Poverty alleviation and resource conservation through development of cost effective technology at foot hill of Shivalik – A case study

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Abstract: The study revealed the development of cost effective technology utilized as a practical tool for treatment of seasonal torrent and addressing erosion problems and land use planning. Technology was implemented in a small agricultural watershed located in foot hill of Shivalik, India, to assess its prediction capacity of runoff, peak runoff flow and sediment yield. Cost effective technology was evaluated at the event scale by using a database of hydrological, geomorphologic and land use data collected during a two-year period. In the catchment, the gullies which are small to medium in size were treated with gully plugging by erecting loose boulder check dams and erected with different species of plants. Different types of spur were constructed with vegetative reinforcement for channelization of stream flow. The sediments deposited in the first year at downstream was recorded 0.09-81.0 tons, while in the second year it was reduced up to 0.07-16.7 tons. Similarly, up stream sediment deposition was recorded 1.0-72.0 tons and 0.37-13.1 tons in two consecutive years. The D-50 analysis of sediment deposited was carried in three different places of torrent and it was found that deposited particle size material decreased after treatment undertaken in the torrent bed. Therefore, the mechanical as well as vegetative measures helped in the channelization of water course towards the central line with the tune of 10-100 m, stabilization of torrent bed and reclamation of degraded land.

Keywords: Integrated watershed management, mechanical measures, D-50, vegetative measures
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1 Introduction

The foothill ecosystem of north India called Shivalik is considered as one of the most degraded and frizle ecosystems of the country, where vegetation, land, water and animal resources have been locked in a complex and vicious cycle of degradation[1]. The terrain is hilly with a narrow belt of largely undeveloped farmland in the foothills with altitudes ranging from about 250-1 500 m from mean sea level. The steep slopes, denuded vegetal cover, monsoon rains and flash floods resulted in continuous soil erosion ultimately leading to ecological imbalance. The climate in Shivalik foot is subtropical with mean annual rainfall varies from 800-1 300 mm. About 80% rainfall occured during three monsoon months (July-September). The mean annual temperature is normally 23-40°C and the hottest month is June in which drought conditions prevail. The rock

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system is weak and of very fragile nature, which is readily prone to disintegration on exposure due to removal of vegetative cover. Most of the terrain is highly susceptible to landslides and excessive erosion[1,2]. The soils in general are shallow, poor in humus and inter bedded with pebbles and boulders. The drainage density in the Shivalik is very high, with 6-10 km of drainage channels/gullies per square killometer, leading to problems of soil erosion, flooding and declining productivity as shown in Figure 1. There is acute scarcity of water in the area during summer months. Even the drinking water supply becomes uncertain and people have to depend on natural springs.

Figure 1 Land degradation problem and constructed gabion wall at Kulahri-Johranpur-Sansiwala watershed (KJS) catchment

Conservation farming techniques such as hillside terraces, stone-lines and bunds, trash-lines, sand-bag lines, earth-contour bunds, crop rotation, vegetation-barriers and organic manuring utilize natural ecological processes to conserve moisture, improve soil structure, curtail soil erosion and enhance soil fertility[3]. Safe disposal of runoff water involves practices such as land shaping, construction of contour-bunds, terraces, waterways and ridges as measures to improve water infiltration and conservation[2]. Adaptation of incompatible technologies on soil environments are noticed limitations that have put most arable lands into perpetual degradation[4]. Thus, farming activities are adversely affected due to diminishing productive capacities of the soils[5].

In recent years it is widely recognized that more site-specific approaches are needed to assess variations in erosion susceptibility in order to select the most suitable land management method[6,7]. Reliable prediction models can help to select the most practical and effective tools in reducing erosion problems and developing appropriate land use planning[8,9]. Simulations under various combinations of different scenarios of land and water management can provide comparative analysis of different options and was proved to be very useful as a guide to what Best Management Practices (BMPs) can be adopted to minimize land degradation[7]. The morphological, land capability classification and socio economic survey of the study area was undertaken. The study was conducted in the Kulahri-Johranpur-Sansiwala watershed (KJS) area with treatments of land and water resource management to assess the effectiveness and resource conservation at Shivalik foot hills for sustainable agriculture practice.

2 Materials and methods

2.1 Study area

The study was conducted at KJS watershed in the District of Solan, Himachal Pradesh, India. The watershed has total area of 530 ha, lying between 350°54′0″ - 300°54′30″ N and 760°30′45″ - 760°54′45″ E, and with different land uses. The Geographical Information System based map of different land use pattern was shown in Figure 2. The watershed having forest and agricultural land where about 22%-30% area is manifested with choes (rainy seasonal torrents). The catchment is largely under scanty natural vegetation and under tremendous pressure of population for energy, timber fiber and fodder. The soils are loose, gravelly and deposited by fluvial action and are very low in productivity. The mining of the river bed for sand gravel, stone is a serious menace in the foot hills and causing great havoc to the fragile eco-system of the area. The study examined the economic viability of cost effective technology for treatment of seasonal torrents and rehabilitation of degraded lands through combination of mechanical and vegetative soil conservation measures.

Shivalik foot hills of Himachal Pradesh commonly, called as “Kandi” area, constitute 21.0% of total geographical area of the state. In the area, the rainy season torrents (choes), which are mountainous stream where water comes in flash floods loaded with sediments are common. They are linked with problem of shifting of their water course as well as degradation of adjoining land by deposition of sediments and cutting of land and stream bank.

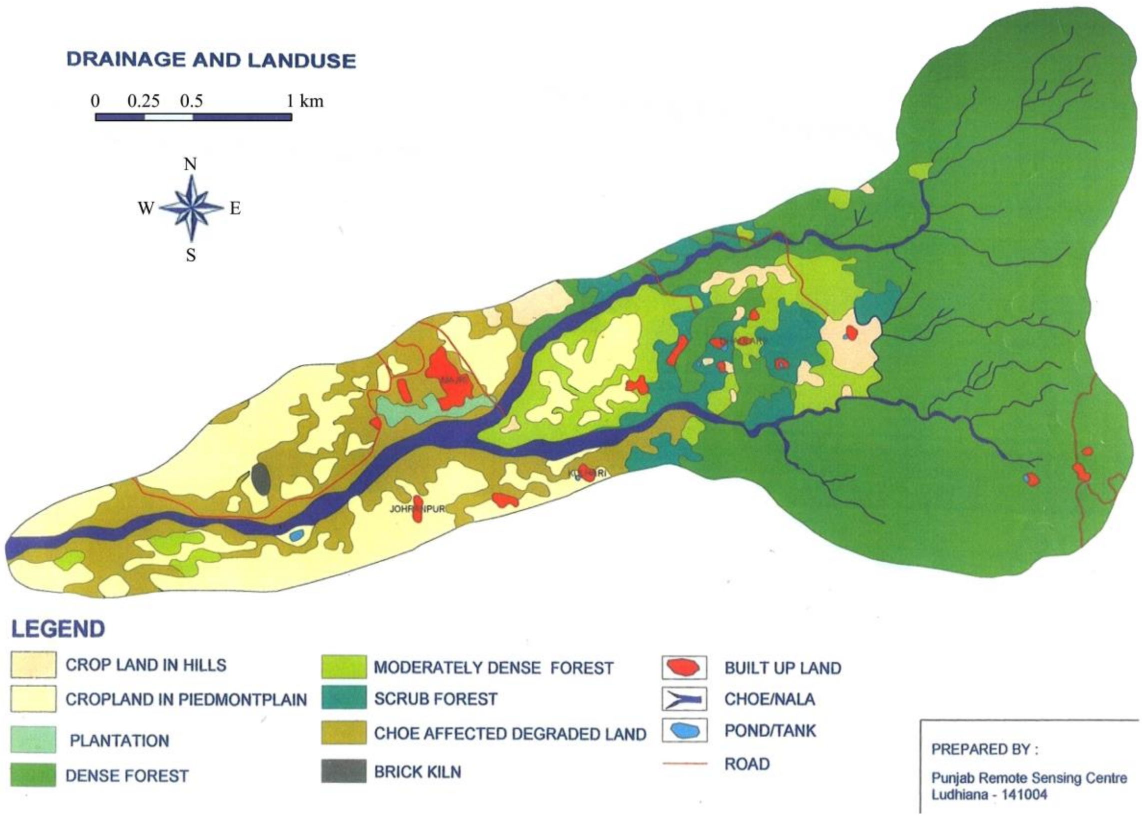

Figure 2 GIS based torrent bed and different land use pattern of Kulahri-Johranpur-Sansiwala watershed (KJS)

The impact evaluations of different treatment in catchment with regard to their efficacy to reduce runoff, ground water recharge, sediment deposition and channel morphology were recorded. The average size and shape of torrent bed and degraded area is summarized in Tables 1 and 2. The degraded area under torrent bed is 99.57 ha.

Table 1 Average size of torrent bed of Kulahri-Johranpur-Sansiwala watershed (KJS)

No.	Site	Average breadth /m	Average length /m	Area /m^2
1	Upstream	7	150	1 050
2	Down up stream	20	300	6 000
3	Upper middle	40	150	6 000
4	Lower middle	200	750	150 000
5	Lower portion	150	400	60 000
6	Upper Sansiwala area	150	300	45 000
7	Lower Sansiwala area	120	200	24 000
	Total			292 050

Table 2 Degraded areas under torrent bed

No.	Site	Average breadth /m	Average length /m	Area /m^2
1	Upstream	8	150	1 200
2	Down up stream	30	300	9 000
3	Upper middle	160	150	24 000
4	Lower middle	850	750	637 500
5	Lower portion	600	400	24 000
6	Sansiwala	600	500	300 000
	Total			995 700

2.2 Cost effective technology for treatment of torrent

The area of KJS watershed was treated with bio-engineering measures. The area is facing severe problems of land degradation and torrent channel shifting every year and becoming larger than that in the previous year (Figure 3). For channelization of flow toward centre line, different percolating type loose boulders spurs were constructed, *i.e.*, deflecting, attracting and repelling types (Figure 4). Both sides of the torrent (2 000 m in length) were stabilized with the line planting of *ipomea sp.* and *sacachrum munja* (Figure 5). The vegetative and mechanical measures adopted in the treatment of catchment and torrent area were monitored with regard to their efficiency to reduce runoff, groundwater recharge, sediment and channel morphology. During the first year in the catchment, the gullies which are small to medium in size were treated with gully plugging of loose boulder check dams of the different size, suitable for the sites and further reinforced with vegetation by planting cuttings of *ipomoea sp*. and *sacachrum munja.* An area of 1.0 ha of upstream catchment of torrent was planted with shisham (*Dalbergia sissoo),* plantation of *'Luucinia'* (*Leucinia* sp) and khair (*Acacia catechu*). In addition, small gabion structures were also constructed in the gullies.

Figure 3 Torrent channel behavior of Kulahri-Johranpur-Sansiwala watershed (KJS)

Figure 4 Mechanical and vegetative spurs at downstream of Kulahri-Johranpur-Sansiwala watershed (KJS)

3 Results and discussion

The technology is effective in channelizing the flow of runoff water, which rehabilitated about 75 acres of land for cultivation in the first year of the project. The farmers diversified their agricultural activities including cash crops and vegetables. Local technologies appeared viable and relevant in conserving soil and water required for sustainable crop production in this study. The survey work was carried out for evaluation the impact of human and cattle population on vegetative cover. There are 90 families/houses holders in the watershed, where they are categorized as marginal (74%), small (18%), medium (5.1%) and large (3%) farmers.

3.1 Channelization of stream flow

The torrent bed was stabilized in both sides with the line planting of 'AK' (*ipomea sp.*) and Jhung grass (*sacachrum munja*) and combination of both. The plantation at individual farmer's land, community land and Govt. land was done in blocks, in pits of 1 × 1 × 1 and 1.5 × 1.5 × 1.5 cubic feet sizes. The bamboo plantation was done in a continuous trench of 1.0 foot deep on one side of torrent. The survival rate of first year plantation on an average was found above 30%. About 43 ha of torrent bed and surrounding affected area was reclaimed through different bio-engineering measures (Figure 5). It is illustrated that vegetative measures are most effective in channelizing the water flow and converting the naked bed to green belt. A quite good volume of sediment was trapped by these vegetative measures. The intensity of rainfall was recorded as high as 80.33 mm/hr. The rains during monsoon caused a lot of disturbance to the mechanical as well as vegetative measures. Scouring with the rains, frequent and changing scouring has also been recorded which on average varies from 0.06 to 49.5 tons at a maximum depth of 1.3 m at distance of 1.1 m away from

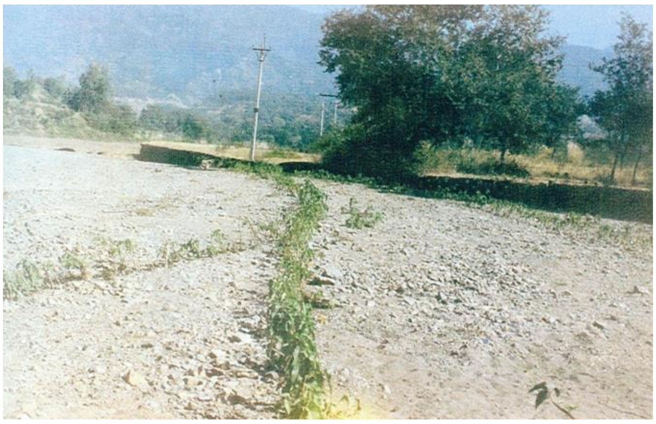

Figure 5 Vegetative spur combination of different species

the spur. The deposition varies at Upstream is 1.0-72.0 tons and 0.37-13.06 tons in 2003 and 2004, respectively. It was observed that the mechanical as well as vegetative measures helped in the channelization of water course towards the central line with the tune of 10-100 m.

3.2 D-50 analysis

D-50 analysis of torrent bed sediment deposition was carried out at three different places of torrent bed, *i.e.*, upstream; middle and downstream. The D-50 of bed material on upstream, middle stream and downstream was found 3.5, 3.70 and 3.1 mm, respectively. D-50 value was decreased in the downstream. Using different measures in primary tributaries of catchment area in the monsoon deposition was found lesser as compared to previous year. This was due to decrease in velocity of flowing water in the channel.

3.3 Monitoring impact evaluation of project intervention on socio-economic status

The land treated minimize the velocity of flowing water, reduce sediment and runoff yield. The various measures for non-arable and arable lands were undertaken. Farmers' field land was shifted to high yield varieties of fruit and vegetable crops. The socio-economic status was analyzed by adopting suitable statistical and economic techniques. The results revealed shifting in the land-use after the project implementation, because of plantation activities (fruits and forestry species) undertaken in the watershed area, both on private holdings and community/Govt. lands. The grown area has been increased about 12.94%. Similarly area under forests, pasture and grassland shows an increase of about 7% each because of plantation of forest species and grasses. The inventory of fixed assets showed more importantly increase in the number of tube-wells/bore-wells and tractors by about 40% and 60%, respectively.

The livestock situation in the project area showing average number of cattle- heads as 3.66% before the project situation which increased to 5.6% in the end of the project thereby showing on increase of about 53.6%. Average numbers of cattles and goats has shown maximum increase *i.e.*, by 48.8% and 56.7%, respectively. In addition the cropping- pattern with average yields on per hectare basis has been also changed. Maize crop show 38.7% increase in yield level er hectare, whereas wheat crop shows an increase in yield by 37.7% to 77.5% depending on the performance of different high yielding varieties, suitable to rainfed conditions, demonstrated amongst the farmers.

The net return from project, *i.e.*, total cost, total returns, net revenue and total benefit-cost ratios of important food crops as well as live-stock were also determined. The benefit-cost ratios of 2.20, 1.98, 2.47 and 1.23 have been found in case of wheat, maize and tomato crops, respectively.

The energy requirement of the farmers in the study area has been also found, that consumption of the fuel wood has shown a decline from 5.88 qt/yr/farm to 4 qt/yr/farm by about decreased 32.0%, whereas dung waste and agriculture waste, have increased by 24.8% and 39.9%, respectively. Increase in the LPG consumption by about 16.7% has been observed to be responsible for decline in the consumption of fuel wood. Average survival rate of forest plantation in catchment area varying from 40.1% to 50.8% of different plant species was shown in Figure 6. Horticulture plants monthly survival rate was also summarized in Figure 7. It is observed that maximum survival rate of plantation is in monsoon month. As per the socio-economic survey, a positive impact has been revealed on shifts in the land-use, increased in productivity of crops, increased in assets and income earned by the farmers in the treated area. In addition, the technological interventions of the project have also contributed in reducing the soil erosion, stabilizing the torrent-bed and shifting the water course towards the central line of the torrent and reclaiming about 43 ha of land by various treatments. Overall, the mechanical/vegetative treatments have helped in channelization of water course towards central line to the tune of 10-100 m and trapping sediments through gullies plugs and vegetative measures. In addition, other activities for increasing productivity of the area were undertaken to improve crop yield, horticulture plantations including percentage survival of horticulture plants and organic farming.

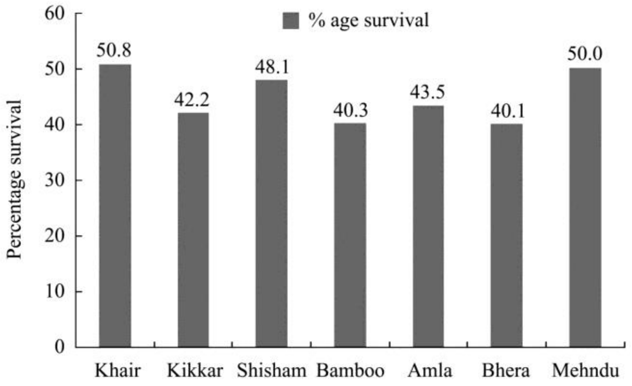

Figure 6 Percentage survival of forestry plantation rate at Kulahri-Johranpur-Sansiwala watershed (KJS)

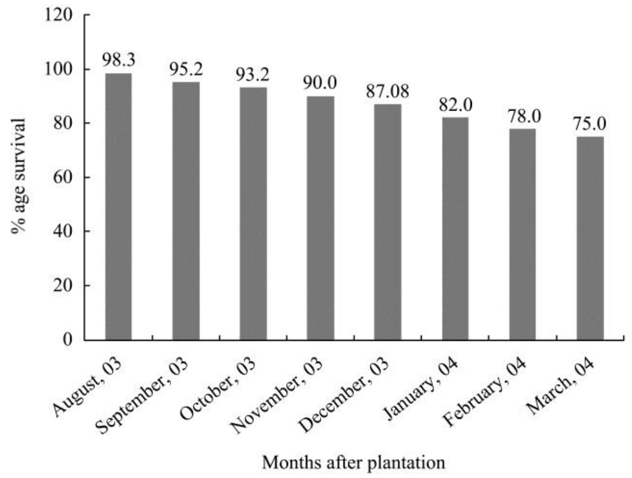

Figure 7 Percentage plants survival of horticultural plants rate at Kulahri-Johranpur-Sansiwala watershed (KJS)

4 Conclusions

The technology is effective in channelizing runoff flow, which rehabilitated and reclaimed about 43 ha land by various treatments. The farmers diversified their agricultural activities towards cash crops and vegetables. The local technologies appeared viable and relevant in conserving soil and water conservation for sustainable crop production. Long term effectiveness was recorded as direct functions of the stony conservation structures established in the catchment area. In the catchment, the gullies which are small to medium in size were treated with gully plugging by erecting loose boulder check dams and erected with different species of plants. The spurs, gabion wall, agro-forestry, suitable grass, shrubs and trees, *i.e.*, khair, kikar, bamboo combinations are most effective to channelize the water courses towards the central line of the torrent. Agro forestry plant species with ombination of engineering measures was effective for stabilizing the nala bank, torrent bed, reducing soil erosion and runoff losses. Therefore, it is recommended that the mechanical as well as vegetative measures would help in the channelization of water course towards the central line with the tune of 10-100 m and stabilization of torrent bed and reclamation of degraded land. Soil and water conservation techniques are indispensable tools in sustaining crop production especially on hilly region.

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