrated Mountain Development, Kathmandu, Nepal.

Sreedevi, T.K., Wani, S.P., Sudi, R., Patel, M.S., Talati, J., Singh, S. N., Shah, Tushaar (2006). On-site and off-site impact of watershed development: A case study of Rajasamadhiyala, Gujarat, India. Global Theme on Agroecosystems report no. 20, Patancheru, Andhra Pradesh, India:ICRISAT.iv, 43P.

Tilala, H. and Shiyani, R.L. (2005). Small Water Harvesting: A Sustainable Way for Equity and Income Generation. IWMI-TATA, Water Policy Program, Gujarat, India.

UNCCD (2008). Desertification-Coping with today's Global Challenges, High Level Policy Dialogue, Boon Germany.

UNEP (1983). Rain and Storm Water harvesting in Rural Areas.Tycooly, Dublin.

UNEP (2002). Global Environmental Outlook 3. State of the Environment and PolicyRetrospective 1972-2002. Nairobi, Kenya: UNEP.

UNEP (2002). Biodiversity of Global Significance in Arid and semi-arid zones in the developing world, Third World Network of Scientific Organization-TWNSO, GEF, Trieste, Italy.

Van Dijk, J.A. (1997). Simple methods for soil moisture assessment in water harvesting projects. Journal of Arid Environment Vol 35, pp 387-394.

WHO (1997). Guidelines for Drinking Water Quality. second edtion, Vol.3, Surveillance and Control of Community Supplies. World Health Organization, Geneva.

World Resource Institute (2005). The Wealth of the Poor: managing Ecosystem to Fight Poverty, Washington D.C. USA.

World Resource Institute (2008). Water Scarcity, Private Investment Opportunity in AgriculturalWater Use Efficiency, Rabobank International, the Netherland.

Wagner, W., Gawel, J., Furumai, H., Souza, M., Teixeira, D.,Rios, R., Ohgaki, S., Zehnder, A., and Hemond, H. (2002). Sustainable Watershed

Management: An International Multi- watershed case Study. Ambio, Vol 31, No. 1 pp 1-12.

Yadav, R. (2005). SABIHAA and its replication: Lesson learned and Future suggestion. District Soil Conservation Office, Kaski, Nepal.

APPENDICES

APPENDIX A

CHECKLIST QUESTIONS FOR KEY-INFORMANT INTERVIEW

Following checklist questions will be used during key informant interview. This will be administered for District Soil Conservation Officials of Dhanusha district and VDC chairman of the VDC where sampled RHD project located. The questions are related with RHD project and respective UG. This interview will be pursued by Bishnu Bahadur Bhandari, student for M.Sc. in Natural Resource Management in Faculty of Environment and Resource Studies, Mahidol University. The privacy of the respondent and informed consent will be maintained.

1. What is the availability of water for UG household before and after implementation of RHD projects?
2. What are the differences of water induced disaster and soil erosion before and after RHD projects?
3. What is the situation of microclimate, moisture condition, water recharge and availability of water in well and aquifer in the downstream and around before and after launching the RHD project?
4. What is the situation of agriculture and forest production before and after implementation of RHD project?
5. What about the condition of individual household income due to this RHD project? Is there increment of their income?
6. Are there any change appeared in UG member's capacity in operation and maintenance of RHD, user group functioning and its dynamic, participation and saving credit?
7. What do you think about site of the RHD? What is the conveyance system currently applied? Is it suitable for proper conveyance?
8. Is there any problem of siltation in reservoir? What is the trend and rate of siltation?

9. What are the conservation activities implemented in upstream management of RHD? Would you give the name of the activities, their maintenance condition, and functions? Are they working well?
10. Could you describe the VDC, UG, and DSCOs' participation for overall implementation and cost contribution for this RHD project?
11. Was there any conflict raised during implementation and now in operation and maintenance regarding objectives of the RHD and its use? Is it hampered to its operation and maintenance?
12. Is RHD well operated and maintained in its full capacity? What about operation and maintenance? Are all these activities worked properly?
13. Was there sufficient budget allocated to complete the RHD project? Was all work for dam, conveyance, and upstream management completed at one working season? Was it hampered due to deficit of budget?
14. Would you describe the implementation procedure of this RHD? For example, site selection, group mobilization, participation, and budget allocation.
15. Do you think this RHD project good to local people and local environment?
16. Was there any managerial, technical, and financial problem during construction and operation of this RHD project? What about present situation, is it operating well?
17. Do you think this RHD project is successful and effective? If so How?
18. Do you think this RHD project can perform better? If so how?
19. Any suggestions, comments, and ideas for better RHD project?
20. Final view (Open thought)?

APPENDIX B

STRUCTURED QUESTIONNAIRE FOR HOUSEHOLD INTERVIEW

This questionnaire has been prepared to accomplish M.Sc. in Natural Resource management thesis research of Mr. Bishnu Bahadur Bhandari. This is divided in to four parts. First part is about demographic information of respondent's household, second part is about services that RHD provides to UG member and benefit harnessed (i.e. effectiveness indicators), third part is about the conditions or prevailing situation that support to be effective (i.e. factor) RHD project and fourth part includes miscellaneous questions about RHD projects and UG. This will be administered to the UG members (household head of each sampled household) of the RHD project. The respondent's identity, privacy, and valuable information will be kept confidential.

"Exchange greetings, share introduction, and brief the purpose of this study, ensure confidentiality and request for his/her time and space"

RHD No.: Name: Location:

Part A: Demographic information

1. Code number:

2. Length of settlements: Migrated from: Reason:

3. Ethnicity:

4. Household information:

No	Position in HHs	Gender	Age (yrs)	Education	Occupation		
					Major	Minor	Others

5. Land holdings:

Home area: (ha/Bigha/kattha) Home garden: (ha/Bigha/kattha)

Farm land: irrigated: (ha/Bigha/kattha) Non-irrigated: (ha/Bigha/kattha)

Total area: (ha/Bigha/kattha) Certificate: (ha/Bigha/kattha)

Uncertificate: (ha/Bigha/kattha)

6. Agriculture production:

Cereals: ton/yr. Consumption: Sell: Buy:

Vegetables: ton/yr. Consumption: Sell: Buy:

Fruits: ton/yr. Consumption: Sell: Buy:

Other: ton/yr. Consumption: Sell: Buy:

7. Forest production/collection:

S.N.	Particulars	NTFP	Fuel wood	Fodder	Grass	Timber	Remark
1.	Name of Spps.						
2.	Collection/year						
3.	Household use						
4.	Sell						

8. Livestock:

S.N.	Type	No.	Food	Sell	Price Rs./Kg.	Grazing/ Stall feeding	Remark
1.	Cow						
2.	Buffalo						
3.	Pigs						
4.	Goats						
5	Poultry						

B. Information related to effectiveness of runoff harvesting dams

1. Water yield

i) Is availability of water increased after RHD project? Yes/No

ii) What is the trend of availability of water after RHD project? Increasing/not increasing

iii) Use of harvested water

S.N.	Use	Before RHD		After RHD	
1.	Irrigation	Area (ha)		Area (ha)	
		Duration (months/days)		Duration (Months/days)	
2.	Consumption	Duration (Months/days)		Duration (Months/days)	
3.	Livestock watering	Livestock (No.)		Livestock (No.)	
		Duration (Months/days)		Duration (Months/days)	
4.	Adequacy of water for HH use (totals)	Yes ( ), No ( )		Yes ( ), No ( )	

2. Water induced disaster and soil erosion

i) Is water induced disaster and soil erosion decreased after RHD project? Yes/No

ii) What is the trend of water induced disaster and soil erosion after RHD project? Increasing/not increasing

iii) Water induced disaster record

S.N.	Type of disaster	Before RHD		After RHD	
		Events (times/yr)	area (ha/yr)	Events (times/yr)	area (ha/yr)
1.	Bank cutting				
2.	Sedimentation / deposition				
3.	Impact on household	Yes ( ), No ( )		Yes ( ), No ( )	

3. Water recharge/moisture rendition

i) Is water recharge and moisture retention increased after RHD project? Yes/No

ii) What is the trend of water recharge and moisture retention after RHD project? Increasing/not increasing

iii) Is microclimate improved after RHD project? Yes/No

iv) Is water availability in well and aquifer increased after RHD project? Yes/No

4. Agriculture and forest production

i) Is agricultural and forest production increased after RHD project? Yes/No

ii)What is the trend of agricultural and forest production after RHD project? Increasing/not increasing

iii) Agricultural and forest production before and after runoff harvesting dam

S.N.	Description	Before RHD	After RHD
1.	Crop spps grown (Name)		
2.	Frequency (crop/year)		
3.	Cereal production (Kg/ha/yr)		
4.	Vegetables production (Kg/ha/yr)		
5.	Fruits production (Kg/ha/yr)		
6.	NTFPs production (Kg/ha/yr)		
7.	Grass and fodder production (Kg/ha/yr)		

5. Household income

i) Do you have increased your income due to RHD project? Yes/No

ii) What is the trend of increase in income? Increasing/not increasing

iii) Average income per year from agriculture production: Rs/yr

iv) Average income per year from forest production: Rs/ yr

v) Average total household income: Rs/yr

6. User capacity building

i) Is user capacity including you built up after RHD project? Yes/No

ii) Type of training you participated (Name):

iv) Do you know and have skill on operation of RHD? Yes/No

v) Do you know and have skill on Maintenance of RHD? Yes/No

vi) Have you been participated in saving/credit scheme? Yes/No

vii) Are you happy with the RHD?

Yes/No

C. Information related to factors for effectiveness of runoff harvesting dams

1. Location

i) Is RHD accessible for you? Yes/No/ partially accessible

ii) What is the distance of RHD from your house? (m)

iii) Is the site suitable for conveyance system? Yes/No/ partially suitable

iv) What is the conveyance system currently used? Canal/pipe/seepage

2. Soil type

i) Do you think the soil in the RHD site is appropriate?

Yes/No/ moderately appropriate

3. Siltation

i) Is there any problem of siltation in RHD pond?

Yes/No/medium problem

ii)What about siltation trend?

Increasing in high/medium and slow rate

iii) How do you act if you see the problem?

iv) Do you participate in solving the problem? If not, why?

4. Upstream management

i) Is there upstream conservation activities practiced?

Practiced/not practiced/ in between practiced and not practiced

ii) What are the activities implemented? Give the number of activities.

1.Gully plugging 2.forest protection and plantation 3. Bioengineering

iii) Are they well maintained? Yes/ No/partially maintained

iv Are conservation activities functioned well?

Well function/partially function/ not function

v) Do you participate or involve in these activities? If yes, what activities? If not why?

5. Participation

i) Were all stakeholders (User group, VDC and DSCO) involved in this RHD project implementation? Yes/No/in between Yes and No

ii) Involvement of User group, VDC and DSCO for project implementation.

DSCO only, DSCO / VDC Only, DSCO/UG only, DSCO/VDC/UG

iii) Who selected this site for RHD construction?

DSCO only, VDC only, UG only, DSCO/UG, DSCO/VDC, VDC/UG, DSCO/VDC/UG

iv) Were all stakeholders (User group, VDC and DSCO) contribute in cost of RHD project?

DSCO only, VDC only, UG only, DSCO/UG, DSCO/VDC, VDC/UG, DSCO/VDC/UG

v) Do you and members of your hh participate in RHD implementation? If yes, what type of activities? If not, why? Would you like to participate? In which way?

6. Conflict of objectives

i) Were there any objectives conflict during implementation of RHD project?

No conflict/partial conflict/ have conflict

If yes, what type of conflict? Any suggestion how to deal with?

ii) Who set the objective of implementation of this RHD project?

DSCO/VDC/UG/DSCO and VDC/DSCO and UG/VDC and UG/DSCO, VDC and UG

7. Operation and maintenance

i) For this RHD project, is there operation and maintenance plan? Yes/No

ii) Is operation and maintenance properly done?

Properly done/partially done/ not done

ii) Is operation and maintenance functioning well?

Well function/ partially function/ not function

8. Budget allocation

i) Was allocated budget sufficient for this RHD project?

Sufficient/ partially sufficient/insufficient

ii) Did allocated budget deficiency cause to incompleteness of RHD project at one working season? (One year project to complete upstream management, conveyance, and dam) Was it completed in one working season?

Completed/ partially completed/ not complete d

D. Miscellaneous

1. What were the objectives set during planning of this RHD?
2. What is the present utilization of this RHD?
3. What is your financial and physical contribution to implement this RHD project?
4. Do you think this RHD project is useful to you and your neighbors? How?
5. What are the strengths and weaknesses of this RHD projects?

Particulars	Strengths	weakness
For RHD structure		
For up-stream conservation		
For conveyance system		

6. Any suggestion/Comments/improvements on what should be done in order to have better RHD.

Thank you very much for your time and valuable information!!

(The End)

APPENDIX C

CHECKLISTS FOR FIELD OBSERVATION

Following checklists will be used during field observation:

1. Operation of saving credit scheme
2. Site suitability for conveyance system and conveyance system currently used
3. Siltation in reservoir
4. Activities of upstream management, their maintenance, and functional condition
5. Operation and maintenance of conservation structure, dam, conveyance and upstream management and their functional condition
6. General physical environment, e.g. moist/dry
7. General condition in upstream and downstream, e.g sign and scare of bank cutting, sedimentation and deposition, soil erosion, flooding and its damage
8. Land use in upstream and downstream, e.g forest and agricultural land and their condition, cropping pattern, forest product
9. Location of RHD, distance from the settlements, soil type, condition of Dam, conveyance and other conservation measure in nearby catchment
10. Completeness of conservation effort
11. Current use of water
12. Water in nearby wells and aquifer

APPENDIX D

CHECKLIST FOR REVIEWING PROJECT BOOKS AND ANNUAL REPORTS

Following checklists will be used for reviewing of project books, annual reports and other relevant documents from District Soil Conservation Office:

1. Availability of water and their different use after RHD project
2. Record of water induced disaster and soil erosion
3. Water recharge and moisture condition
4. Information related to agriculture and forest production after RHDs
5. Information about enhancement of household income
6. Information about user participation in training, their capacity building on group mobilization, group dynamics, and harvested water management
7. Conveyance system currently used
8. Soil type of the location, siltation rate in reservoir
9. Upstream management, activities, maintenance, and their function
10. Information about stakeholder participation for implementation, maintenance, and cost contribution
11. Information about conflict among stakeholders for objective setting and its influence on operation and maintenance
12. Operation and maintenance plan and its implementation
13. Information about budget allocation and per unit cost and total estimated budget Contribution by DSCO, UG, and VDC
14. Distance from the settlements, photos of different years
15. Duration for completion of the RHD project
16. Objective set during planning, target for irrigation areas
17. Present utilization of RHD, Future plan to make it more effective
18. Saving /credit, training record
19. Effects, impacts, evaluation on its success

APPENDIX E

NONPARAMETRIC CORRELATIONS

		Level of effectiveness of RHD	Location of RHD site	Type of soil of RHD site	Siltation	Upstream conservation	participation	Conflict of objective	Operation and maintenance	Budget allocation
Level of effectiveness of RHD	Correlation Coefficient	1.000	-.333	.115	.693	.949(**)	.	.	1.000(**)	.000
	Sig. (2-tailed)	.	.519	.828	.127	.004	.	.	.	1.000
	N	6	6	6	6	6	6	6	6	6
Location of RHD site	Correlation Coefficient	-.333	1.000	-.115	-.693	-.211	.	.	-.333	.707
	Sig. (2-tailed)	.519	.	.828	.127	.688	.	.	.519	.116
	N	6	6	6	6	6	6	6	6	6
Type of soil of RHD site	Correlation Coefficient	.115	-.115	1.000	.220	.018	.	.	.115	.122
	Sig. (2-tailed)	.828	.828	.	.675	.973	.	.	.828	.817
	N	6	6	6	6	6	6	6	6	6
Siltation of storage reservoir	Correlation Coefficient	.693	-.693	.220	1.000	.657	.	.	.693	-.490
	Sig. (2-tailed)	.127	.127	.675	.	.156	.	.	.127	.324
	N	6	6	6	6	6	6	6	6	6

** Correlation is significant at the 0.01 level (2-tailed).

APPENDIX E

NONPARAMETRIC CORRELATIONS (Cont.)

		Level of effectiveness of RHD	Location of RHD site	Type of soil of RHD site	Siltation	Upstream conservation	participation	Conflict of objective	Operation and maintenance	Budget allocation
Upstream conservation of RHD	Correlation Coefficient	.949(**)	-.211	.018	.657	1.000	.	.	.949(**)	-.112
	Sig. (2-tailed)	.004	.688	.973	.156	.	.	.	.004	.833
	N	6	6	6	6	6	6	6	6	6
participation of stakeholder	Correlation Coefficient	.	.	.	.	.	.	.	.	.
	Sig. (2-tailed)	.	.	.	.	.	.	.	.	.
	N	6	6	6	6	6	6	6	6	6
Conflict of objective among stakeholder	Correlation Coefficient	.	.	.	.	.	.	.	.	.
	Sig. (2-tailed)	.	.	.	.	.	.	.	.	.
	N	6	6	6	6	6	6	6	6	6
Operation and maintenance of RHD project	Correlation Coefficient	1.000(**)	-.333	.115	.693	.949(**)	.	.	1.000	.000
	Sig. (2-tailed)	.	.519	.828	.127	.004	.	.	.	1.000
	N	6	6	6	6	6	6	6	6	6
Budget allocation for RHD project	Correlation Coefficient	.000	.707	.122	-.490	-.112	.	.	.000	1.000
	Sig. (2-tailed)	1.000	.116	.817	.324	.833	.	.	1.000	.
	N	6	6	6	6	6	6	6	6	6

** Correlation is significant at the 0.01 level (2-tailed).

APPENDIX F

RUNOFF HARVESTING DAMS AND ASSOCIATED ACTIVITIES

1. *Dhanauji* runoff harvesting dam, *Bengadabar*-9

Runoff harvesting dam

Conservation storage and upstream forest

Conveyance/Small earthen canal

Cereal crop

NTFPs/Broom grass

Fruits and NTFPs

2. *Sabedanda* runoff harvesting dam, *Dhalkebar*-3


Conservation storage


Runoff harvesting dam and conveyance


Cereals


Vegetables


Downstream gully bank stabilization


Plantation on reclaimed land

3. *Aurahi* runoff harvesting dam, *Naktajhij*-9

Runoff harvesting dam /Conservation storage

Outlet for conveyance

Conveyance/Small earthen canal

Fruits and NTFPs

Cereals

Fruits and NTFPs

4. *Madhubasha* runoff harvesting dam, *Pushpwalpur*-9


Runoff harvesting dam with conveyance


Conservation storage


Downstream farmlands


User group settlement


Upstream conservation/Bioengineering


Upstream conservation/Masonry check dam and forest protection

5. *Chireshwor* runoff harvesting dam, *Hariharpur*-5

Runoff harvesting dam

Researcher, conservation storage and upstream forest

Fruit tree plantation in reclaimed land

Forest plantation in reclaimed land

Data collection team with user group members

Village well

6. *Haripur* runoff harvesting dam, *Umaprempur*-4

Conservation storage

Upper catchment and water ways

Farmlands

Runoff harvesting dam/Spillway

Water conveyance/Earthen canal

User group members

BIOGRAPHY

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