R & D in Rainwater Harvesting: Lessons Learnt regarding Multiple Use

R & D Report

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1. Introduction

Over thousands of years, people living in various geographical and climatic regions of the world have evolved diverse indigenous rain water harvesting and management systems as an adaptation to variation in precipitation and climate change. Some of these practices continue to remain in use, particularly in South Asia where rainwater harvesting differs to some extent from that in many other parts of the world.

Biogas Sector Partnership, Nepal (BSP-N) implemented rainwater harvesting program for the first time in 2005, when several RWH systems were constructed by utilizing the prize money won from the Ashden Award in 2005 with the objective of providing water solely for operation of biogas plants in the water scarce areas (Malla et.al. 2009). After 2005, encouraged by the successful implementation of the programme and the demand it created in the communities BSP-N started the projects for providing water for drinking, household use and other purposes like for hygiene and sanitation as well. Soon BSP-N was selected as Rainwater Harvesting Capacity Centre (RHCC) for Nepal in 2006 with an initiative of and with the support from RAIN Foundation (the Netherlands). It aims to promote rainwater harvesting technology in Nepal through capacity building, knowledge sharing and feeding inputs for policy making. At the same time it also aims at creating a strong network of implementing partners. Thus Research and Development (R & D) along with dissemination of findings has become one of the very important components of its program.

1.1 Brief Introduction to Rainwater Harvesting R & D Projects in Nepal

BSP-Nepal, in the beginning promoted rainwater harvesting for providing water to operate biogas plants in water scarce areas of Nepal. However, it soon realized that rainwater can be put to other uses as well. So BSP-Nepal decided to embark upon the rainwater harvesting projects with a view of developing better designs of the system to get multiple benefits to the people of Nepal.

The rainfall is unevenly distributed in the country- Range of water requirement is multifold- drinking, washing, bathing, cooking, producing biogas, rearing domestic animals recharging groundwater and so on. But there are impending crisis occurring as a consequence of the climate change.

In addition to the implementation of the usual rainwater systems, rainwater harvesting research and development (R & D) projects are also taken up at different places in Nepal.

1.2 Justification of the Rainwater Harvesting Projects in Nepal

The very fact that Nepal has a monsoon type of climate clearly indicates seasonal nature of rainfall that occurs over here. A very great portion of annual rainfall occurs in Nepal in general within a span of just four months from June to September, when almost 85 % of the total rainfall is received. The rest of the year, as many as two thirds of the year the country has to face a very dry condition. Thus management of water plays a very important place in the life of the Nepalese people.

A systematic support to local innovations on rain water harvesting could provide ample amount of water. For example, one hectare of land with just 100 mm of rainfall annually could theoretically yield 1,000,000 liters of water per year from harvesting rainwater. Simple local techniques such as ponds and embankments, - even earthen ones - can help in harvesting and storage of rain. These devices will have to be reviewed from time to time and new findings can be utilized in improving the system in a more useful and profitable manner to serve humanity.

Herein lies the importance of the R & D practices also in RHS which can be called a creative systematic activity in order to increase the stock of knowledge and practice of new techniques but at the same time including a close and intimate knowledge and understanding of man, culture and society and use this knowledge and practice to devise new and beneficial applications.

The R & D projects therefore have considered these specific points and it has been expected that the local community will find them quite useful not only for meeting their day-to-day requirements but also for income generation. At the same time since the members of the households would not need to spend their valuable time to fetch water from a longer distance unlike earlier, there will be more energy saving, plenty of time for proper rest and social healthy activities, less accidents (particularly due to falling down on the slippery path earlier when they were bound to walk a long way to the water source for fetching water), more time available for engaging themselves in income generating activities, increased attendance of children at school, less expenditure buying water pots such as gagris, baskets and ropes.

2. Objectives, Methodology and Limitation

2.1 Objectives

The main objective of the research is to assess the possibilities and limitations of using RWH for drinking water, biogas and irrigation and identity the possibilities and limitations of combining these different uses.
The specific objectives are to:

- Assess the water use practices and water needs with respect to different purposes in rural household presently challenged with water scarcity to identify the need for rainwater harvesting for MUS
- Identify the effectiveness of combining roof water harvesting systems with surface runoff systems for MUS
- Analysis of financial and economic aspects and impacts of MUS from rainwater harvesting systems
- Test the combination of Ferro-cement tanks with “1bag cement” systems and plastic ponds (technical functioning, management, maintenance, design etc)

2.2 Methodology

No sophisticated methodology has been adopted in the study since it is meant to be a modest attempt in examining how far the implementation of the project has taken the expected track. However it can be said that the following steps were taken in the process of the study and the materials have been drawn from both primary and secondary sources.

Secondary Sources:
Related literatures and reports including relevant documents and information concerned with the rainwater harvesting system in Nepal in general and progress report and other materials were also consulted. In particular, desk study was carried out to collect necessary data from district profiles, topographical sheets, district maps, rainfall data from Nepal Department of Hydrology and Meteorology, publications from Central Bureau of Statistics Nepal, manuals and technical reports on biogas and rainwater harvesting technology along with clay-cement lined water storage pond published by BSP-Nepal and IDE respectively.

Primary Sources:

To garner information, special interviews with key informants like representatives of local government bodies, social mobilizers, local NGOs and focus group discussions (FGD) with users of the potential sites were arranged. At every such gathering attempt were made to include as many people as possible to represent the people of the community from different walks of life. Special care was also taken to include people, with a greater emphasis on the Dalits and poor households for assessing the outcome from gendered perspectives; women were also particularly invited to join the interaction meetings. Female motivators were expedited for enabling the process. For such discussions specific checklists were also used to get a clear picture of the situation before implementation of project, which could be used as a comparison tool for further evaluation.

Picture 1: Interacting with beneficiaries

Pre-feasibility study was carried out prior to site selection, after which detailed baseline survey for each site was conducted with structured questionnaire covering - socio-economic background, water use practice, cropping pattern and income generating activities.

Field visits were planned such that maximum information could be gathered to meet the above objectives. In order to understand the benefits that the people have derived from project each sites were visited at least twice, along with periodic supervision by the local partners during implementation.

Field observations have been backed up by the use of photographs including documentary and visuals.

Local support and programme implementation partners:

IDE Nepal is the principal partner for providing technical support in the implementation of 1 m3 clay cement lined pond with drip irrigation unit and training to the users in Kavrepalchowk and Syangja for the systems operation and maintenance.

People's Awareness Centre for Rural Development (PARD-Nepal), a local NGO provided necessary support in case of the plastic lined ponds in Salyan district. They were particularly very useful in getting the informants together for various purposes including FGDs, conducting baseline activities during pre-feasibility study and supervision during implementation of project in the field. The R&D work was conducted with formal agreement between PARD-Nepal and community groups which had already been formed effectively as functioning groups in project area.

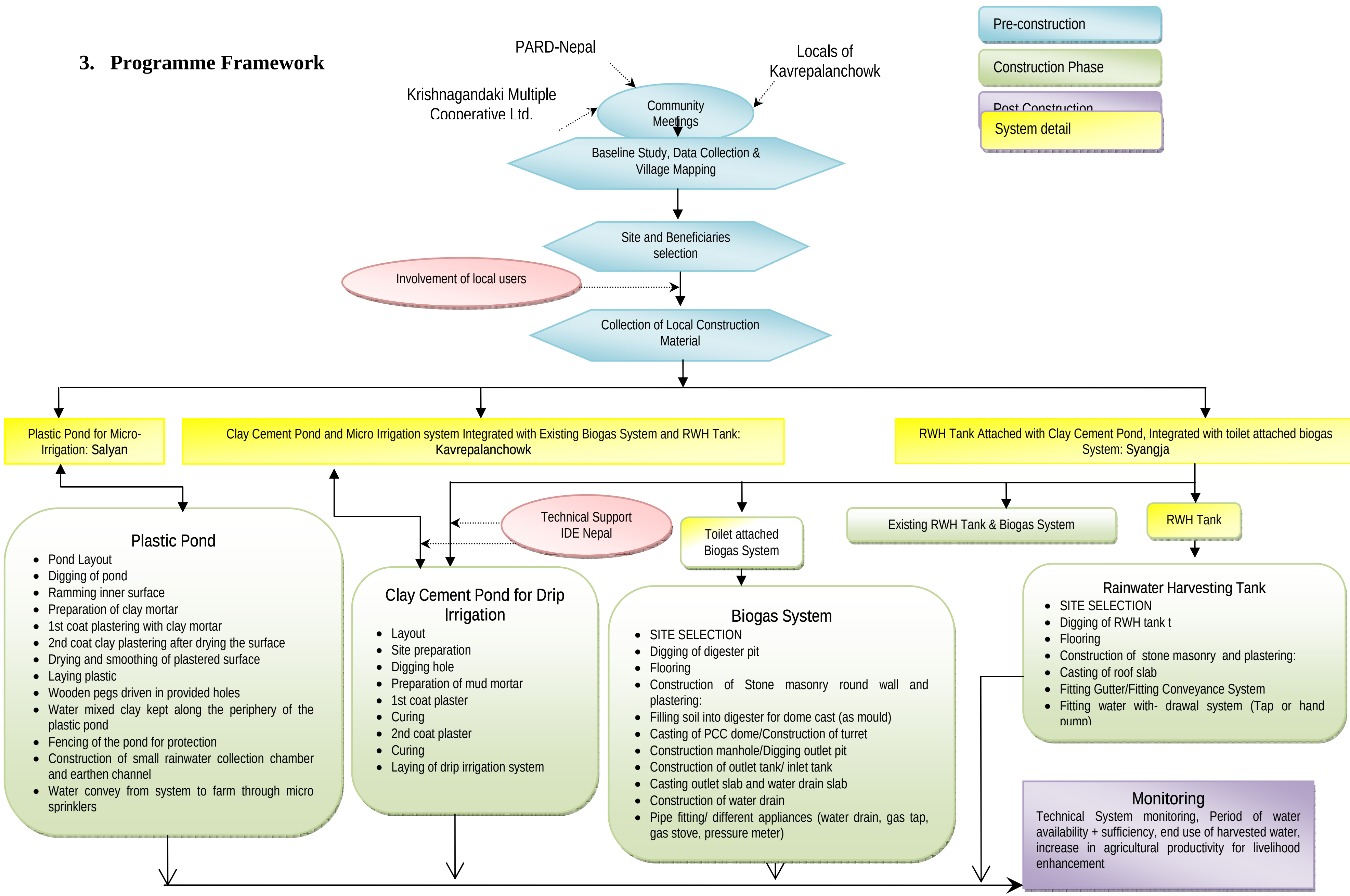
A local cooperative, Krishnagandaki Multipurpose Cooperatives Limited was selected as a local partner for community mobilization in Shree Krishnagandaki and Krishnagandaki VDC, Syangja. BSP-N provided close technical support for effective implementation of the projects. The R&D work was conducted with formal agreement of Krishnagandaki Multipurpose Cooperatives Limited and Bageshwari Biogas Company- A biogas Construction Company provided necessary technical and support for social mobilization for integrating with biogas systems in Shree Krishnagandaki of Syangja.

Support from already formed community group in Kavrepalanchowk during the implementation of RWH project by Nepal Red Cross Society in 2009 was taken for beneficiaries' selection, supervision of the programme and information dissemination between the selected households.

2.3 Limitations

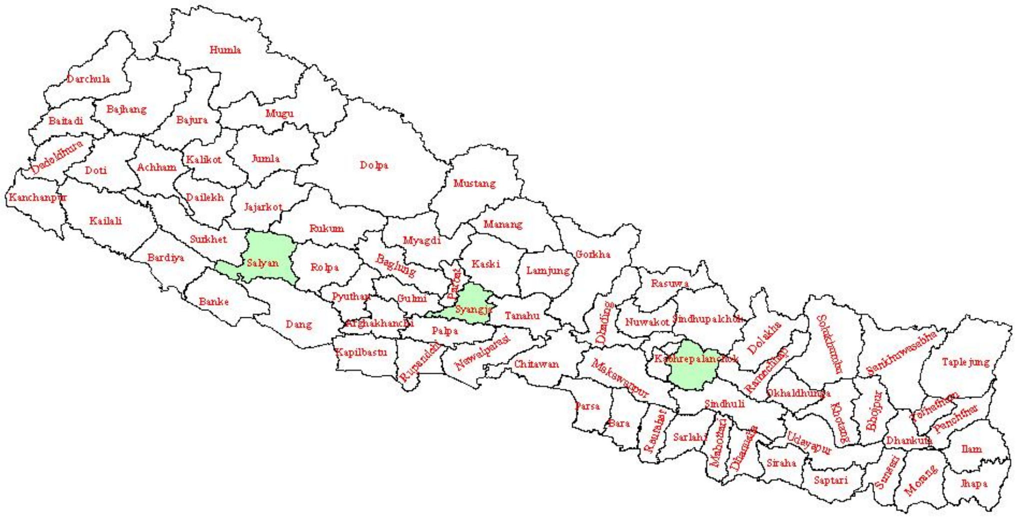
The limitation lies in the fact that information regarding the benefits accrued by the users is still at its preliminary stages. It is to be accepted that full realization of the benefits will be realistic only after using the systems for a couple of years – three years. Other limitations are time taken in the motivation of users, delay in local fund raising, collecting and transporting materials to the construction site and the monsoon itself.

3. Programme Framework



4. Description of the Test Sites

Three sites in three different districts were selected for the R & D Study with each of the sites testing different rainwater harvesting systems. Map below represents the test site while Table 1 presents the details of the specific systems tested in each of these areas.



Map 1: Map of Nepal showing the districts where the R & D Projects are launched

Table 1: Sites Identified For the Implementation of the R & D Projects

S. No	Site / VDC	District	Type of System
1	Kalimati Kalche	Salyan	Silpaulin Plastic lined pond
2	Kalimati Rampur	Salyan	Silpaulin Plastic lined pond
3	Kubhinde	Salyan	Silpaulin Plastic lined pond
4	Panchkhal	Kavrepalanchowk	$1m^3$ clay-cement lined pond
5	Shree Krishna Gandaki	Syangja	Mixed Structure: Toilet attached Biodigester+RHS+$1m^3$ clay-cement lined pond

Source: BSP-N 2010

4.1 Salyan District

Map 2: Salyan District and the VDCs with R &D sites

Salyan district is a hilly district some 320 km. west of Kathmandu valley in Rapti Zone of Nepal's Mid-Western Region with some strips of land which may be included in the Upper Terai area which is usually termed as Bhaber and Inner Terai. Salyan covers an area of 1,462 km² with population of 213,500 (C.B.S 2001). The district's administrative center is Salyan Bazar or Salyan Khalanga. It has 47 VDCs.

One component of the R&D activities of Rain Water Harvesting- Irrigation using plastic ponds is being experimented in Kalimati Rampur, Kalimati Kalche and Kupindedah VDCs of Salyan district for irrigation. In the project area water scarcity is very high. Table 2 shows the amount of rainfall at Salyan Khalanga. However, it cannot be taken as representing all the three areas where experiments are being conducted.

Table 2: Annual Rainfall at Khalanga, Salyan

Month	Rainfall (mm)
January	58.2
February	15.4
March	12.5
April	5.8
May	90.3
June	288.5
July	440.2
August	92.9
September	76.8
October	28.7
November	0.0
December	0.0
Total	1109.6

Source: District profile 2007/08

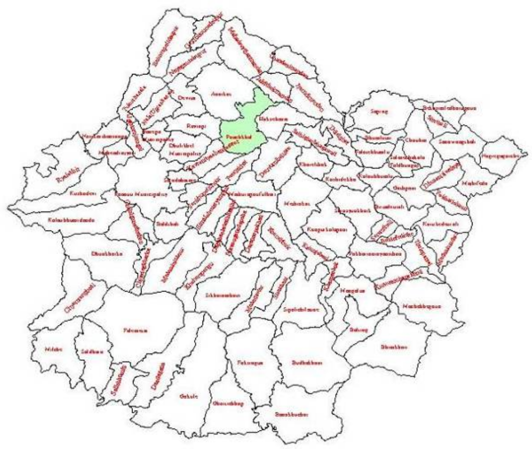
It is clear from the data that the rainfall is unevenly distributed throughout the year. It is basically concentrated in one rainy season when 80.97 per cent of annual precipitation occurs during the four months of the summer monsoon season, from June to September. Although it is not easy to divide the rest of the year precisely into convenient parts, the distribution of rainfall can be roughly said to have the pattern as indicated in Table 3:

Table 3: Annual Rainfall Pattern

Months	Period	Rainfall (mm)
April-May	Pre- Monsoon Period	96.1 (8.66%)
June-September	Summer Monsoon Period	898.4 (80.97%)
October-November	Post Monsoon Period	28.7 (2.59%)
December-January	Dry Winter Period	58.5 (5.27%)
February-March	Winter Monsoon Period	27.9 (2.51%)
Total for the year		1109.6 (100%)

In some project areas there is a provision of drinking water supply system; it is not enough to meet the demand for domestic use particularly in dry and winter seasons. Most springs used for drinking water do not have uniform discharge throughout the year. The discharge is highest during the rainy season and reduces gradually through the dry season. Due to the scarcity of water during winter and dry season, there had been no practices of vegetable farming. For subsistence more than 95% of the population in project area is inclined towards agriculture which is entirely rain fed irrigation. The reality is that there are no water resources to fulfill the demand of the community for irrigation purpose except the rainwater and excess water from the public water supply in summer. Ground water is unavailable in hills and adequate water supply from a long distance by canal and pipe conveyance system is almost impossible due to the poor availability of source of water, difficult geological features, and needing high investment to reap any benefits. So, low cost water storage tanks are the best means to address the problem. In these circumstances, plastic ponds have been expected to be useful to collect the rainwater and excess water from public water supply which can ultimately be used to irrigate the land by different micro-irrigation techniques such as sprinkler, piped and drip irrigation systems.

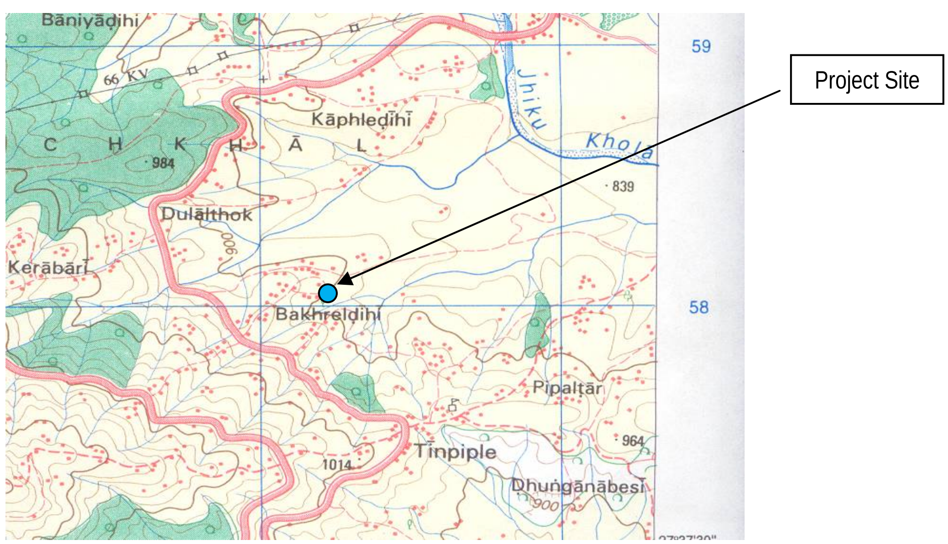
4.2 Kavrepalanchowk



Map 3: Kavrepalanchowk District and the VDCs with R &D sites

Kavrepalanchowk is a district which is very close to Kathmandu. It is a hilly district and the selected VDC Pachkhal is not very far from the highway.

For implementation of clay-cement lined pond, ward No. 7 and Ward No. 8 (well known as Bakhreldi and Poudyalthok respectively) were selected. These wards are separated by a small rivulet, a tributary to Okhare. They are situated at spur sloping towards the ridge of the spur which gradually descends down to the main river of the Panchkhal VDC, the Jhiku Khola. The entire VDC is a small part of the Panchkhal Basin. The area consists of sedimentary rocks which have been affected by varying degrees of metamorphism. It has also resulted in the occurrence of landslides as well as disappearance of springs soon after the Monsoon rains. However, it appears that the present condition of the water scarcity is also due to drying up of springs, dug wells and limited or no supply from public water taps. According to the local knowledgeable persons there are deforestation at the upper slopes of Jhiku Watershed, increase in population of Panchkhal Valley mainly due to migration from the ridge settlements after the gradual eradication of malaria, recent indications of the climate change and consequently felt need for greater amount of water for irrigation with increased cropping intensity which relatively aggravated the water the problem of water scarcity.



Map 4: Site at Bakhreldi and Poudelthok, Panchkhal VDCPanchkhal VDC

At the same time, situation of the site at the coordinates, represented by the parallel of 270 37' 35" N and the meridian of 850 36' 30" E and at an altitude of 1012 metres above sea level has placed it in the Warm Temperate Monsoon belt with warm summers and cool winters and quite a substantial amount of rainfall which, however, is distributed unevenly throughout the year. The following table shows the amount of precipitation that is received in the Panchkhal Area (See Map 4).

It appears from the data that the rainfall is unevenly distributed throughout the year. It is basically concentrated in one rainy season when 73.63 per cent of annual precipitation occurs during the four months of the summer monsoon season, from June to September. Although it is not easy to divide the rest of the year precisely into convenient parts, the distribution of rainfall can be roughly said to have the pattern as in Table 4 and 5:

Table 4: Annual Rainfall at Kaverpalanchowk

Month	Rainfall (mm)
January	54.6
February	11.6
March	39.8
April	43.5
May	57.8
June	119.8
July	230.1
August	506.2
September	58.8
October	120.2
November	0.0
December	0.0
Total	1242.4

Table 5: Seasonal Pattern of Rainfall at Panchkhal VDC

Months	Period	Rainfall (mm)
April-May	Pre- Monsoon Period	101.3 (8.15%)
June-September	Summer Monsoon Period	914.9 (73.63%)
October-November	Post Monsoon Period	120.2 (9.68%)
December-January	Dry Winter Period	54.6 (4.39%)
February-March	Winter Monsoon Period	51.4 (4.14%)
Total for the year		1242.4 (100%)

Source: Field Work, 2010

From the studies conducted in the pre-feasibility phase it showed that the research sites had been suffering from the problem of water scarcity. The villagers had been spending 2-3 hours each day for fetching water from the far-off spring sources. The reality is that the potentials of few sources like rainwater have never been explored and never been the source of drinking water and income generation. On the other hand, the problems are directly or indirectly linked. It is clear from the rainfall data how Panchkhal, not unlike in most of the hill areas of Nepal, in general, they have much water during the monsoon rainy season (June – September) but too little water in rest of the year. So, most springs do not have uniform discharge throughout the year, as the discharge is highest at the end of the rainy season and reduces gradually through the dry season. Eventually, majority of the small farmers have to depend on seasonal rains for irrigation. The traditional furrow or flood irrigation requires large quantities of water, and they are costly if it is to be done by pumping or by making a channel from a distant source. Hence, all of these farmers need an affordable technology. Lastly, ground water is unavailable in the hills where dug wells and tube wells are not easy to construct. In line with these circumstances, it was perceived that clay-cement lined ponds might be useful in addressing these problems.

These ponds might be useful for both waste water collection and rainwater harvesting. If these ponds are used for harvesting wastewater from kitchen, it can be used for the productive uses by means of drip systems. If rainwater is harvested, the water might serve for domestic uses. For small plot irrigation in water scarce areas and to increase the income of smallholders, a simplified low cost drip has been developed by IDE/N and it is considered a very efficient method for irrigation, as water is applied directly to the root zone of the plants.

4.3 Syangja

From the carried pre-feasibility study it reflected the characteristics of the site chosen for the special study. It is situated almost at the ridge of spur which gradually descends down to Mirmi between the Kali Gandaki River and its tributary, Andi Khola, which drains the main part of the district of Syangja by dividing it into two parts, Eastern and Western. The entire VDC consists of highly metamorphosed schistose rocks with very fine and fragile flakes of micaceous layers rendering the whole area very much permeable on the one hand and susceptible to erosion on the other (See Map 5). It has also resulted in the occurrence of landslides as well as disappearance of springs soon after the Monsoon rains.

Map 5: Syangja District, Nepal Showing project VDC

At the same time, the situation of the site at the coordinates, represented by the parallel of 27 57’ 45” N and the meridian of 83 39’ 31” E has put it in the warm temperate monsoon belt with warm summers and cool winters and quite a substantial amount of rainfall which, however, is distributed unevenly throughout the year. Although the VDC is situated close to the very well known hydro-electric project of Nepal the rainfall data (See Table 6) could not be officially obtained at the short time of our visit.

Table 6: Annual Rainfall at Syangja

Month	Rainfall (mm)
January	69.8
February	12.4
March	45.8
April	95.4
May	252.7
June	318.0
July	591.2
August	493.1
September	196.9
October	173.7
November	0

December	0
Total	2249

Source: District profile 2007/08

It appears from the data that the rainfall is unevenly distributed throughout the year. It is basically concentrated in one rainy season when 71.1 per cent of annual precipitation occurs during the four months of the summer monsoon season, from June to September. Although it is not easy to divide the rest of the year precisely into convenient parts, the distribution of rainfall can be roughly said to have the pattern as in Table 7.

Table 7: Seasonal Pattern of Rainfall at Shree Krishna VDC

Months	Period	Rainfall (mm)
April-May	Pre- Monsoon Period	348.1 (15.48%)
June-September	Summer Monsoon Period	1599.2 (71.1%)
October-November	Post Monsoon Period	173.7 (7.73%)
December-January	Dry Winter Period	69.8 (3.11%)
February-March	Winter Monsoon Period	58.2 (2.58%)
Total for the year		2249 (100%)

Source: Field Work, 2010.

Figure 1 Provides a comparative annual rainfall of the three districts- Salyan, Kavrepalanchowk and Syangja

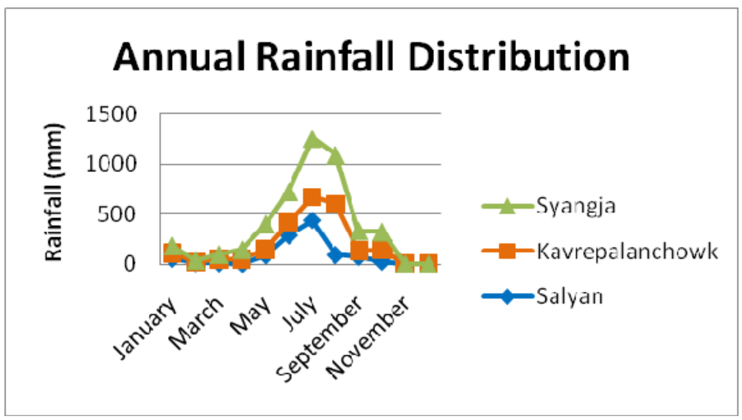


Figure 1: Annual Rainfall Distribution of Salyan, Kaverepalanchowk and Syangja

5. Technologies Tested:

5.1 Silpaulin Plastic Ponds:

Picture 2: *Silpaulin Plastic Pond*

BSP-N embarked upon experimenting the usefulness of plastic lined ponds at the selected sites namely Jayatpani, Burase and Bhangeri of Kupindedaha VDC, Balle of Kalimatirampur VDC and Sunchaur, Nange and Baluwa of Kalimati Kalche VDC of Salyan district from May 2010 to February 2011 with financial support of RAIN Foundation, the Netherlands. In quest of the best method of low cost and community friendly technology in water harvesting, BSP- Nepal has decided to examine the potentiality, effectiveness and sustainability of the technology as a part of R&D program in aforementioned communities of the Salyan district based on the practices, case studies, findings and recommendations from elsewhere. Under this research project 20 plastic ponds integrated with micro –

sprinkler have been installed for harvesting rainwater with an objective to enhance the livelihood of the rural people.

The shape of the ponds is trapezoidal .The capacity of the each constructed tanks is 18 m^3. Top length of the pond is 7.40 m; top width 3.40 m; bottom width 3.40 m; bottom length 5.40m, vertical depth 1.5 m and the side slops is 1:1.5. Figure 2 provides the technical details.

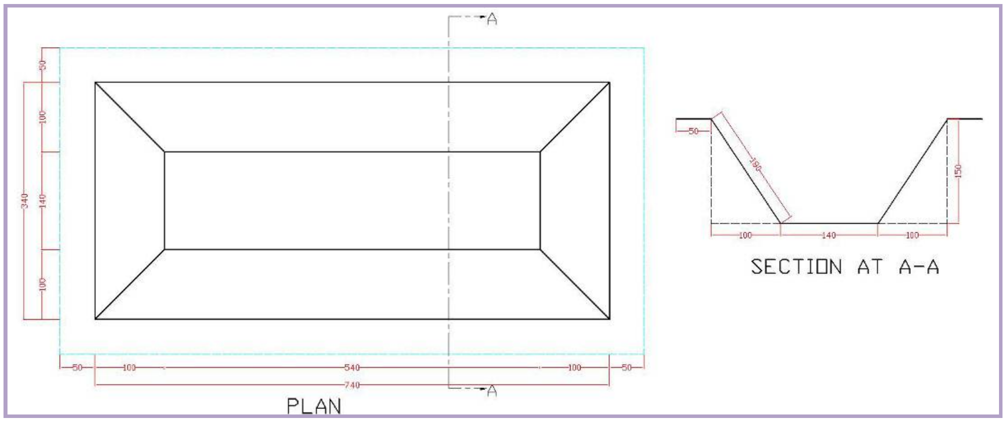


Figure 2: Plan and Cross Section of the Pond

The research was carried out in a systematic way as mentioned above. All the sites were selected from decision of community with the facilitation of staffs of PARD-Nepal and BSP -Nepal in the sense of technical and social issues. In all systems, local manpower from the respective community contributed for unskilled labor and locally available material for overall construction process with technical guidance of BSP-N and PARD-N.

5.2 Clay-cement Lined Pond with Drip Irrigation System

As mentioned before, 1m^3 clay-cement lined pond was taken as the research subject in collaboration with International development enterprises (IDE/N) and the site chosen is the Panchkhal VDC of Kavrepalanchowk District.

Picture 3: *Clay Cement Lined Pond*

IDE/N is learnt to have successfully demonstrated various soil cement tanks in some parts of the mid-hills of Nepal. With an objective to address supplementary multiple water needs (domestic and productive) in the water scarce villages, IDE/N had initiated a research in such water tanks. The result was quite encouraging. It appears that the community has preferred the technology because of its affordability and simplicity in handling. So BSP/N has now decided to take up an in-depth research, in collaboration with IDE/N, at the Panchkhal VDC of the district of Kavrepalanchowk.

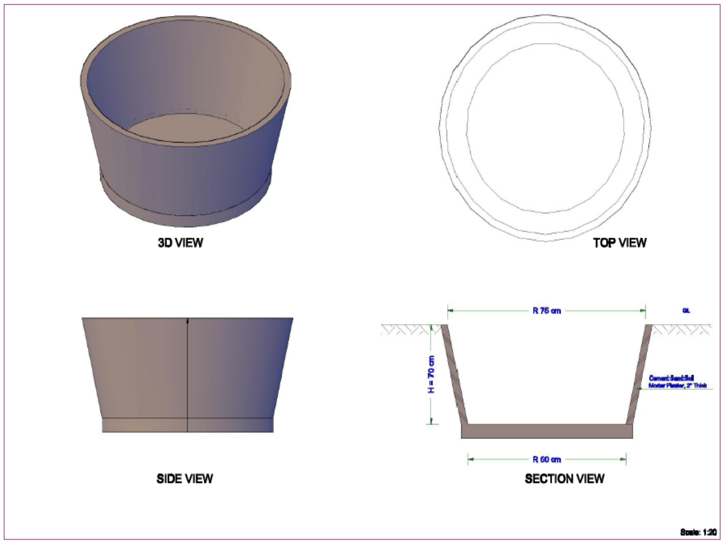


Figure 3: Schematic diagram of the 1 m^3 clay-cement lined pond

Clay-cement lined water storage ponds is a new technology. Clay –cement-sand ratio is one of the important factors that determine the life as well as performance of the pond. So, to understand the physical properties of the clay in the project sites, necessary test like shrinkage, permeability and strength test were carried out for the cement : sand : clay ratios of 1:6:6, 1:4:6, 1:3:6, 1:3:5, 1:3:3. (Annex Soil Test Report for Shrinkage, Permeability and Strength test for Clay-cement- Sand Mortar)

The overall objective was to study the compressive strength, shrinkage behavior and permeability characteristics of cement treated soils for different ratios (Cement: Sand: Clay – 1:3:3, 1:3:5, 1:3:6, 1:4:6 and 1:6:6). Therefore from the laboratory test of the samples prepared at the given ratio, it was concluded that the strength of the sample at the ratio of 1:3:3 has the higher strength, lower shrinkage value and very low permeability. The sample with ratios 1:3:5 and 1:3:6 have very low difference in the strength on 3rd and 7th day. The strength of the sample on 28th day shows high variation. The permeability of the samples at 1:3:3, 1:3:5 and 1:3:6 were found to be practically impossible. At the ratios 1:4:6 and 1:6:6, the strength is low, the permeability is very low and has increasing shrinkage limit. Thus the ratio of 1:3:6 was found more appropriate in terms of strength, shrinkage limit and permeability for strength, cracks and seepage control.

Construction Procedures

The capacity of all the installed tanks was 1m^3 with the dimension of -Top Radius-75cm, Bottom Radius-60 cm and Height-70 cm. The construction procedures is presented in the flow-chart Figure 3 and Figure 4 provides the schematic drawing of the structure.

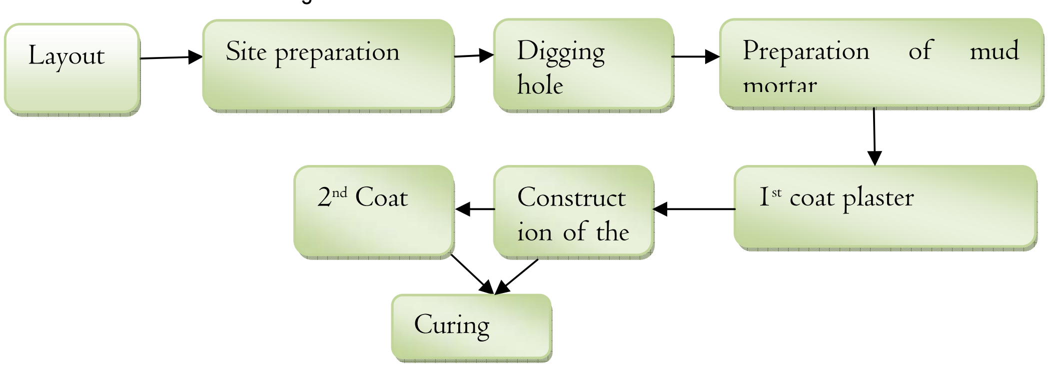


Figure 4: Flowchart for construction of the 1m^3 Clay-cement lined pond

The research was carried out in a systematic way as shown in the programme framework diagram above. The sites were selected in consultation with the BSP-N staff and the respective household. Site preparation, pit digging and collection of local materials were the household's responsibility. For the construction of pond, trained mason from IDE was used in all the research sites.

Labor breakdown: In an average 1.5 tanks were completed per day. For this to make possible some works like rough excavation of tank hole, collection of local materials was done by the user HHs. Rest of the installation work was carried out by the IDE trained mason.

Direct and Indirect Cost per Tank: The direct cost was calculated to be around Rs .1500 (excluding the community contribution).This included the cost of cement, sand, aggregate and skilled labor. When evaluating the community contribution (unskilled labor, collection of local materials, screening of soil and other support), the total cost come to be around Rs. 2100.The calculation does not include the cost of transportation of cement from the nearby local market

Plastering Material

Clay used for mud mortar was well screened. Plastering commenced within 30 minutes of the soil cement mortar preparation. The mortar was prepared in such a way that it would stick at the wall while plastering. The soil cement mortar ranged from semi solid to solid and looked like a ball (*Dalla*). Red soil transported from the nearby sites was used for the mud mortar. Red soil because of the high cementing material content is considered better for plastering as compared to other types of soil.

As soon as the second coat settled (after 3-5 hours), farmers were requested to cure the tank with the wet jute bags and continued it up to four days. After four days, tanks were filled up with water. Then users were especially instructed that tanks should not be left without water to prevent possible cracking as the soil content is high in the mud mortar. With this practice, life of the tank increases. If the tank has to be left for longer time without completing second coat, curing should continue. It requires less curing in the more shade and more curing in the sun exposed tanks.

5.3 Integration of RWH tank, Biogas, Toilet and Clay-Cement Lined Pond with Drip System

BSP-N has embarked upon experimenting the usefulness of an integrated RWH system aiming at multiple-use and have constructed stone masonry tank for meeting household water need, toilet attached biogas plants for energy generation along with clay-cement lined water collection pond integrated with drip irrigation system at selected 20 households of Sarkidanda, Shrikrishnagandaki VDC in Syangja district with the financial support of the RAIN Foundation. In quest of the best method, management and effective operation of multiple uses of rainwater through the integrated system of low cost and community friendly technology in water harvesting, energy generation, good sanitation and economic promotion through appropriate technology. BSP-N has decided to examine the potentiality, effectiveness and sustainability of the technology as a part of R&D program in aforementioned community of the Syangja district based on the practices, case studies, findings and recommendations from elsewhere (See Map 6 and Figure 6) from May 2010 to February 2011.

The rainwater collecting systems integrated with biogas, toilet, clay-cement lined ponds and drip irrigation technology for the multiple use of rainwater as drinking, irrigation, energy generation and sanitation, in particular were installed with direct supervision, monitoring and follow up of local partner and BSP-N. The whole process of the research project was conducted with a participatory approach. Woman, poor and disadvantaged groups were directly involved in every process such as project data collection, identification, selection, implementation as well as monitoring the actual performances of the project activities.

The shape of the RWH tank is cylindrical .The capacity of the each constructed RWH tanks; Biogas plant and Water pond are 10 cubic meters, 4 cubic meters and 1 cubic meter respectively. The size of the toilet varies as per the necessity, availability of land and resources of the community people (See Figure 5).

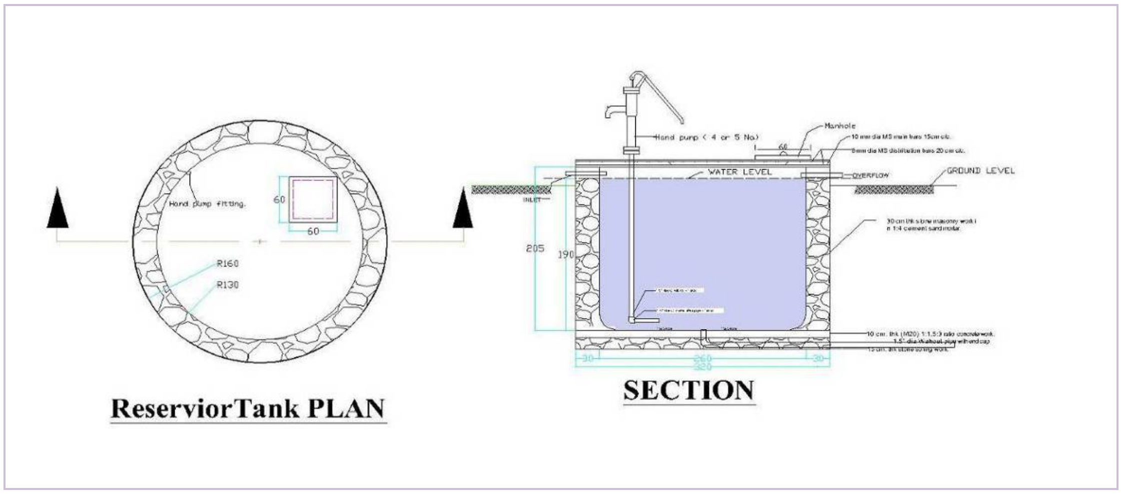


Figure 5: Plan and Cross Section of the RWH Tank

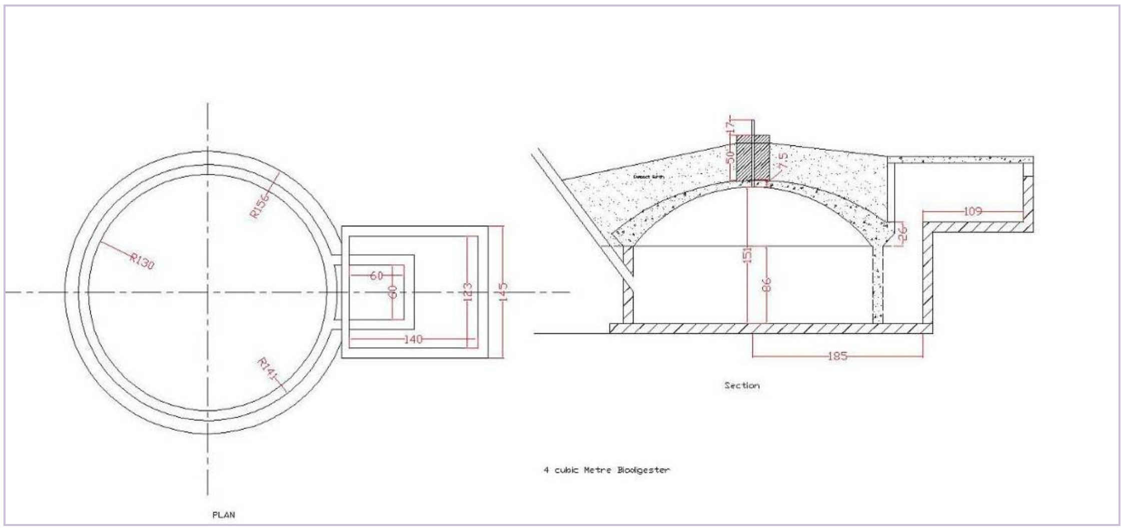


Figure 6: Plan and Cross Section of the Biogas Plant

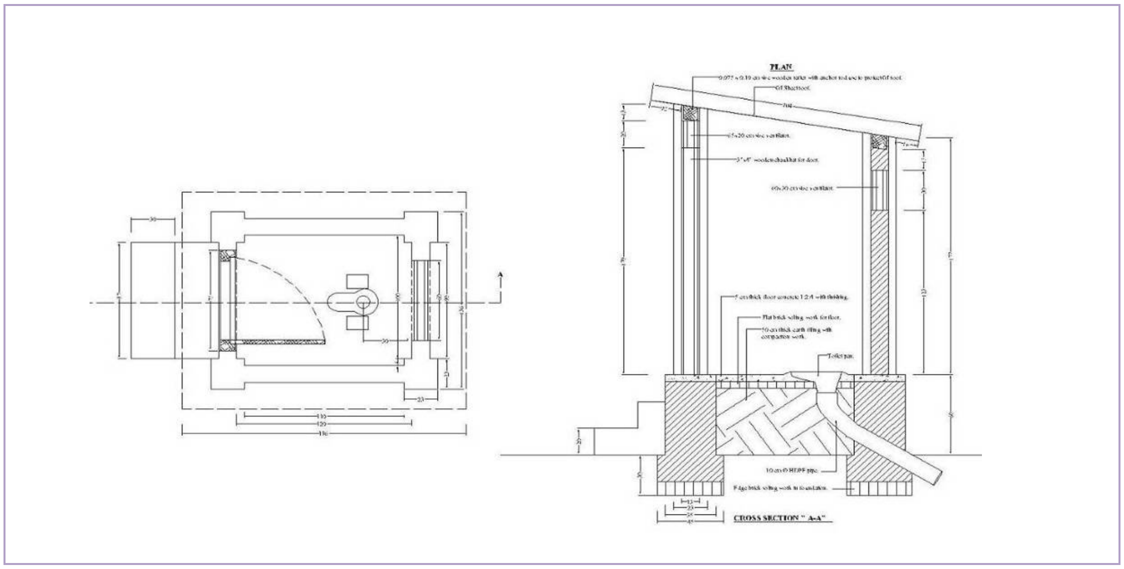
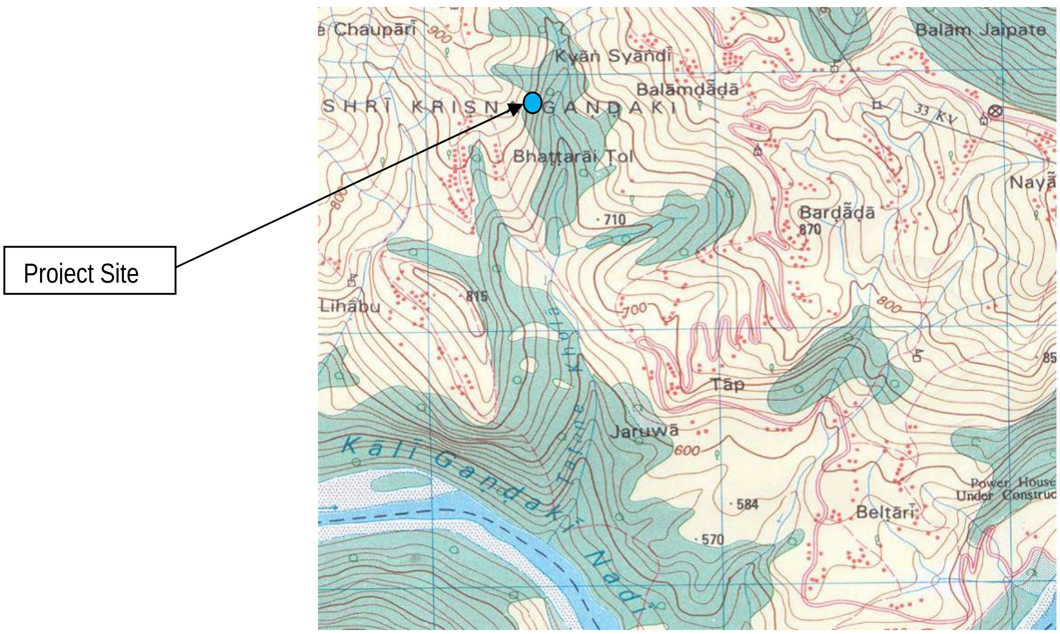


Figure 7: Plan and Cross Section of the Toilet



Map 6: Sites with Integrated RWHS and Biogas systems

6. Beneficiaries: demographic and socio economic information:

1.1 Salyan

Multiple use of harvested water:

With the completion of Silpaulin plastic lined ponds, the harvested water from the pond is mainly used for irrigation. The total number of respondents is 135. Out of 135 respondents, 29.6% are using the water for irrigation only, 51.9% of the households are using the water for cattle rearing, cooking the cattle feed and irrigation purposes, 14.8% are using water for washing and irrigation purpose and 3.7% of the households are using the harvested water for irrigation, cattle rearing and washing purposes (See Figure 8).

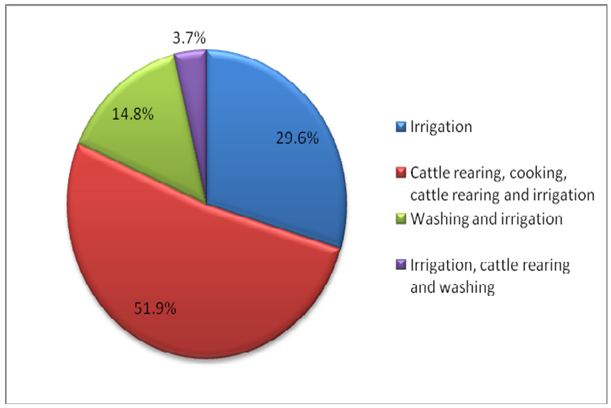


Figure 8: Multiple use of the harvested water

Source: Field Survey, 2010

Population distribution:

In total 852 people, 433 male and 419 female, from 135 households are benefited in the project. The average HH size in project coverage is 6.30. Figure 9 gives the detail of beneficiaries. See Annex for detail.

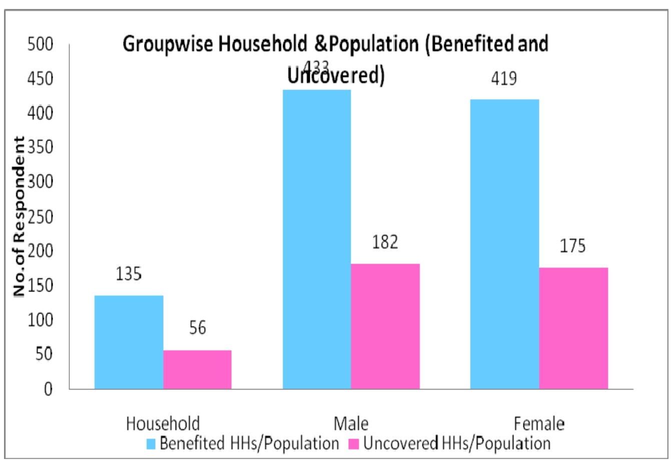


Figure 9: Household and Population in the Project site in Salyan

Source: Field survey, 2010

All of the households belong to the already formed user's groups for other income generating programmes, there are still some other households (56 out of 191) which have not been covered. Those households could not be included due to the following reasons:

- Scattered land
- Limited resources
- Highly undulated grounds (Elevation difference in a small area)

- Limited size of the ponds
- Water demand and water availability
- Lack of adequate space for pond construction
- Existence of the additional sources.

Ethnic composition of project area

The community of the service area has mixed ethnic composition of Brahmin, Chhetri, Janajati and Dalit, as can be seen in the Figure 10.

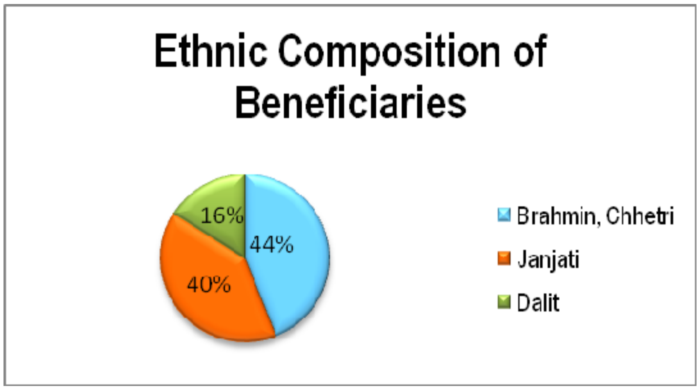


Figure 10: Ethnic Composition of Beneficiaries

Source: Field survey, 2010

Food Sufficiency Level of the beneficiaries

The project area belongs to the community with low food sufficiency from their own agricultural land. It was found that, HHs in project implemented Kubhindedaha VDC and Kalimati-kalche VDC have food sufficiency for 3 to 6 months and cannot afford to save food crops for entire year.

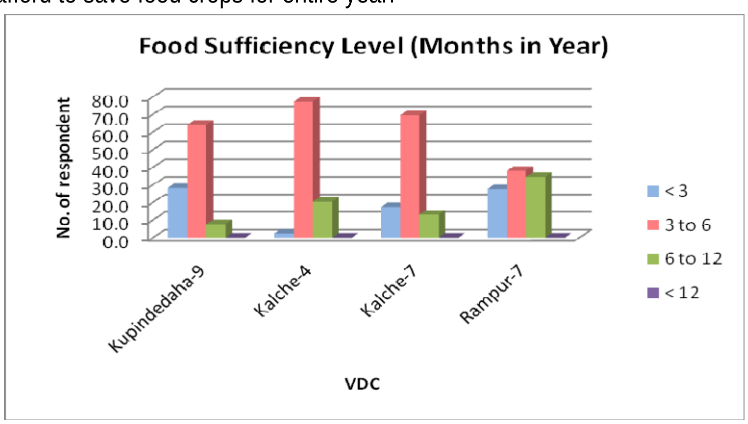


Figure 11: Food Sufficiency Level in households in Salyan Project sites

Source: Field Survey, 2010

Sources of water harvesting:

The main source of water collection is rain water. One pond is completely dependent on rain water and remaining 19 have the additional sources such as the excess water coming from nearby public pipe water supply. But it is not possible to collect water in dry season also from the additional sources due to the high scarcity of water for domestic use from the existing water supply systems.

Methods of Irrigation:

From the study of the project area, it is found that 83 % households are irrigating their lands by pipe conveyance and use sprinkler to irrigate their land, 10 % households by fetching the water by pot from the pond and 7 % by the pipe conveyance and micro sprinkler system.

The withdrawal of water from the pond to surface level for irrigation was found mostly by means of pipe, driven in to the pond (90%) and 10 % households take the water out of the ponds directly by means of some buckets or similar pots

Cropping pattern:

The major crops of the project area are maize, wheat and millet. The community had nort been practicing vegetable farming due to unavailability of water but after completion of plastic ponds the beneficiaries been able to irrigate their field through micro sprinkler and have started to grow cash crops. Table 8 shows the system wise cropping detail before and after the project in summer, winter and off season.

Table 8: Cropping Pattern before and after the project

Name of User's Group	Location	Crops (Before Project)			Crops (After Project)		
		Winter	Summer	Offseason	Winter	Summer	Offseason
Hariyali Swabalamban	Kupindedaha-9	Wheat, Mustard, Lintel	Maize, Millet	Potato	Tomato, beans, Vegetables	Maize, Vegetables	Potato, Vegetable
Sharada Swabalamban	Kalche-7	Wheat, Mustard	Maize, Paddy	Gram, Lintel	Wheat, Mustard, Vegetables	Maize, paddy, Beans, Vegetables	Beans, cucumber, Vegetables
Laligurash Swabalamban	Kupindedaha-9	Wheat, Mustard, Lintel	Maize, Millet	Potato	Tomato, Beans, Vegetables	Maize, Vegetables	Potato, Vegetable
Jharana Swabalamban	Kalche-4	Wheat, Mustard, Lintel	Maize	No	Wheat, Gram, Lintel, Vegetables	Maize, Beans	Vegetables
Pragati Swabalamban	Kupindedaha-9	Wheat, Mustard, Lintel	Maize	Potato	Tomato, Beans, Vegetables	Maize, Vegetables	Vegetables
Bhuwanesori Swabalamban	Kupindedaha-9	Wheat, Mustard	Maize	No	Wheat, Gram, Tomato, Beans, Vegetables	Maize, Vegetables	Vegetables
Chandrama Swabalamban	Kalche-4	Wheat, Gram, Lintel	Maize, Beans	No	Wheat, Gram, Lintel, Vegetables	Maize, Ginger, beans	Potato, Vegetables

Source: Field survey, 2010

Irrigated Area

Total irrigated area of the irrigation systems is 165 "Ropani". The average irrigated area per household is 1.22 "Ropani". Table 9 shows the system wise average land per house hold that has been irrigated by the system.

Table 9: Average Irrigation command area per household

Name of User's Group	Location	Avg. Irrigated land (Ropani) per HH
Hariyali Swabalamban Samuh	Kupindedaha-9	2
		3.6
Sharada Swabalamban Samuh	Kalche-7	1
		0.5
Sundhara Swabalamban samuh	Rampur-7	0.5
Laligurash Swabalamban samuh	Kupindedaha-9	2.6
		2.5
Jharana Swabalamban samuh	Kalche-4	1
		1.25
Pragati Swabalamban Samuh	Kupindedaha-9	3.5
		2
Bhuwanesori Swabalamban Samuh	Kupindedaha-9	1
Chandrama Swabalamban Samuh	Kalche-4	0.75

Source: Field survey, 2010

Impact in Irrigation Production and its Cash value

Changes have been observed in winter and off season farming. Irrigation systems are providing the services for vegetable farming, wheat, mustard and other cash crops. Table 10 shows the aggregated details of the project area. Any seasonal change in the summer crops has yet to be seen. According to the beneficiaries the marked change in crop quantity was mainly due to the availability of water for irrigation.

Table 10: Change in agriculture production

Crops	Quantity (Kg)			Avg. rate	Amount	Remarks
	Before	After	Increase/ Decrease			
Maize	12150	12150	0	50	0	
Millet	4050	4050	0	75	0	
Potato	675	4050	3375	45	151875	
Tomato	140	3375	3235	35	113225	
Beans	3375	4000	625	125	78125	
Gram	2025	2550	525	150	78750	
Mustard	1350	1755	405	120	48600	
Paddy	4200	4200	0	25	0	
Wheat	5560	6116	556	120	66720	
Other Vegetables	1620	3240	1620	20	32400	
Total					569695	
Avg. per Household					4220.0	

Source: Field survey, 2010

1.2 Syangja

Multiple use of harvested water:

The harvested rainwater is mainly used for drinking, mixing the feed for the biogas plant, toilet and irrigation. All the respondents have been using the water for drinking, sanitation, biogas operation and irrigation, cooking, cattle rearing and washing purposes as per the sufficiency of water. The waste water from kitchen, collected in clay-cement lined pond will be used for irrigation via micro drip system.

Population distribution:

In total 144 people from 20 households are benefited from the project. Of which total male population is 66 and female population is 78. The average HH size in project coverage is 7.20 (See Figure 12).

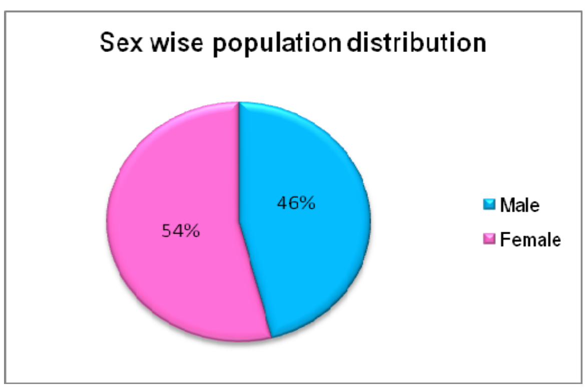


Figure 12: Figure: Sex wise Population Distribution

Source: Field survey, 2011

Ethnic composition

The community of the project area has mixed ethnic composition of Brahmin, Janajati and Dalit with high majority of Dalit. They are men and women of farming households who are small farmers or farmers with limited land or tenants. Figure 13 shows the ethnic composition of the beneficiaries.

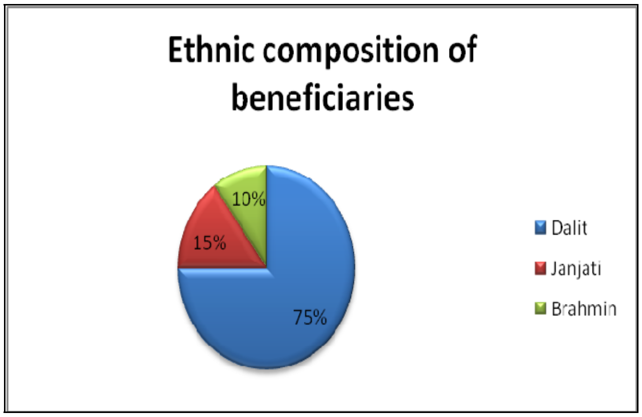


Figure 13: Ethnic Composition of Beneficiaries

Source: Field survey, 2010

Food Sufficiency Level of the beneficiaries

The project area belongs to the community with low food sufficiency level with income mostly from their agricultural land. From the field study, about 60 % of the HHs grows food crops to last less than 3 months, 30% HHs between 3 and 6 months and 10% HHs between 6 to 12 months.

Sources of water harvesting:

The water collected from roof top is harvested in stone masonry RWH tank and kitchen waste water and overflowed water from the RWH tank is collected in the clay-cement lined pond.

Methods of water use:

From the study of the project area, it is learnt that the collected rainwater is used for drinking, biogas and toilet use and for irrigation after getting the water from the tank by means drippers. The beneficiaries will adopt the drip Irrigation system for the purpose of irrigation to vegetable farming.

Command Area:

Total command area for the irrigation systems is 5 "Ropani" which will be served by the system through drip irrigation. Thus the average command area per household will be 1/4 "Ropani".

Toilet attached biogas plant:

Integrating toilet with biogas system has helped sanitized the environment, minimized utilization of fuel wood for cooking purpose and helped saved time as well. Owing private toilet has reduced open defecation in the programme area. The beneficiaries using the integrated system are now enjoying biogas approximately four hours per day for cooking their morning and evening meals. This has reduced their burden of fuel wood collection, health problems related to respiration and eye and most of all has saved time. The time saved particularly by women are being utilized for productive activities like kitchen gardening and tailoring which is helping them to generate small amount of income for the family.

1.3 Kavrepalanchowk

Multiple use of harvested water:

Water harvested in 1m^3 clay cement lined pond is mainly waste water from kitchen used for washing vegetables, utensils and water from personal use such as washing hands and feets. The collected water in the tank is primarily used for irrigation through micro drip system but at times the owners have also been carrying water in buckets to irrigate their farmlands. Along with this, remaining water in the tank is also used by the beneficiaries to feed cattle. Consuming used water for irrigation has allowed beneficiaries to initiate kitchen gardening. The owners have cultivated seasonal vegetables during dry condition and have fulfilled their requirement and have also sold remaining vegetables in the market.

Population distribution:

In total 86 people from 20 households are benefited from the project. Of which total male population is 44 and female population is 42. (See Figure 14)

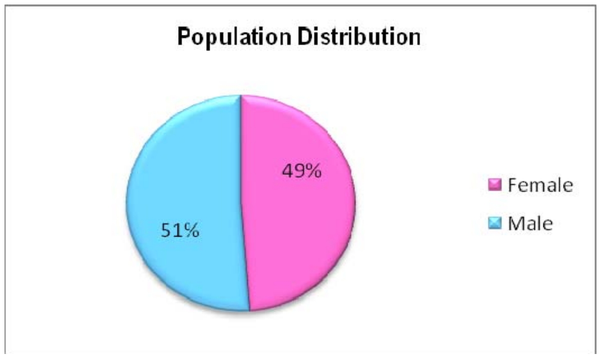


Figure 14: Population distribution

Source: Field survey, 2010

Ethnic Composition and occupational status

The pie chart and bar graph below depicts ethnic composition and occupational status of beneficiaries in the programme area. Brahmins are by far the most benefitted. In terms of occupational status, most of the households have farming as their main source of income followed by teaching and others.

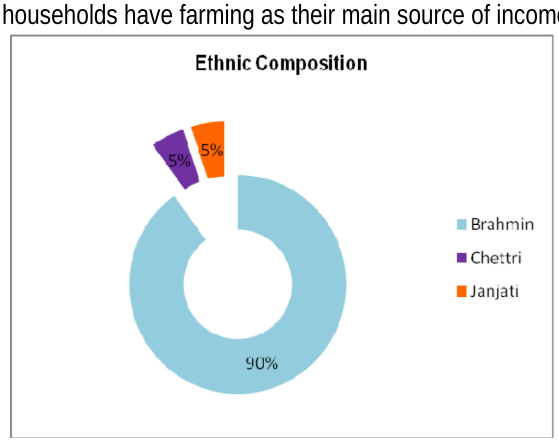


Figure 15: Ethnic composition

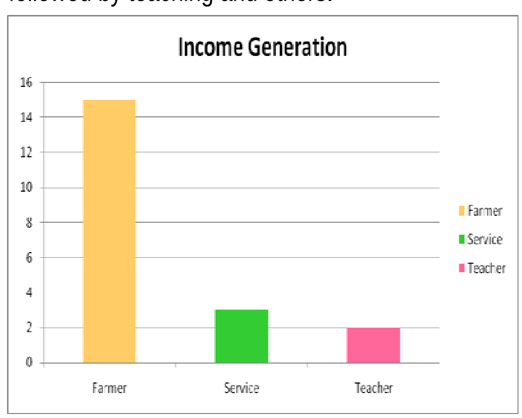


Figure 16: Income generation

Source: Field survey, 2010

Source of water harvesting

Water harvested in 1m^3 clay cement lined pond is mainly waste water from kitchen used for washing vegetables, utensils and water from personal use such as washing hands and feet.

Methods of irrigation

The beneficiaries have been irrigating their land using the micro drip irrigation systems. From the survey in project area, it was found that two system owners have also been using sprinkler or spray heads to irrigate their land. Some of the owners also stated that they carry water in buckets and irrigate their cropland.

Cropping pattern

Due to unavailability of water in the programme area the beneficiaries were not cultivating vegetables like coriander, onion, garlic, fenugreek which are now being cultivated in their farm and kitchen garden using the harvested waste water from clay cement lined ponds. During the extreme dry condition when vegetable farming is minimal, production is low and price is high, with the availability of clay cement lined pond the users have now been able to enjoy fresh vegetables from their kitchen garden.

Irrigated Area

From the site visit it was noted that the harvested water was used to irrigate an area 256 sq.m by most of the pond owners using the micro drip irrigation system. It was also found that the farmers using the system had been irrigating their land upto 512 sq. m by carrying collected water in buckets and pouring it to the plants.

7. Cost of the systems:

7.1 Direct Cost contribution in each system: plastic pond

Direct average total cost of each system is NRs 54510.00. Total community contribution NRs 22500.00 (41%) in kind and total grant amount from the research project is NRs 32010.00 (59%). Supervision and monitoring expenses and local NGO support cost is not included in the calculation. Table 11 shows the cost contribution detail in each system.

Table 11: Average Project Cost per System

SN	Particulars	Project Grant	Community Contribution	Total
1	Silpolin Plastic, HDPE pipe, Sprinkler Cement for collection chamber	22010.00	0	22010.00
2	External Material Transportation	500.00	0	500.00
3	Site clearance and excavation		8000.00	8000.00
4	Side finishing, ramming, mud plastering	2000.00	3000.00	5000.00
5	Fencing and other protection work	7000.00	8000.00	15000.00
6	Seed support and cultivation	500.00	3500.00	4000.00
Total		32010.00	22500.00	54510.00

Source: Field survey, 2010

External materials like Plastic for pond, HDPE pipes, sprinkler, cement are purchased from grant amount. The project support is also helpful for skilled mason for ramming, finishing, fencing, seed support. Excavation work, local material collection and transportation were contributed by the community people.

7.2 Cost of 1 m^3 clay-cement lined water pond:

The total direct cost of each system is NRs. 3,850.00 only. Total users' contribution in kind and is only 500.00 (which of course will vary from place to place depending upon the use of unskilled labor) following table shows the summary of cost of the construction (See Table 12)

Table 12: Summary of direct cost of 1m³ clay-cement lined pond

S.N.	Description	No	Rate	Total	Remarks
1	Skilled Laour (Days)	1	500.00	500.00	
2	Unskilled Labour(Days)	2	250.00	500.00	
3	Cement with transportation(Bags)	1	750.00	750.00	
4	Drip Irrigation System with Transportation	1	1600.00	1600.00	
	Sub Total (Project Grant)			3350.00	
	User's Contribution in Kind (Lump sump)			500.00	
Total				3850.00	

External materials were purchased from grant amount. Excavation work and local material collections were contributed by the users.

7.3 Direct Cost contribution from Households for integration of different multi use system:

Direct average total cost of each system is estimated to be NRs 114527.00. Total community contribution NRs 71327.00 (62%) in kind and total grant amount from the research project and GON Subsidy is NRs 43200.00 (38%). Supervision and monitoring expenses of BSP-N and IDE and local Partner support cost is not included in the calculation. Table 13 shows the cost contribution detail in each system.

Table 13: Average Project Cost per Household

SN	Particulars	Project Grant	Community Contribution	GON Subsidy	Total
1	RWH System	2000.00	32785.00	0	52785.00
2	Biogas Plant	0	27542.00	15200.00	42742.00
3	Toilet	5000.00	10000.00	0	15000.00
4	Clay Cement tank	1400.00	1000.00	0	2400.00
5	Drip Irrigation System	1600.00	0	0	1600.00
Total		28000.00	71327.00	15200.00	114527.00

Source: Field survey, 2010

External materials like Cement, HDPE pipes, Fittings, Drip Irrigation System and other appliances are purchased from grant amount. The project support is also used for skilled mason. Excavation work, local material collection and transportation were contributed by the community people.

24 % amount is covered from project grant and GON subsidy, 25 % amount is covered by kind contribution of local people and 51 % amount is contributed by the community people taking the loan from different sources and they are trying to get more support after verbal commitment from other line agencies like DDC and VDC to pay the loan. Aggregate support was provided by Kaligandaki -A hydro electric project excluding transportation charge.

8. Cost Sharing

Salyan

The total project cost for 20 systems is NRs.10, 90,200.00 and Total Project grant is 6, 40,200.00. Per liter cost as per total contribution is NRs.3.02 and the per liter cost as per RAIN contribution is NRs. 1.78. Total benefited population is 852. Per person direct cost of RAIN contribution is NRs. 751.00. Total numbers of the benefitted households are 135. Average household size is 6.30

Storage tanks provide 1300 liter water per household once the pond is full. Every household needs 25 liter of water per day for 50 plants like tomato & cabbage for dry period which is assumed to be about the 3 months period before and after the winter rainfall. So every household needs 2250 litres per day. Thus our system is expected to provide the irrigation facility for 25 plants in each household.

Average contribution in kind and fertilizer per household is NRs. 2,000.00 in a year. Average annual gross income increased from the project support is NRs. 4,220 per household. About 40 percent of the production is to be consumed by them to fulfill their daily need. Average household net income per year after the project support is NRs. 2220 after deducting the beneficiaries' investment. It shows that the users may successfully install such systems themselves after 2 to 3 years assuming one system serves 4-10 HHs.

Kavrepalanchowk:

The total project cost for 20 systems is NRs.77, 000.00 and Total Project grant is NRs. 67,000.00. Total benefited population is 118. Per person direct cost of RAIN contribution is NRs.567.79. Total numbers of the beneficiary households are 20.

9. Users perception

Acceptance and rejection of any technology by the users is most important while conducting research and development activities. The ideas, suggestions and comments given by the users during discussions are summarized as follows:

- Since the technology of plastic lined pond according to beneficiaries, is affordable, acceptable and applicable, they would like to construct pond with larger capacity.
- Care is needed to protect the plastic from tearing from different factors such as physical, environmental and social conditions.
- The size of the RWH tank and water pond for irrigation may not be sufficient to fulfill water requirement for daily use as the systems are mainly constructed with an aim to provide ease to people during extreme dry condition.
- The technology of clay-cement lined water pond is simple, cheaper and it can be constructed and handled easily. Within a short span of time after construction the users have collected waste water from kitchen, washing utensils and have irrigated their crops, particularly green vegetables including cauliflower, peas, radish etc. and have found that the yield has increased.
- The operation procedure of micro drip irrigation is very time consuming and tiresome, in addition it requires utmost care for its protection.
- The integrated technology of RWH system, toilet attached biogas plant, clay cement lined pond with micro drip irrigation system has brought change in livelihood of the people in programme area. The beneficiaries feel that the environment is sanitized in comparison to previous condition.

Saving of time and its proper utilization

- It was revealed by focus group discussion in Syangja and Kavrepalanchowk that the participants on an average, every family will be able to save at least 5 hours in a day during rainy season from the difficulty and sometimes very risky task of carrying water along the slippery village path. The time thus saved, according to them, could be profitably utilized by engaging themselves in a number of different useful ways.

- Ms. Kumari Sarki of Jaipati Sarki Tole, Syangja who is a Primary School Teacher herself was happy that she would now be able to look after her children properly and give extra time for their care. She would utilize her saved time to take care of their cleanliness, send them to school on time and even help them to complete their home assignments. She expects with water available at her doorstep her children will no longer need to spend time in fetching water. In addition she also plans to conduct vegetable farming to earn for her living by utilizing waste water via micro dripper and adding slurry from biogas for better productivity.

- The users from plastic lined pond and RWH tank expressed that they will be able to use saved time for resting as they expect to get rid of wearisome chore of carrying water which would take quite of a substantial part of the day. They could at least have the pleasure of a more peaceful sleep for a little longer period as they would not need to wake up at dawn and spend their entire morning waiting in queue to collect water from communal spring. The female users expect to utilize their saved time for vegetable farming, tailoring and other income generating activities.

- Some of the users from Syangja also felt that the saved time could be utilized in animal farming like goat rearing activity. They were aware of the monetary benefits that could be enjoyed from such activity.

- Mr. Tej Prasad Timilsina of Pachkhal, Kavre expressed that accumulating kitchen waste water in $1m^3$ clay cement lined pond and utilizing it for irrigation via micro dripper has allowed him to grow vegetables during dry condition as well. At time when vegetable price ascends due to water paucity, his family was able to enjoy fresh home grown vegetables. Constructing this system has increased the practice of consuming seasonal vegetables too.

Financial Commitments

It can be estimated that the household member might devote about 7.5 days to construct rainwater harvesting system. In addition to the voluntary labor, each household will have to pay the cost of some construction materials in cash as well. They felt the need of water in the house so acute that they expressed their willingness to pay for it if no other assistance will be coming from anywhere.

They even were ready to take loan from any viable institution, if available. They were eager to get the money and they were confident enough to pay the loan back by earning some money by working for others, carrying loads, if necessary. But most of them were sure that they would be able to pay back the loan by selling the vegetables, fruits and goats farming, if necessary.

They appeared to be so much motivated by the need itself on the one hand and some of the selected groups were from the *Dalit* group of the society and they had their own traditional occupations. In Shree Krishna Gandaki VDC, Syangja there were many *Sarkis,* the traditional occupational caste of shoe making. They were sure that after certain training they will be able to produce more marketable products to sell in the market. It was to be found that some of them have already received the training for making better quality shoes. They are, therefore, already earning some cash by selling their products in the market.

Thus they seem to have cultivated a considerable degree of confidence which has inspired and encouraged them for a strong commitment that they will be pay back the loan soon. All that was required at this moment was a definite and dependable arrangement so that micro-credit would be easily made available for them to adopt the rainwater harvesting system

The R & D projects therefore have considered these specific points and it has been expected that the local community will find them quite useful not only for meeting their day-to-day requirements but also for enhancing their livelihood directly and indirectly by improved personal as well as community hygiene and cleanliness, improved latrines and their proper use, improved kitchen garden, proper care of livestock as a result of the availability of a greater quantity of water. At the same time since the members of the households would not need to spend their valuable time to fetch water from a longer distance unlike earlier, there will be more energy saving, plenty of time for proper rest and social healthy activities, less accidents (particularly due to falling down on the slippery path earlier when they were bound to walk a long way to the water source for fetching water), more time available for engaging themselves in income generating activities, increased attendance of children at school, less expenditure buying water pots such as *gagris*, baskets and ropes.

10. Key findings and lessons learnt:

- All the implemented technologies are cost effective.
- It was quite difficult for the people to realize the adaptability of technologies like plastic lined pond and clay-cement lined ponds integrated with micro-irrigation. They required sometime to get convinced that it should be better solution for the small irrigation. Regular follow-up and supervision was needed during the construction of all the implemented technologies.

Salyan

- From the experience of plastic lined pond construction, it was obvious that the calculation of water availability and crop water requirement is absolutely necessary before deciding the size of the pond.
- Size of the plastic lined pond should have capacity to fulfill the crop water requirement at least for 3 months for 100 plants (before & after winter rain).
- In current constructed plastic lined pond there is no provision of fixed outlet which was felt to be a necessity and an important component.
- No serious problems regarding the technical failure have been observed yet but fencing of the plastic lined pond has been done to prevent accidents.
- Maintaining smooth slide slope and well finished inner side of the pond is required as per design but the presence of hard rock at site could cause obstruction while constructing the pond.

Syangja

- Selecting a suitable area for locating the systems of RWH tank, toilet attached biogas plant and irrigation pond in ones courtyard is a very important task. Therefore it occurred that locating the systems at a place where it requires minimum space, limited resources and easiness for operating the systems is a significant task while project implementation.
- Constructing filtration unit to the inlet of RWH tank was found to be essential as per users view. Although regular cleaning of catchment area and tank improves water quality it was found that some of the users were a little hesitant in drinking rainwater and expressed the need to filtration unit.

Kavrepalanchowk

- The tanks should be free from the possible external damage. If cracks appear in some part, it may spread to other parts as well. So, immediate maintenance is required.
- If cracks are seen even after the second coat, an additional thin layer of plaster is needed.
- For construction of clay-cement lined pond shady area where the land has minimum exposure to sun should be selected. Tank construction should not be done near big trees as it has deep root penetration and proper curing is required to avoid cracking the pond.
- Incorporating micro drip irrigation system for irrigation is beneficial to control soil erosion and to reduce surface runoff.
- Presence of family head during the construction period is important to make sure that the instructions given are implemented in proper manner to avoid problems and misunderstanding in future.
- Production of green and seasonal vegetables has increased the practice of consuming vegetables as a daily food item which has direct health benefit.

11. Recommendation

From this research project, the following recommendations are put forward on the basis of the study of project area, user's perceptions and their feed backs during the field visit as derived from focus group discussions:

Salyan

- The size of community pond should meet requirement of the community; taking into consideration water requirement for crop plantation, annual rainfall, and availability of additional water sources.
- Sloppy land, earth filled area, site prone to landslide and other natural hazards and nearest top of household settlement etc. should be avoided for pond construction.
- It should be located at a place where maximum number of household can take advantage of the system.
- Small quantity of regular source of water for addition in the pond would be beneficial so that the pond would not be completely dry and will protect the plastic from sunlight and will assure longer life of plastic pond.
- Ponds should be properly fenced for the safety of animals and children.
- Mosquito breeding problem may arise, so it needs safety measures of keeping the surroundings clean
- People must be aware for regular and periodic repair & maintenance.
- Involvement of woman at every step of the project provides the support in gender mainstreaming.

Syangja

- Integrating a number of technologies like RWH system, biogas plant, toilet and clay-cement lined pond with micro drip irrigation requires substantial amount of space hence the availability of open space in ones courtyard should be examined before itself.
- Periodic monitoring to learn about the actual benefits from the integrated technologies is required.
- Involvement of household members from the beginning of project implementation is required to develop a sense of ownership of the constructed systems.
- Poverty mapping and need assessment of the community is required to be conducted in programme area before implementation to learn about actual scenario.
- While implementing such programmes it could be a plus point to lobby for generating matching funds from the local governmental organizations, this would enhance programme sustainability.

Kaverpalanchowk

- Pond should not be constructed in sloping land and area where there are stone, roots and loose soil.
- The type of soil in farmer's land should be studied as thoroughly as possible and the purpose must be identified.
- If red soil is not available nearby, the soil from the same pit (below 10 cm) can be used for mud mortar.
- Water using pattern, feasibility of income generating activities, analysis of irrigable land, market studies of required construction materials, existing health and sanitation situation and cost benefit

analysis should be analyzed before starting the implementation of the project in order to acquire in-depth information of the programme area.

- Cropping pattern, feasibility of cash crop, market and cost benefit analysis should be analyzed before commencing the project.
- The implementation schedule should be prepared giving due consideration to rainfall pattern, seasonal festivals, farmers' cropping pattern so as to avoid disturbance in the progress of the construction and to complete the work in stipulated timeframe.
- As waste water is accumulated in clay cement lined pond mosquito breeding problem may arise, therefore it requires keeping the surroundings clean.
- We recommend using eye glass. Use of glass prevents from the possibility of hitting into eye from the splash (Splash is common as the mason has to plaster the mortar ball by hitting against the wall face by force).
- However, close monitoring of the clay cement lined pond is required to make a right decision for future promotion.
- If bigger clay cement lined ponds (more than 1000 liters) are to be constructed, additional research will be required to decide regarding the shape and appropriate ratio of mud mortar.

12. Conclusion

Salyan

It must, however be reiterate that plastic ponds seem to be very much liked by the people; but the greatest problem seems to be the difficulty of getting the plastic itself from the market which may be an obstacle to its adoptability as well as affordability. As per the preliminary market survey conducted for Silpaulin plastic by BSP-N it revealed that there are limited suppliers of the plastic in Nepal, therefore this could be a constraint for construction of plastic pond. At the same time people should be careful and cautious of the plastic during the dry period is very obvious. If required care is not taken for operation and maintenance of the plastic pond, the plastic will have to be replaced almost about every year which will make it quite unaffordable.

Secondly, plastic ponds are feasible more on a level ground than at sloping lands if drip irrigation system is to be adopted. At the moment the use of sprinkler that has been distributed has minimum operating pressure which does not help the best use of the scarce water. However, while using sprinkler field layouts to ensure correct combination of spacing, operating pressure, sprinkler head and nozzle size and type should be properly studied so that it will help crops such as wheat or others covering a comparatively wide area provided the terrain is good enough and the amount of water is high enough to guarantee the required pressure to run the larger sprinkler.

Syangja

Integration of various systems such as the one experimented at Shreekrishna Gandaki, Syangja is no doubt good but its result in a concrete form is yet to be seen. Due to implementation of program some social changes were noticed like people believe in each other to raise voice, using toilet than open defecation, biogas use for cooking rather than wood and kerosene. Beneficiaries were motivated in cash crops cultivation through use of drip irrigation systems and they were even enthusiastic to motivate other villagers to take part in such program. It is difficult to come to any conclusion immediately needs some tangible time frame to draw solid conclusion.

Kavrepalanchowk

Since the technology of clay cement lined pond is low cost and simple technology, it does not require any sophisticated and specialized methods of operation. The technology can easily be transferred and replicated elsewhere as well, as it is environmental and user friendly. The technology provides an example of best use of waste water management.

13. Way forward

- It is essential to monitor the entire R&D programme at least for two more year to gain social and other benefits
- To gain depth knowledge other R& D activities needs to be initiated such as:

- Rehabilitation of traditional communal spring sources in water scarce areas
- Reduce concentration of arsenic and iron in groundwater by recharging rainwater into the ground by using suitable technologies.
- Conducting water quality test of harvested rainwater by defining and comparing parameters like catchment types, different water sources, water storage systems etc.
- Study to carry out rainwater user's survey.
- Knowledge from other countries has to explore for further implementation

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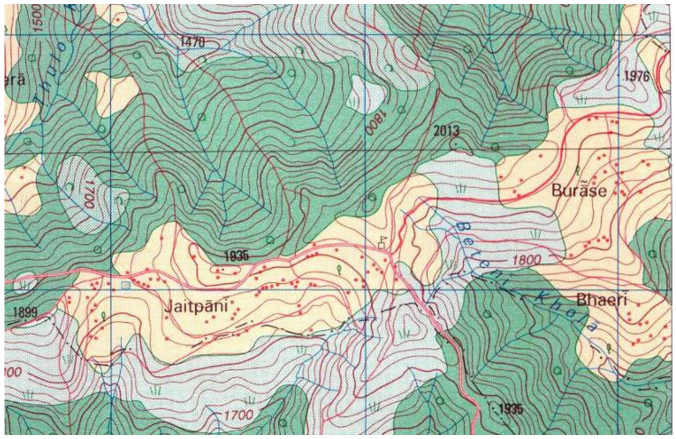
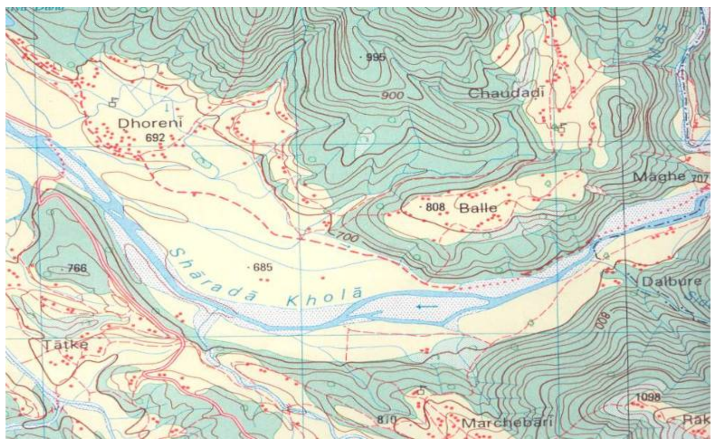
15. Annex

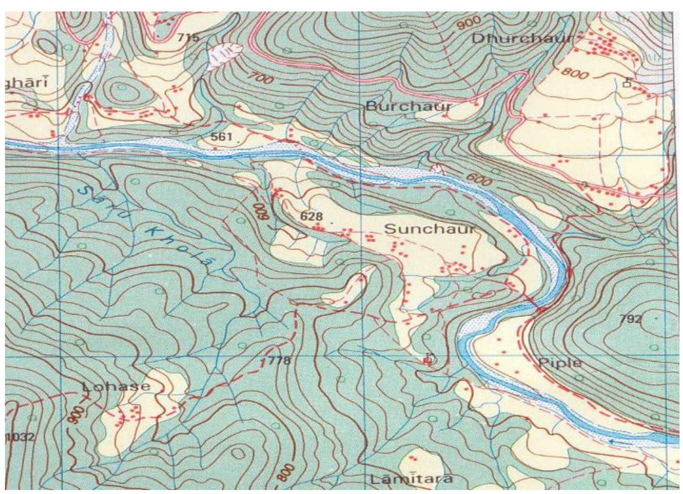
A. Maps



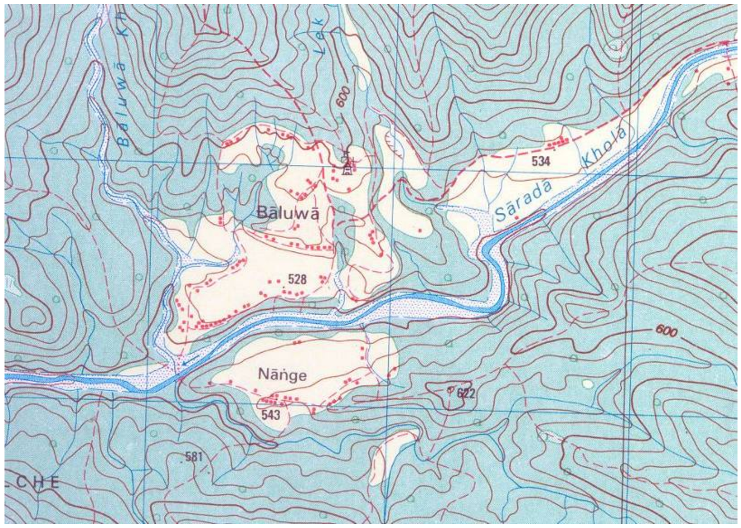
Map showing the location of sites in Kupindedah VDC (Jayatpani, Buranse and Bhangeri)



Map showing, site at Balle, Kalimati Rampur VDC



Map showing the site at Sunchaur, Kalimati Kalche VDC



Map showing Baluwa and Nange, sites at Kalimati Kalche VDC

B. Pictures of Plastic Pond Constructions


Interaction with beneficiaries


Pit dug for the construction of pond


Rammed Pond before second coat


Pond on drying after mud plastering


Laying the Silpaulin Plastic


Dried pond after water use


Fencing of the plastic pond


Plastic pond with water


Micro Sprinkler used in the field for irrigation


Irrigated crops from the plastic pond

C. Integrated Systems of RWH system and Biogas


Scaling for commencing the construction


Interaction with the beneficiaries


Layout of RWH tank


Excavation Work


Earthwork excavation for tank


Excavated Foundation


Stone soling


Sand filling after stone soling

Stone masonry round wall construction

Plastering of round wall

External plastering

Internal Plastering work

RCC work

RCC Slab and Manhole

Gutter, First flush and Down pipe work

Hand pump or Tap

D. Construction pictures of 1m^3 Clay-Cement Lined Pond


Preparation of layout for 1 bag cement pond


Pit dug for 1 bag cement pond construction


Preparing the pit


Cement pond with PCC and single coating


Recoating of the pond


Treating of the cracks

E. Construction pictures of biogas plant


Digging digester


Stone soling


Round wall completion


Dome concreting


Inlet Construction


Outlet and manhole construction

Biogas and toilet

Biogas system with inlet and outlet

Pipe fittings

Compost pits

F. Group wise Households(benefited and uncovered) - Salyan

S. N.	Name of User's Group	Location	Tank No./Tole	Benefited HHs/Population					Uncovered HHs/Population				
				HHs	M	F	Total	Avg. HH Size	HHs	M	F	Total	Avg. HH Size
1	Hariyali Swabalamban Samuh	Kupindedaha-9	1/Pallo Jayatpani	5	22	16	38	7.6	10	36	31	67	6.7
2	Hariyali Swabalamban Samuh	Kupindedaha-9	2/Tallo Tole	5	8	20	28	5.6	7	19	23	42	6.0
3	Sharada Swabalamban Samuh	Kalche-7	1/ Sunchaur	11	36	38	74	6.7	0	0	0	0	0
4	Sharada Swabalamban Samuh	Kalche-7	2/Sunchaur	12	37	30	67	5.6	0	0	0	0	0
5	Sharada Swabalamban Samuh	Kalche-7	3/Sunchaur	6	22	23	45	7.5	0	0	0	0	0
6	Sharada Swabalamban Samuh	Kalche-7	4/Sireni	5	19	12	31	6.2	3	11	9	20	6.7
7	Sundhara Swabalamban Samuh	Rampur-7	1/ Mathillo Balle	9	30	33	63	7	0	0	0	0	0
8	Sundhara Swabalamban Samuh	Rampur-7	2/ Bich Balle	10	34	39	73	7.3	5	13	13	26	5.2
9	Sundhara Swabalamban Samuh	Rampur-7	3/ Puchhar Balle	10	40	33	73	7.3	1	4	1	5	5.0
10	Laligurash Swabalamban Samuh	Kupindedaha-9	1/ Burase	5	11	15	26	5.2	3	9	8	17	5.7
11	Laligurash Swabalamban Samuh	Kupindedaha-9	2/Burase	7	18	20	38	5.4	2	6	8	14	7
12	Jharana Swabalamban Smauh	Kalche-4	1/Baluwa Pallo tole	5	11	12	23	4.6	0	0	0	0	0
13	Jharana Swabalamban Smauh	Kalche-4	2/Upallosamma Baluwa	5	14	12	26	5.2	5	16	15	31	6.2
14	Jharana Swabalamban Smauh	Kalche-4	3/Mathillo tole Baluwa	8	23	19	42	5.3	0	0	0	0	0
15	Jharana Swabalamban Smauh	Kalche-4	4/Lose tole Baluwa	8	24	18	42	5.3	4	9	9	18	4.5
16	Pragati Swabalamban Samuh	Kupindedaha-9	1/Jayatpani	4	14	7	21	5.3	1	4	1	5	5
17	Pragati Swabalamban Samuh	Kupindedaha-9	2/ Jayatpami	4	15	15	30	7.5	3	10	9	19	6.3
18	Bhuwanesori Swabalamban Samuh	Kupindedaha-9	1/ Bhangeri	4	12	14	26	6.5	3	10	11	21	7
19	Bhuwanesori Swabalamban Samuh	Kupindedaha-9	2/Bhangeri	5	15	18	33	6.6	4	13	15	28	7
20	Chandrama Swabalamban Samuh	Kalche-4	1/Nange	7	28	25	53	7.6	5	22	22	44	8.8
Total				135	433	419	852	6.3	56	182	175	357	6.4

G. Group wise ethnic composition of beneficiaries -Salyan

S.N.	Name of User's Group	Location	Ethnicity		
			Brahmin, Chhetri	Janajati	Dalit
1	Hariyali Swabalamban Samuh	Kupindedaha-9	2	3	0
2	Hariyali Swabalamban Samuh	Kupindedaha-9	0	5	0
3	Sharada Swabalamban Samuh	Kalche-7	0	11	0
4	Sharada Swabalamban Samuh	Kalche-7	6	5	1
5	Sharada Swabalamban Samuh	Kalche-7	0	3	3
6	Sharada Swabalamban Samuh	Kalche-7	4	1	0
7	Sundhara Swabalamban Samuh	Rampur-7	6	1	2
8	Sundhara Swabalamban Samuh	Rampur-7	4	6	0
9	Sundhara Swabalamban Samuh	Rampur-7	1	6	3
10	Laligurash Swabalamban Samuh	Kupindedaha-9	5	0	0
11	Laligurash Swabalamban Samuh	Kupindedaha-9	2	0	5
12	Jharana Swabalamban Smauh	Kalche-4	2	0	3
13	Jharana Swabalamban Smauh	Kalche-4	2	3	0
14	Jharana Swabalamban Smauh	Kalche-4	6	1	1
15	Jharana Swabalamban Smauh	Kalche-4	6	2	0
16	Pragati Swabalamban Samuh	Kupindedaha-9	4	0	0
17	Pragati Swabalamban Samuh	Kupindedaha-9	4	0	0
18	Bhuwanesori Swabalamban Samuh	Kupindedaha-9	2	0	2
19	Bhuwanesori Swabalamban Samuh	Kupindedaha-9	4	0	1
20	Chandrama Swabalamban Samuh	Kalche-4	0	7	0
Total			60	54	21

H. Food sufficiency level of the benefited households

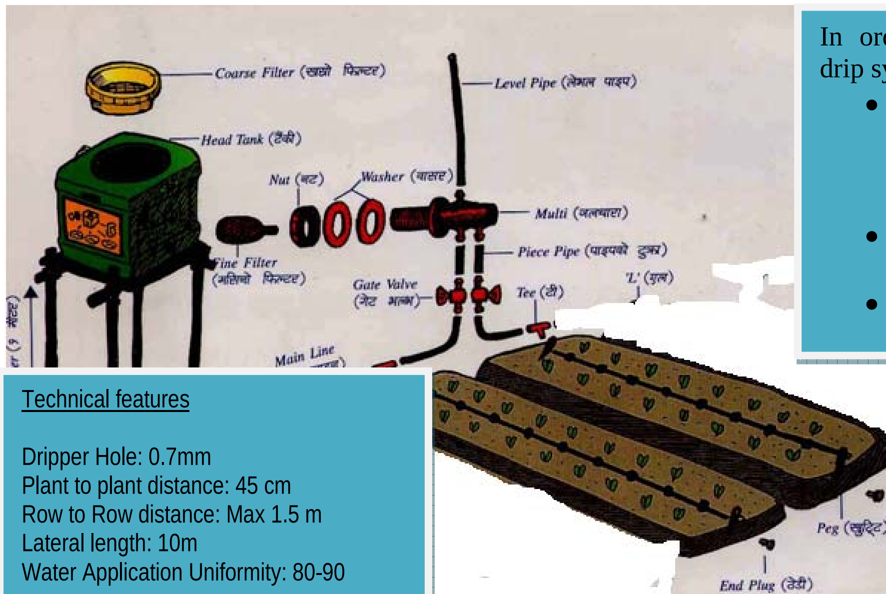
S.N.	Name of User's Group	Location	Food Sufficiency Level (Months in Year)			
			< 3	3 to 6	6 to 12	< 12
1	Hariyali Swabalamban Samuh	Kupindedaha-9	0	4	1	0
2	Hariyali Swabalamban Samuh	Kupindedaha-9	0	5	0	0
3	Sharada Swabalamban Samuh	Kalche-7	0	10	1	0
4	Sharada Swabalamban Samuh	Kalche-7	0	10	2	0
5	Sharada Swabalamban Samuh	Kalche-7	4	2	0	0
6	Sharada Swabalamban Samuh	Kalche-7	0	4	1	0
7	Sundhara Swabalamban Samuh	Rampur-7	1	4	4	0
8	Sundhara Swabalamban Samuh	Rampur-7	2	2	6	0
9	Sundhara Swabalamban Samuh	Rampur-7	5	5	0	0
10	Laligurash Swabalamban Samuh	Kupindedaha-9	5	0	0	0
11	Laligurash Swabalamban Samuh	Kupindedaha-9	0	5	2	0
12	Jharana Swabalamban Smauh	Kalche-4	0	5	0	0
13	Jharana Swabalamban Smauh	Kalche-4	0	4	1	0
14	Jharana Swabalamban Smauh	Kalche-4	0	3	5	0
15	Jharana Swabalamban Smauh	Kalche-4	1	6	1	0
16	Pragati Swabalamban Samuh	Kupindedaha-9	1	3	0	0
17	Pragati Swabalamban Samuh	Kupindedaha-9	0	4	0	0
18	Bhuwanesori Swabalamban Samuh	Kupindedaha-9	2	2	0	0
19	Bhuwanesori Swabalamban Samuh	Kupindedaha-9	3	2	0	0
20	Chandrama Swabalamban Samuh	Kalche-4	0	6	1	0
Total			24	86	25	0

I. Beneficiaries list of Pachkhal, Kavrepalanchowk district

S. N	Name	Address	Occupation	No. of Family Members			Remarks
				Female	Male	Total	
1	Balram Poudel	Pachkhal-8, Poudel Thok	Farmer	7	5	12	
2	Maniram Poudel	Pachkhal-8, Poudel Thok	Farmer	3	2	5	
3	Niranjan Dungana	Pachkhal-8, Poudel Thok	Teacher	4	7	11	
4	Hari Prasad Pant	Pachkhal-8, Poudel Thok	Service	2	2	4	V.D.C Secretary
5	Bhojraj Pant	Pachkhal-8, Poudel Thok	Farmer	4	2	6	
6	Ramhari Poudel	Pachkhal-8, Poudel Thok	Teacher	3	2	5	
7	Laxmi Prasad Sapkota	Pachkhal-8, Poudel Thok	Farmer	5	5	10	
8	Tanka Prasad Adhikari	Pachkhal-8 Dhotra	Service	3	2	5	V.D.C Secretary
9	Tej Prasad Timilsina	Pachkhal-8, Poudel Thok	Farmer	3	1	4	
10	Devi Prasad Timilsina	Pachkhal-8, Poudel Thok	Farmer	3	2	5	
11	Chandra Prasad Timilsina	Pachkhal-8, Poudel Thok	Farmer	2	3	5	
12	Kamal Prasad Gautam	Pachkhal-8, Poudel Thok	Farmer	3	4	7	
13	Krishna Prasad Gautam	Pachkhal-7 Bhakredi	Farmer	2	3	5	
14	Hem Bdr. Baniya	Pachkhal-7 Bhakredi	Farmer	2	4	6	
15	Hutta Bdr. Bakrel	Pachkhal-7 Bhakredi	Service	2	3	5	
16	Bhim Prasad Kafle	Pachkhal-7 Bhakredi	Farmer	1	3	4	
17	Druga Prasad Dhungana	Pachkhal-7 Bhakredi	Farmer	2	3	5	
18	Tara Prasad Sitaula	Pachkhal-7 Bhakredi	Farmer	2	3	5	
19	Jharindra Prasad Sitaula	Pachkhal-7 Bhakredi	Farmer	1	2	3	
20	Gadoralal Shrestha	Pachkhal-7 Bhakredi	Farmer	2	4	6	

Drip Irrigation System:

Drip irrigation is considered the most efficient method of irrigation because it applies water only to the plant root zone. All the households, who have been supported the soil cement tank are facilitated with a set of drip system for the efficient use of water. The detail features of the system are illustrated below:



In order to properly operate the drip system-

- The drip pipes are correctly laid and the baffles are close to the plants
- There is no debris or dirt in the filters
- Fittings are tight enough to prevent leaking

Technical features

Dripper Hole: 0.7mm
Plant to plant distance: 45 cm
Row to Row distance: Max 1.5 m
Lateral length: 10m
Water Application Uniformity: 80-90

Advantages

- More crops irrigated with less water.
- Simple & easy to install, operate and maintain.
- Time and labor saving.
- Reduce weed growth.
- Low investment with high returns.
- Feasible for all types of land (except very steep ones) and soil.
- Possibility of fertilizer application with irrigation water.
- Suitable for high value crops (tomato, cucumber etc).

Limitations

- Not suitable for closely growing crops such as garlic, onion, and leafy vegetables.
- Fixed spacing.
- Small quantity of water storage and not enough for larger plots with single unit.
- If filters are not properly maintained, the emitters can become clogged with solids.
- Damage or theft of the components, if not well attended, especially if the crop field is not close to the house.

Protection Measures

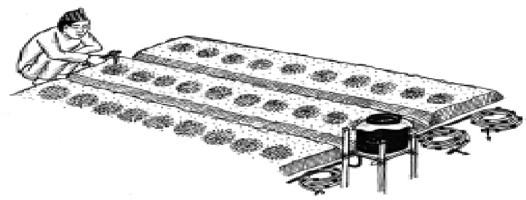
- Fencing the crop field.
- Flushing of pipes.
- Protecting the tanks with plastic sheets (during the non-irrigation hours).

Repair and Maintenance

- The tanks should be always filled up with water.
- Thin plaster is required if cracks appear. Such cracks should not be ignored.

- Periodic cleaning (normally once in six months) is required if tanks are used for waste water storage.
- In order to protect the tank from any accidental damage by animals and to save the small children of the household, fences should be erected round the tank.
- Special care should be taken so that rodents and other animals would not fall down inside the tanks.

Filling the tank



Marking the wet spots

Soil Test Report for Shrinkage, Permeability and Strength test for Clay-cement- Sand Mortar

Submitted to :
BSP Nepal, Bagdole, Lalitpur

Submitted by –
Rajesh Kumar Yadav

Introduction

Soil cement stabilization technique has also been in existence for a long time. A construction project near Johnsonville, South Carolina in 1935 was one of the first controlled construction project in which cement was used as a soil stabilizer in the United States (Das 1990). Cement treatment causes chemical reaction similar to lime and can be used for both modification and stabilization purposes. Cement can be applied to stabilize any type of soil, except those with organic content greater than 2% or having pH lower than 5.3 (ACI 230.1R-90 1990).

Many studies have shown that granular soils and clayey materials with low plasticity index are better suited to be stabilized with cement (Currin et al. 1976; Engineering manual 1110-3-137 1984).

Significant reduction in plasticity index and swell potential, and remarkable increase in strength, modulus of elasticity and resistance against the effects of moisture and freeze-thaw can be achieved by cement stabilization. The addition of cement was also found to increase optimum water content but decrease the maximum dry density (Tabatabi 1997). In addition cement treatment causes immediate decrease in water content (Bergado et al. 1996). Cement treated materials behave in a more brittle manner than non-treated materials.

The effect of cement content and curing time on compressive strength for 28 days curing shows that, as cement content increases compressive strength of fine-grained as well as coarse-grained soils increases. Improvement in compressive strength varies from 40 times of cement content for fine-grained soils up to 150 times of cement content for coarse-grained soils. In addition, compressive strength increases with increasing curing time. Results of investigations showed that unconfined compressive strength increases with increasing relative compaction.

Delays between mixing and compaction leads to significant reduction in compressive strength of cement treated material. Results of a particular research showed that, losses in unconfined compressive strength were 10% to 20% and up to 40% for four and 24 hours delay, respectively (White and Gnanendran 2005).

Objectives

The overall objective of this research is to study the compressive strength, shrinkage behavior and permeability characteristics of cement treated soils for different ratios (Cement: Sand: Clay – 1:3:3, 1:3:5, 1:3:6, 1:4:6 and 1:6:6). The specific objectives of the study are as follows:

- Investigation of the compressive strength characteristics of Portland cement treated soils.
- Investigation of the shrinkage properties of cement treated soils.
- Investigation of the permeability properties of cement treated soils.

Tests were performed on five different types of ratios with the soil provided by BSP-Nepal. The clay was normal soil and the sand used was locally available where as Portland cement was Maruti, a local brand. The effect of different percentages of cement, sand and clay was evaluated using compressive strength characteristics, shrinkage limit values and modulus the permeability. The results are interpreted using the values obtained from the different test carried out during the research work.

Organization of report

Chapter one presents an introduction of the study. It includes the effect and performance of Portland cement. The chapter two highlights the objectives of the study and chapter four presents methodology of the research experimental work and the way of sample preparation. This chapter presents a summary of material properties and testing programs. This includes tests on compressive strength, shrinkage behavior and permeability properties. Results and discussion are presented in Chapter five. Chapter six presents' conclusions drawn from this study of cement treated soil.

Methodology

The methodology adopted for the sample preparation for the test was based on the different test standards, as for the sample preparation there are not any definite standards. The methodology adopted for the sample preparation for the different tests are described below:

a) Shrinkage test:

The shrinkage limit was determined according to ASTM for the samples at different ratios of cement, sand and clay under the provided condition state of the sample. The dry soil sample of different proportions of cement, sand and clay by weight as per the required ratios, was prepared into slurry following the same procedure as for the liquid limit and plastic limit tests. The sample in the form of paste was then placed in the shrinkage dish. The weight of the wet soil was measured and the sample was dried in the oven at 105^0C. The weight of the oven dried sample was measured. In this method, mercury was used to determine the volume of wet soil and dry soil. The volume of the mercury in the shrinkage dish represented the volume of the wet soil and the displaced volume of the mercury in the glass cup obtained by forcing the dry soil sample with glass plate of the three prongs represented the volume of the dry soil. The shrinkage limit was calculated using the following formula,

$$S_L = \frac{100M_W}{M_s} - \frac{100(V - V_0)}{M_S} \times \rho_W$$

Where,

M_S = Mass of oven dried soil sample

M_W = Mass of water in wet soil

ρ_W = Density of water

V_0 = Volume of the oven dried soil

V = Volume of the wet soil

S_L = Shrinkage limit

b) Compressive Strength test

Compressive strength test was done based on the method adopted for cement mortar test. The cube of 7x7x7 cm cube was used for this test. For the sample preparation for this test, the amount of cement, sand and clay by weight for the predefined ratio, were mixed in a tray and the amount of water that was used in practice (about 15~ 20 litres for 20 kg of cement) was used. As practiced by BSP-Nepal, the sample prepared with 12% water content was found dry as it can be seen in photo 3. The cubes prepared on this amount of water shows less compressive strength. Then it was decided to increase the amount of water by 1% to see at which the sample could give better consistency and workable so that it sticks on the wall when thrown. Finally, for the compressive strength test, sample cubes with water content of 15% were decided to be used for. The sample prepared for this test can be seen in right side of the photo 3.

The sample was prepared on 15%, Maruti cement, a local brand of Nepal, locally available sand and the provided clay was used for the sample preparation. The sample mixed was placed on the mortar cube in three layers and was shaken at each layer. The sample so prepared was left for a day and then it was put in the curing tank. The test was carried on 3^{rd}, 7^{th} and 28^{th} days of the casting.

c) **Permeability test**

The falling head method was used to find the permeability of the sample prepared at different ratios. The sample preparation was done in the test mold for different ratios. The amount of cement, sand and clay by weight corresponding to its ratio, and the amount of water corresponding to 15% were mixed thoroughly and was kept in the test mold at three layers and was compacted to try to achieve the density corresponding to the density of the cube prepared for the compressive strength test. Only about 81% to 87% relative density was achieved. The sample with the test mold was left for saturation and then the test was conducted on each samples of different ratios.

Results and Discussions

The shrinkage test was carried out on the samples prepared at different ratios of 1:3:3, 1:3:5, 1:3:6, 1:4:6 and 1:6:6. Three samples were prepared for each of ratios and by application of mercury the shrinkage ratio was found out. The value of shrinkage limit at different proportion of the ratios does not show drastic variation. The value ranges from 18.12% to 21.15%. There is slight increase in the value at the ratio of 1:3:5.

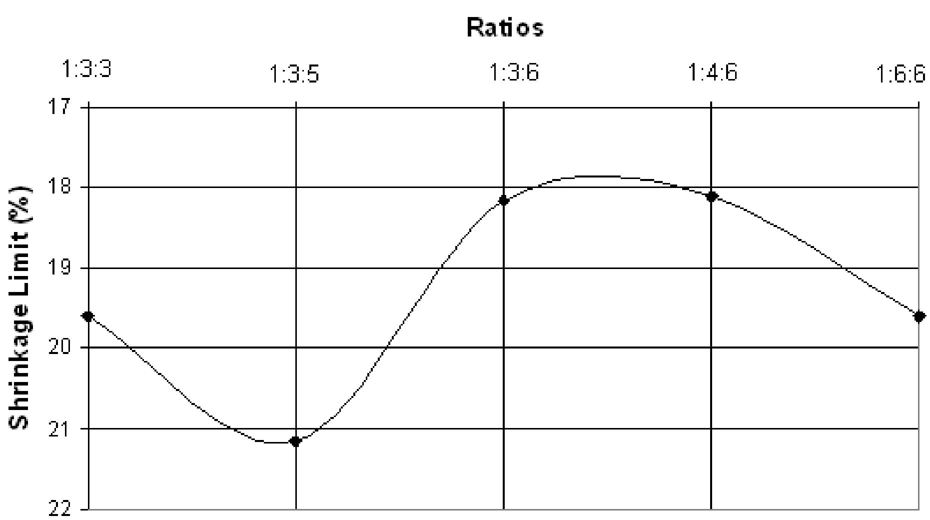


Figure: 1 Comparison of shrinkage limits at different ratios of sample

For the preparation of the sample for the compressive strength test, initially the sample was prepared at the ratio of 12% water content. The sample prepared at this water content was found to be dry and not practically workable. The water content then was increased with 1% and finally at 15%, the sample prepared as found to be sticky and workable, which was used for entire tests. For each test three samples were prepared and were tested on 3rd day, 7th day and 28th day.

The value of the compressive strength test also shows great variation in the strength at different ratios. The values at 3, 7 and 28 days strength at different proportions are presented in table 1 below.

Table: 1 Strength of the sample for different days of curing at different ratios.

Ratio	**3 days** (kg/cm^2)	**7 days** (kg/cm^2)	**28 days** (kg/cm^2)
1:3:3	66.7	76.19	115.65
1:3:5	57.1	70.75	121.09
1:3:6	54.4	68.03	97.96
1:4:6	21.8	34.01	50.34
1:6:6	17.7	21.77	42.18

The results obtained from the laboratory test also shows that there is increase in strength of sample with increase on curing period. From the laboratory test the strength of the sample was highest for the ratio 1:3:5.

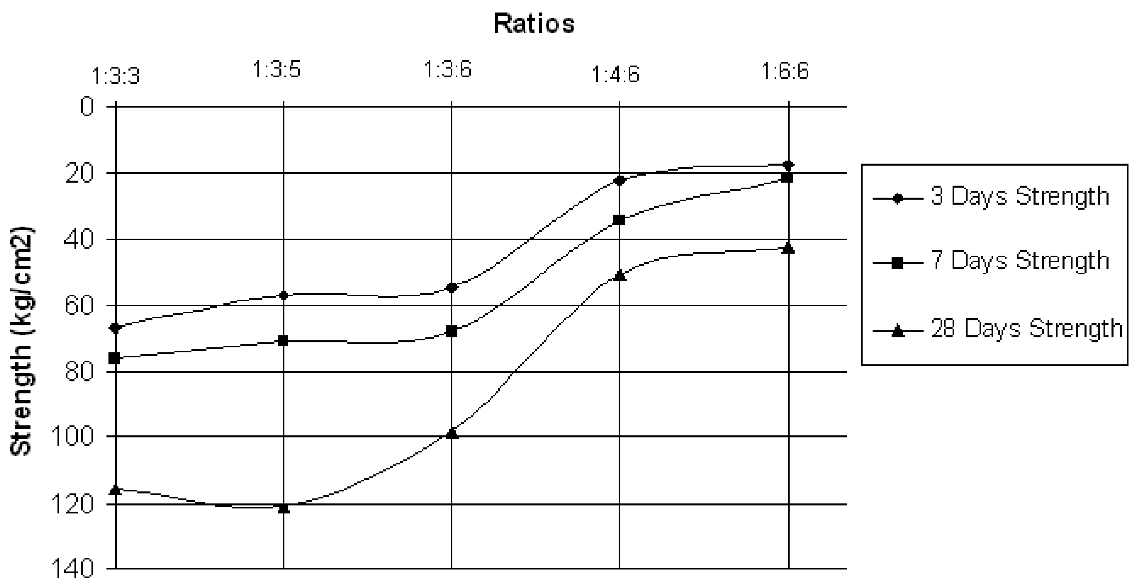


Figure 1: Strength of the sample for different days of curing at different ratios.

The permeability test was carried out on the samples prepared at different ratios of 1:3:3, 1:3:5, 1:3:6, 1:4:6 and 1:6:6. Three sample cubes were prepared for each of ratios with relative density of **81% to 87%** for the compressive strength test. The samples prepared for the test was left for 5 days for the permeability test; in most of the cases the permeability was found to be very much low which can be even said as practically impossible. The ratio of higher cement content also shows the permeability to be very poor in the range of 10^{-8} m/s to 10^{-10} m/s.

Conclusions

From the laboratory test of the samples prepared at different ratio, it can be concluded that the strength of the sample at the ratio of 1:3:3 has the higher strength, lower shrinkage value and very low permeability. The sample with ratios 1:3:5 and 1:3:6 have very low difference in the strength on 3rd and 7th day. The strength of the sample on 28th day shows high variation. The permeability of the samples at 1:3:3, 1:3:5 and 1:3:6 were found to be practically impossible. At the ratios 1:4:6 and 1:6:6, the strength is low, the permeability is very low and has increasing shrinkage limit.

Thus the ratio of 1:3:6 was found more appropriate in terms of strength, shrinkage limit and permeability for strength, cracks and seepage control.

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