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PARTICIPATORY GRAVITY-FED WATER CONVEYANCE SYSTEM FOR IRRIGATION IN HIMALAYAN FOOT HILLS

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ABSTRACT

Increasing demand of water for industrial, domestic and power sectors necessitates urgent need for development of water saving technologies to ensure accessibility of water to every field (Har khet ko pani) through following the approach – "per drop more crop" in agriculture. Efficient water management in agriculture is the major challenge to ensure sustainable food production in India. While, the situation is more aggravating in mostly rainfed type of farming in hill and mountains. Low productivity and cropping intensity, subsistence level of farming are attributed to poor water resource development in the hilly areas. To enhance the productivity and livelihood in the Himalayan foothills, a participatory gravity-fed Irrigation System has been developed with major emphasis on the participation of beneficiary farmers in all activities, starting from surveying, planning, implementation, monitoring and operation of the system. In this endeavor, 1830 m GI pipeline (100 mm ϕ) from source to Distribution Tank (DT) as a water conveyance and 1500 m PVC pipeline (110 mm ϕ) as a water distribution are laid out in the command area (26.28 ha) in the adopted villages – Pasauli and Devthala. The conveyance efficiency was recorded > 95 % with design discharge at remotest riser in the command area. Productivity of major crops increased by 48% with enhanced cropping intensity by 29% due to the intervening crop of Toria in between Maize-Wheat sequence. Cultivation of Rabi wheat on fallow land resulted increased additional net income of Rs. 17500/- ha. Availability of fodder increased by 350% resulted in increased milk productivity by 97% due to introduction of hybrid Napier grass on field bunds and higher productivity of fodder sorghum and Berseem. This has also reduced dependency on forest for fodder by 60%. Additional regular employment generated to the tune of 65 mandays per ha per annum.

INTRODUCTION

Himalayas is environmentally sensitive, economically marginalized and densely populated in proximity of the arable lands is highly vulnerable to the impacts of these changes that may cause a substantial decrease in availability of water for drinking and food production, and consequently increase the vulnerability of food and agricultural systems in the entire region (Cline, 2008), that aggravate the situation of already existing Critically Diversified Risk prone Agriculture (CDRA). In the prevailing system under non-availability of irrigation water, farmers grow rain-fed cereals with very low yields. However, farmers use water of low-discharge springs (discharge <20 l/min) at very small scale in an unsystematic and scattered manner for vegetable production. Plant to plant hand watering is the most efficient water application method, but it requires a huge amount of labour and time.

The study area, comprising a village cluster – Gadoria, Devthala, Pasauli, and Dungakhet, is about 40 km away from Dehradun on Vikasnagar - Langha Road. The area represents a typical sub-tropical climate with high intensity rain storms during the rainy season and scanty rainfall thereafter. The area is drained by two torrents, namely Utmadi Rao and Gauna. Undulating topography, faulty land management practices coupled with high intensity storms result in high runoff and soil loss from the area during the rainy season while acute water shortage is experienced in the lean period. Preliminary survey conducted in 2005 indicated that out of total 321 farm families of these villages, 82% belonged to socially backward (SC, ST & OBC) and about 80% were economically poor. Total agricultural land of the four villages is 165.08 ha and majority (about 85%) of it is rainfed. The irrigated area in Dungakhet, Pasauli, and Godaria was 20%, 11% and 98%, respectively but Devthala had only rain dependant agriculture. This clearly indicates a very meager irrigation facility in Pasauli & Devthala villages so they were selected for the intervention of water resource generation.

Keeping all these in view, a major activity on water conveyance and water resource generation under the project - 'Participatory Dissemination and Assessment of Land and Water Management Technologies for Livelihood Security in Rain-fed Areas of North Western Himalayas, funded by the Ministry of Rural development, was envisaged. In this endeavor, rain-fed cultivable lands of the villages – Pasauli and Devthala were selected for setting up a water conveyance system towards developing irrigation facility on the basis of the participatory approach.

Description of Site and Water Conveyance System

In participatory rural appraisal and subsequent topographical engineering survey, a site situated at latitude – $30^0$27'40.16''N, longitude -$77^0$53'59.77'' E and altitude - 745 m amsl in a Serukhala perennial stream, was identified to tap the surplus water for creating an irrigation facility in Pasauli and part of Devthala villages. The minimum lean flow recorded during the study period (2005-2010) was 11.4 Litre/Second (LPS). An elevation difference of 26.5 m between water source and delivery point indicated the possibility of development of gravity fed conveyance system for irrigation. An Intake Structure (IS) was constructed at the source to convey water from source to Distribution Tank (DT) through 1830 m long Galvanized Iron (GI) pipe (diameter,ϕ,: 100 mm) with hydraulic gradient 1.96 %. Distribution tank having a capacity of 50,000 liters and inflow at DT is 10 - 12 LPS. The tank is located at the head of the command area (26.28 ha) in order to convey the water through underground PVC pipelines (110 mm ϕ) to the farmers' fields, by gravity flow with maximum 26.5 m gravity head. PVC pipeline

(1500m) was laid across the command area in such a way that it can supply the water to the farmers' fields spread in the command area with 10-12 LPS discharge. The command area is divided into 19 Unit Command Areas (UCA) and an UCA covers 1.5 ha. At the head of each UCA, one riser (outlet) is fitted on the PVC pipeline to uniformly deliver the water. In order to enhance the field application efficiency, collapsible synthetic pipes are being used by the farmers. Distribution of water for the irrigation to each beneficiary farmer is regulated by the committee constituted by the Water Users Association (WUA). Water being shared among the farmers' fields on the rotation basis as decided by the WUA and farmers get his turn in 15 days (irrigation period). In one season, delivery of water follows the sequence from head to the tail riser and in next season delivery sequence gets reversed (tail to head) to negate the clash among the farmers.

The plan of the irrigation system, comprising of different components, *viz;* water conveyance system; intake structure, GI pipeline and distribution tanks, and water distribution system; PVC distribution pipelines and risers are described below.

Implementation of the System

Water Conveyance

It covers the part of system from source to distribution tank which was constructed at the head of the command area, and consists of Intake Structure, GI Pipeline and Distribution Tank. The plan of the water conveyance is presented in Fig. 1.

Intake Structure

Water source of the GRAvity-fed Irrigation System (GRAIS) was identified below the inlet structure of the drinking water supply scheme of Uttarakhand Jal Sansthan (UJS) located on the bank of the stream (SeruKhala). Owing to sufficient surplus flow over the inlet structure of UJS, the site has specific advantage without arising social dispute between old drinking scheme of UJS and newly proposed water conveyance system envisaged under the project. Besides, it is a perennial stream having average minimum lean flow 11.4 LPS as recorded during the study period, and a tributary of Gauna river which flows along North-Eastern boundary of the command area. On the basis of firmness of stream banks and gentle slopes the site was selected for construction of an intake structure. It was constructed in the stream as two tier chambers in a cascading manner as upper and lower. Plan and side elevation views of the intake structure are presented in Fig. 2 and 3, respectively. First, stone masonry cutoff wall (depth – 1.20 m, length – 8.50 m and thickness – 0.50m) was constructed for setting up the upper chamber in order to make a bypass arrangement for uninterrupted flow with adequate head to watermill lying just below the selected site. For this purpose, a low height (0.8 m) wall was raised above the bed surface towards maintaining the adequate head required for operating the watermill as owner of the watermill raised his concern about insufficient head for running the watermill. A R.C.C. headwall (height -2, length – 7.4 m and wall thickness – 0.50m) was constructed at a distance of 4m from the cutoff wall for the lower chamber as the capacity of water storage of lower chamber was comparatively large. Side walls (thickness – 0.5 m) of both the chambers were made up with stone masonry. In order to check sub-surface water flow, the foundation of the wall was extended deeper to form an impervious barrier below the head wall. On the downside, a gabion base was constructed because of sudden drop and unstable debris deposit that served the purpose of the apron as well. In fact this base was constructed in step manner to act as a retaining wall of the intake structure, along with protection

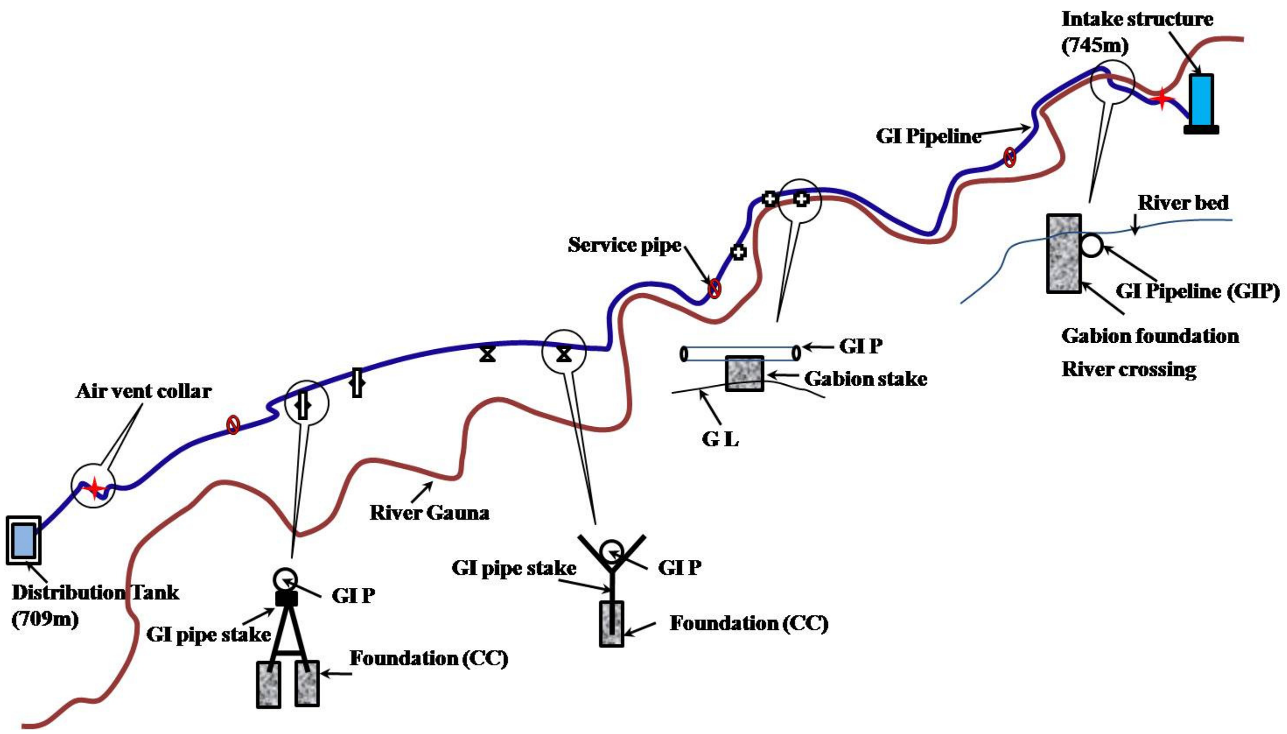

Fig. 1: Layout of water conveyance from intake structure to Distribution tank

of bank from erosion. An inlet well (rectangular in shape and 1x1x2m in size) was set up at down, left end of the R.C.C headwall of the lower chamber. It was connected with lower chamber by perforated GI pipe of 120 mm ϕ that acts as a filter. For smooth inflow to the inlet, two GI pipes of 3 m long each with 1.25mm ϕ holes (as a perforation) were used. The opening space on each pipe was kept 40%, so that hydraulic friction by constriction of flow into the holes would not affect the smooth flow into the inlet well. Hence the total opening area of perforations was kept much larger than the cross-sectional area of the main GI pipeline. Filter materials such as gravels, pebbles and stones were packed around the filter pipes in three layers, *viz;* outer layer with 10 – 20 mm size of gravel, second layer with pebbles of size (>20 mm) and third inner layer around the perforated pipes with stones. The reason behind the arrangement of filter is to make the flow free from any blockage in the pipe. For water conveyance, the main GI pipeline was fixed at a height of 45 cm from the bottom of inlet well, so that the fine soil particles get settled on the bottom of inlet well.

Laying of GI pipeline

GI pipeline, 100 mm ϕ, was laid out from inlet well to a distribution tank located at the head of the command area,

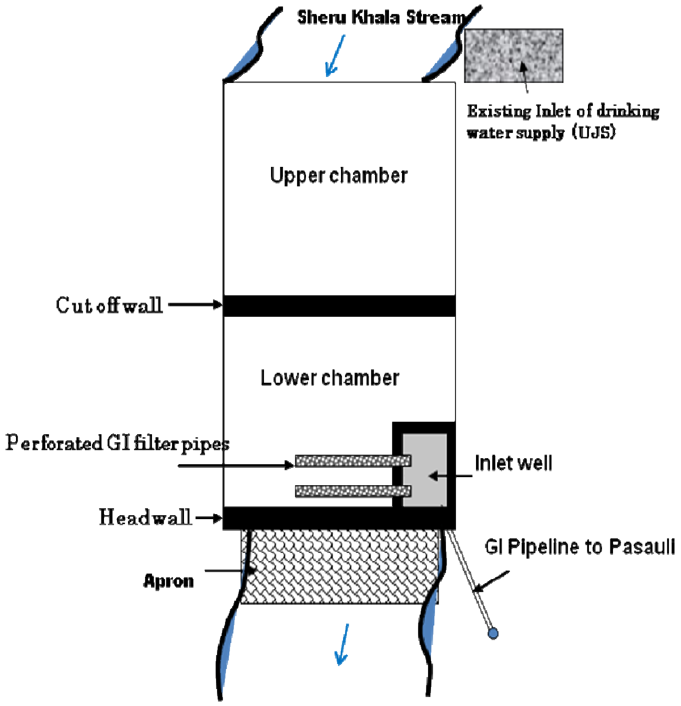

Fig. 2: Plan of the intake structure of the water conveyance system

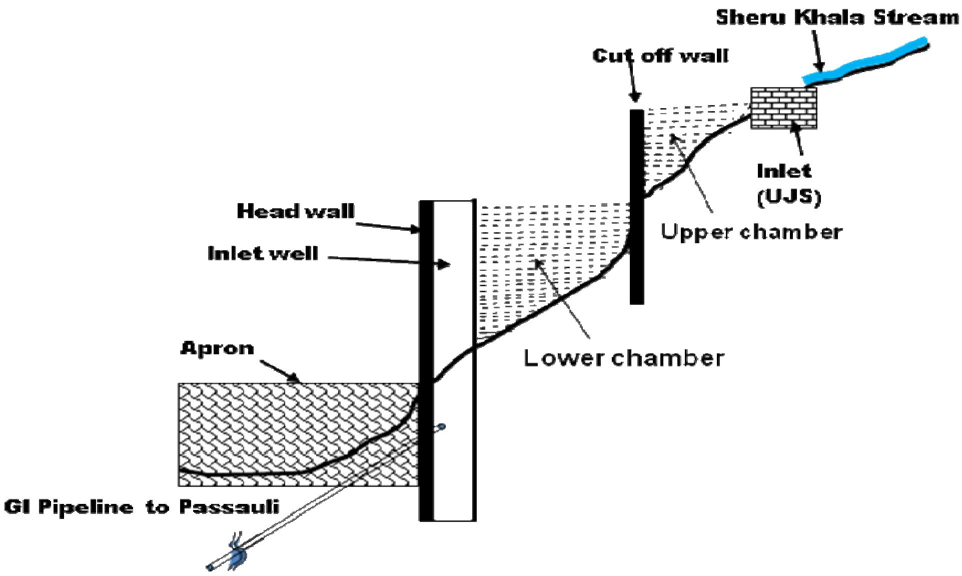

Fig. 3: Elevation of intake structure along left bank of the stream

covering a distance of 1.9 km. A sluice valve was fixed on the pipeline near the inlet well in order to control the flow and for the purpose of repair & maintenance of 1.9 km long pipeline laid on the unstable and precipitous slopes of Gauna river in Outer Himalaya. At 185 m from the source, the pipe was laid underground to cross the river which is 18 m wide. For protection of the pipe from flowing debris in the river, particularly in the monsoon, gabion barrier on the down side of the pipeline along the width of the river was erected. Fig.4 shows that longitudinal section of the proposed pipeline is 3-4 m above the hydraulic line (drawn with the data collected from surveying the line) in the segment between 1600 m and 2000 m. Thus, a trench with varying depth (3 to 4m) in the elevated segment was dug befitting with the hydraulic gradient. The main conveyance GI pipeline was connected with the distribution tank which is located in a drop of 36.48 m with reference to the elevation of the source.

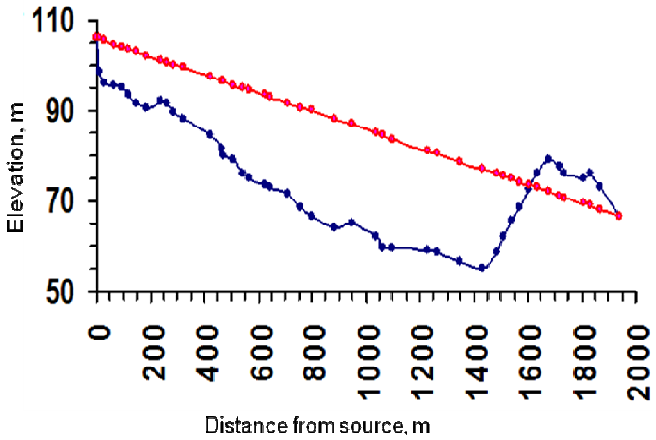

Fig. 4: L-section of line between source and distribution tank

Distribution Tank

A masonry tank of size (7.4 x 5.5 x 1.8 m) with a capacity of 50,000 liters was constructed at an altitude of 709 m amsl and was fed with water conveying through the main GI pipe by gravity flow from the source. A gate valve was fixed to the main GI pipe before delivering the water into the tank with an objective to control the discharge of incoming pipeline.

DISTRIBUTION PIPELINE

It was laid out from the distribution tank in the command area with an objective to distribute the water to each farm of the farmers who were members of the water users association. In order to minimize the cost of the system, PVC pipes of 110 mm ϕ with pressure 8 kg/sq cm was laid out in the command area, instead of GI pipes. A plan of the distribution of underground PVC pipeline is shown in Fig. 5. A gate valve was fixed on the pipeline near the DT to control the flow into the distribution pipeline. A small segment (185m) of distribution line was laid with GI pipeline (100 mm ϕ) from DT to Diversion Box as there are crossings of the road (Langha to Dehradun) at two places in this segment. For efficient management of irrigation, at the end of 185 m of GI pipe segment, a diversion box with gate valves were set up to regulate and distribute the flow either side of the road which divides the command area into two blocks, namely Pasauli-East and Pasauli-West. A network of underground PVC pipeline starting from diversion box was laid out in the entire command area. The gravity head between DT and end point of the distribution line in the Pasuali - west was calculated 26.5 m and discharge recorded at that point was 12 lps. For irrigation to the farmers' fields, risers (outlets) with complete assembly were fitted on underground PVC pipeline using Female Treaded Adapter (FTA). One riser in each around 1.5 ha area was installed in order to maintain minimum discharge of 10 lps in the designed set up of risers. Control valve and locking device were also equipped with each riser for controlling the discharge and protecting riser from misuse by any other person. Keys of the locking device of all the riders were maintained by an operator appointed by the water user association. Operator of the system maintains the roster of turn of the irrigation to individual fields or follows the instruction of the association. Risers at the end points of the branches of the pipeline were fixed with pressure gauges to identify any low pressure/choking or any other problems by checking the pressure in the particular line.

In the middle of the project work progress, farmers of one more village – Devthala well comprehended the outcome of the project and they thus came forward to participate in the project after a formal agreement with the Water User Association which was competent to take such decisions. While, this village is separated from the existing command area by a torrent (stream) named Udmadi, an additional PVC pipeline, 400 m in length and 110 mmϕ, was laid out from the last riser point in Pasauli-west block to the Devthala block. GI pipe was laid to cross Udmadi torrent (12 m width) and the pipe segment in the stream was placed between two gabion barriers laid along the width of the stream. The banks of the stream at both ends of the GI pipe lying in the torrent were stabilized by gabion protection walls and retards.

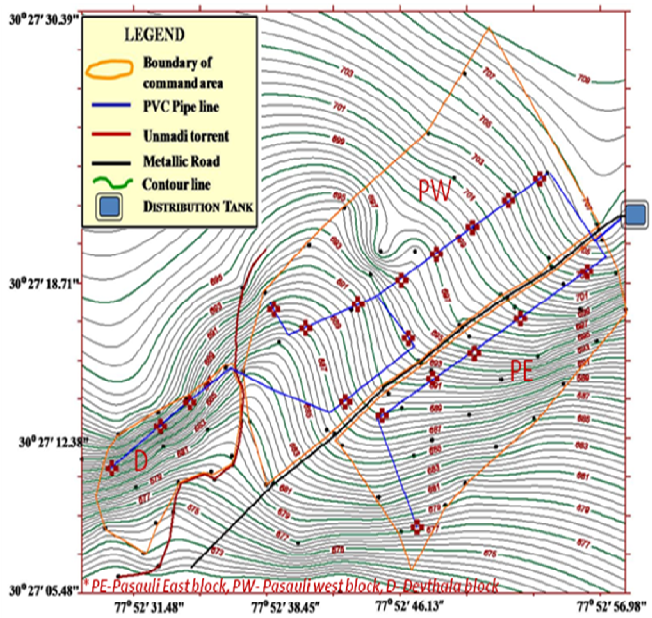

Fig. 5: Plan of PVC distribution pipeline in the command area.

COMMAND AREA

Command area of the irrigation project is divided into three blocks, *viz*; Pasauli-East, Pasauli- West and Devthala (Fig. 5).

Pasauli-East block is spread over an area of 5.5 ha with altitudinal variation ranging from 673 to 706.5 m amsl. The land slope varies from 7 to 12 % across the length and 3 % along the length, which clearly indicates multi directional land slope in the block with high variability. The length of block extends from North to South along the road and breadth from East to West. The farm holding size varies from 0.30 to 0.64 ha and 50 farm families are benefitted by the project. PVC pipeline (110 mm ϕ) with 6 risers was laid, which was 10 m east from the road. The second block, Pasauli-West, is sprawled over 16.28 ha area with an altitudinal variation from 684 to 707m asml. The farm size varies from 0.07 to 2.0 ha and 59 farm families are benefitted by the system. PVC pipeline (110 mm ϕ) with 10 risers was laid out in the block. This block is largest among all three blocks and has a relatively gentle land slope, i.e. 1 -2% across the length and 4.3 % along the length. This block follows the same pattern of length and breadth of earlier block. To obtain desired flow at each riser, the PVC pipeline is laid in the middle of the block along the length. The last block, Devthala, is spread over 4.5 ha area with an altitudinal variation from 673 to 692 m amsl. Variation in farm size is similar to Pasauli-west block and 6 farm families are benefited by the system. PVC pipeline (110 mm ϕ) with 3 risers was laid out in the block. This block is separated from Pasauli-West by Udmadi river. Hence special arrangements were made to install the pipeline for crossing the river. The pipeline of this block is connected with last riser set up in Pasauli-West block.

On-farm Water Management

In all three blocks, one riser is provided at every 1.5 ha, this is termed as unit command area. A committee of beneficiary farmers of each unit command area is formed to decide turn to irrigate their fields. To enhance the application efficiency of irrigation, the farmers of unit command area use collapsible synthetic pipes. Even in the unit command area, water is delivered to the individual field head by a collapsible synthetic pipe. With continuous motivation to the farmers, adoption of the optimum size of border for irrigating wheat crop and strengthening of field bunds for minimizing the seepage loss from the field bunds, particularly from downfield bund is popularized in the command area.

In order to avoid any conflict regarding the turn of irrigation to the farmers' fields; a mechanism is evolved with common consensus. In this mechanism, in one season, water follows from head to the tail riser and in next season delivery sequence gets reversed order to negate the clash among the farmers.

*i) **Optimizing the dimension of surface Irrigation methods***

To optimize the design of border and check basin irrigation in the slopping land, field dimensions, slope, discharge and soil information were collected from 3 blocks of Langha watershed. Surface irrigation system model SIRMOD developed by Utah State University was used for the study. The SIRMOD model (Walker, 1998) simulates the hydraulics of surface irrigation (border, basin and furrow) at the field level. The simulation method used in SIRMOD is based on the numerical solution of the Saint-Venant equations for conservation of mass and momentum as described by Walker and Skogerboe (1987).

The SIRMOD software includes three modeling choices: (1) kinematic wave model; (2) zero-inertia model; and (3) hydrodynamic model. The default model is the hydrodynamic model which was used for simulation. The initial continuous flow infiltration characteristics for a particular soil type were considered from soil catalogue available in the model. The cutoff time was decided based on intake opportunity time as suggested by Walker (1989). The value of design flow was considered based on the discharge available per unit width of the field (lps/m).

Table 1: Optimum dimensions of check and border irrigation methods designed in available discharge (10 lps) in mildly slopping land using SIRMOD

Soil type	Length (m)	Width (m)	Discharge (lps)	Slope (%)
Basin Irrigation				
Sandy loam	20	15	5-6	1-2
Sandy Loam	30	15	8	1-2
Border irrigation				
Sandy Loam	40	15	10	0.5-1.5
Clay Loam	50-70	15	10	0.5-1.0

*ii) **Drip irrigation method***

Gravity-fed in-line drip irrigation system was installed at five farmers' fields having 1.5- 4 % land slope and covering total 1.6 acres with an objective to demonstrate the system among the farmers. The main line of each unit of drip irrigation was coupled with riser existing in the respective unit command areas, and strainer type filters having capacity 25 m^3/hr was also fitted to the main line near the riser. In order to minimize the cost of the system, different sizes (50, 63 and 75mm ϕ) of submain were laid out in the field 4,600 m in-line laterals of 16 mm ϕ was laid out in the fields in order to irrigate vegetable crops-tomato, brinjal, cauliflower. Uniformity coefficient varied from 74 to 82 %, depending on the land slope of the field.

Impact of the Irrigation system

Prior to the project, agriculture in adopted villages was predominantly rain dependent, except Godaria, which had 98% land under limited irrigation. Project activities increased irrigated land in all the adopted villages with a total increase, 173.8%. The maximum increase in irrigated land was 391.9% in village Pasauli followed by 22% in Dungakhet and least (0.8%) in Godaria. Gross irrigated area during Pre-project (PrP) was 46.92 ha and reached to the level of 130.15 ha at End of project (EoP) indicating that gross irrigated area increased by 83.23 ha though the net irrigated area was increased by 25.3 ha. Thus irrigability index (II) was 3.29. The high value of II revealed that developed water resources are being utilized effectively. It is attributed to new cropping sequence, maize – *toria* – wheat or maize – vegetable-vegetable or oat – *berseem – berseem or* vegetable-vegetable at EoP in place of maize-wheat or Paddy-Wheat/fallow cropping sequence followed in the irrigated land during PrP. Consequently a total crop production from the project area showed about 191% improvement over pre-project (2008) production level.

Productivity of major crops *viz.,* Maize, Paddy, Wheat and *Toria* were increased by 48%, and cropping intensity by 29% due to intervening crop of *Toria* in between Maize-Wheat sequence and cultivation of *Rabi* wheat on fallow land resulted in increased additional net income of Rs. 17500/- ha. Crop diversification index improved from 0.84 (pre-project) to 0.96 at the end of the project. This helped to minimize the negative impact of climatic aberrations.

Availability of fodder increased by 350% resulted in increased milk productivity by 97% due to introduction of hybrid Napier grass on field bunds and higher productivity of fodder sorghum and Berseem. This has reduced dependency on forest for fodder by 60% besides reducing time spent on collection of fodder to the extent of 23,457 woman days per annum. Overall additional regular employment generated was to the tune of 65 mandays per ha per annum.

Induced Eco-development Index (IEI) of the irrigated command area was found 0.316 showing 31.6% area of cultivated land is under some form of permanent vegetation. Sodding of Napier grass on the field boundaries and terrace shoulder bunds and their survival (92%) in around 93% agricultural area, particularly Pasauli and Devthala, clearly showed the impact of creating the irrigation facility. Beneficiary farmers contributed 15 % of the total cost of the component, i.e. Rs 25,91,932.00.

CONCLUSION

Himalayan hills have great potential to convert least economic rainfed farming into the most profitable irrigated farming system through participatory water resource development and management. The study revealed that active involvement of beneficiary farming community at all the stages of the project life holds the key for sustainability of the system. Development of an efficient irrigation system, *i.e.* technically as well as socially acceptable, is followed by many other activities such as land leveling, bunding, terracing in the area, coupled with niche farming with intensive land use management system; ultimately leads to sustainable livelihood security in the area. However, the proactive strategies for conflict resolution among the beneficiaries as well as upstream – downstream areas is equally important and essential.

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