Vol. 44, No. 1, pp 25-29, 2016
Indian Journal of Soil Conservation
Online URL:http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home

Development of cost effective technology for treatment of torrents in Shivalik hills, India

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ARTICLE INFO

Article history :
Received : July, 2014
Revised : August, 2015
Accepted : October, 2015

Key words:
Farm pond,
Mechanical measures,
Vegetative measures,
Watershed management

ABSTRACT

In North Western Himalayan region, Shivalik hills occupy an area of 2.14 mha and this area is perhaps the most degraded and fragile ecosystem in India. The present study was conducted to develop the cost effective technologies for treatment of seasonal torrents in mid hill of Shivalik. There was an urgent need to develop water resource for mitigation and adaptation to minimize the impacts of climate change in the region. Through cost effective technology, the torrent bank was stabilized against erosion. The stream flow was channelized and land reclamation of adjoining area was achieved through bio-engineering measures *i.e.* by applying mechanical barriers in conjunction with vegetative measures. Low density polyethylene (LDPE) lined farm ponds were also constructed for rain water harvesting. Farm pond is an ideal proposition for the hill farmers having small and fragmented land holdings for resource generation. The cost effective technology was evaluated using a database of hydrological, geomorphologic and land use. In the catchment, the gullies were small to medium in size which were treated with gully plugging by constructing loose boulder check dams and erecting with different species of plants. Attracting and deflecting type of spurs were constructed with vegetative reinforcement for channelization of stream flow. Agroforestry plant species in combination of engineering measures were found effective for stabilizing the nala bank which reduced soil erosion and runoff. The sediments deposited in first year at downstream was recorded 0.09-14 t and in second year it was reduced up to 0.07-8 t. Similarly, upstream sediment deposition was recorded 1.0-21.0 and 0.37-12 t in two consecutive years, respectively. Thus, the bio-engineering measures were found effective in channelizing the torrent flow stabilizing the stream beds and banks.

1. INTRODUCTION

Land degradation from water-induced soil erosion is a serious problem in India (Amine *et al.*, 2015). The foothill ecosystem of north India called Shivalik is considered as one of the most degraded and fragile ecosystems of the country where vegetation, land, water and animal resources have been locked in a complex and vicious cycle of degradation (Sharma *et al.,* 2000, Kumar *et al.,* 2012). The Shivalik region, occupying nearly 2.14 m ha area in the north-western Himalaya (Sidhu *et al.,* 2000). Soil water erosion is a very dynamic spatial phenomenon and the area is affected by moderate to severe soil erosion due to water, thus playing a major role in land degradation process in the region. Soil erosion rate was found to be greater in the Shivaliks as compared to other physiographic regions in India (Singh *et al.,* 1992) due to steep terrain, poor vegetal cover, unstable geology and immature soil conditions. The combined impact of these factors leads to continuous depletion in the fertility and productivity of soil as well as deterioration in the water quality (Lal, 1998). High soil erosion causes sedimentation of reservoirs, resulting in severe economic losses to irrigation and hydroelectric projects (Arya *et al.,* 2010). Several watershed development programmes were implemented by State and Central Governments to conserve soil against erosion and to improve the soil fertility for sustainable development of natural resources. Water is one of the most vital natural resources. Availability and quality of water determines ecosystem productivity, both for agricultural and natural systems. There is increasing demand on water resources for development whilst maintaining healthy ecosystems, which put water resources under pressure.

Soil erosion is a complex phenomenon governed by a large number of factors, such as rainfall erosivity, soil erodibility, slope, land use and conservation measures. The steep slopes, denuded vegetal cover, monsoon rains and flash floods result in continuous soil erosion ultimately leading to ecological imbalance. Most of the terrain is highly susceptible to landslides and excessive erosion (Kumar *et al.,* 2011; Kumar *et al.,* 2012). 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. 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 (Kumar *et al.,* 2011; Anon., 1999). 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 methods (Adinarayana *et al.,* 1998; Shrestha *et al.,* 2006). Reliable prediction models can help to select the most practical and effective tools in reducing erosion problems and developing appropriate land use planning (Licciardello *et al.,* 2007, 2009). 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 was considered in the study area. Such type of study helped in reducing seasonal migration of landless people in search of work in the nearby areas by providing higher on-farm employment opportunities and enhancing the value of land. Keeping in view, the present study was conducted in order to assess the effectiveness of resource conservation measures in Shivalik foot hills for sustainable agriculture practice.

2. MATERIALS AND METHODS

Study Area

The study was conducted at Johranpur watershed in District Solan, Himachal Pradesh, India. The watershed is spread over 530 ha and lies between latitudes 35^{0}54' to 30^{0}54'30" N and longitudes 76^{0}30'-76^{0}54'45" E with elevation ranging from 400 to 800 m above msl. The land area was put under different land uses of cultivation of cereal crop, horticulture crop and forest plantation. The mean annual rainfall of the study area varies from 800-1300 mm, and about 80% is received during the three monsoon months (July-September). The watershed is having forest and agricultural lands where about 22-30% area is manifested with choes (rainy seasonal torrents). The topography of the area is undulating and facing towards south-east aspect.

To combat the problem of study area different bio engineering measures, crop improvement, shifting in land use horticulture and forestry plantation, fodder and fuel demands of the local people and natural resource conservation were undertaken. The impact evaluation of different treatments was carried out with regard to their efficacy to reduce runoff, ground water recharge, sediment deposition and channel morphology. For sustainable management, rain water harvesting through an integrated approach which includes tapping, storage and conservation of water so as to utilize the same during the lean period and recharge the underground.

Conservation Measures

Vegetative measures

The torrent bed was stabilized on both sides with the line planting of 'AK' (*Ipomea* sp.) and jhung grass (*Sacachrum munja*) and combination of both. In addition, the plantation was done at individual farmer's land, community land and at Government land lying in the adjoing area of the torrent. For plantation, different sizes of pits (1' x 1' x 1' and 1.5' x 1.5' x 1.5') were done, considering the type of species and their requirement. The bamboo was planted in a continuous trench of one foot deep on one side of torrent.

Engineering measures / structures

Spurs

Torrents cause serious damage to the infrastructure, agricultural fields and human habitations. The selected watershed has an area of 530 ha, out of which 20% was severely affected by torrents. In the catchment, forest and agriculture spread over approximately 80% of the total land. The area was facing severe problem of land degradation and torrent channel shifted every year and become larger than previous year. For channelization of flow toward center line, 20 number of percolating type loose boulder spurs were constructed. Three different types of spurs *i.e.* deflecting, attracting and repelling types were constructed. Different engineering structures were reinforced with vegetation by planting cuttings of *Ipomoea* sp. and *Sacachrum munja*. An area of 1.5 ha of upstream catchment of torrent was planted with shisham (*Dalbergia sissoo*), plantation of 'Leucinia' (*Leucinia* sp.) and khair (*Acacia catechu*). In addition, small gabion structures were also constructed. The location of various types of spurs and retards used in the torrent bed is depicted in Fig. 1.

Trenches

In upper catchment, contour trenches were constructed to reduce the velocity of runoff and soil erosion rate which promote the ground water recharge. Trenches having size

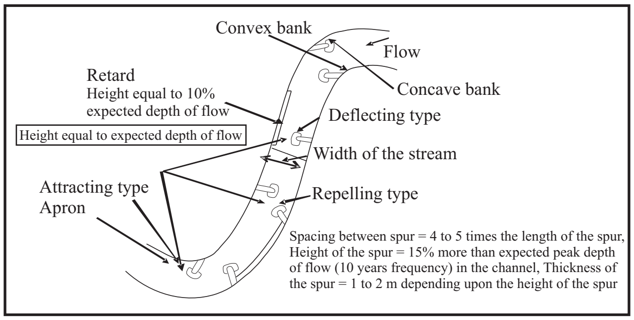

Fig. 1. Location of various types of spur and retard in the torrent bed

(L x W x H) from 7' x 1.5' x 1.5' to 15' x 1.5' x 2' dug out along the contour lines, reduced silt load into the water harvesting structures constructed at downstream.

Water harvesting technology (WHT)

The term water harvesting in its original application is defined as the collection and storage of water, either runoff or creek flow for irrigation or other uses. The water harvesting is a dominant source of irrigation in Shivalik foothill region, where there is less possibility of developing other sources of irrigation. Harvesting water increased the agricultural production in the area. The novel idea of rehabilitation of 'Village Ponds' were constructed. The village johads, which in earlier times served the purpose of storing rain water to be used for various water requirements in the village, had slowly degenerated owing to disuse. In addition, low density polyethylene (LDPE) lined farm ponds, percolation pond and V- ditches were constructed for water harvesting. The stored water is used for irrigation in the lean period. The capacity of constructed storage tanks varies from 10 - 30 m^3.

Soil and water conservation structures

The catchment was treated with structural interventions coupled with biological remedial measures and social fencing to reduce soil erosion, break slope length and reduce degree of slope and prevent scouring and undercutting of hill surfaces, channel banks and stabilized channel bed slopes. The structural measures included staggered contour trenches, peripheral bunds, gully plugs, spurs, check dams, silt retention dams, relevant crate-wire gabions and drop structures. The bio-remedial measures include vegetative/ brushwood check dams across channels, vegetative spurs in single or double lines, vegetative filters and grass barriers, vegetative gully plugs and stabilization of pondage area by planting trees and mulching with locally available biomass.

In addition to structural and bio-remedial measures, SWC measures were implemented to prevent animal grazing and illicit felling of vegetation by involving active participation of people as social fencing measure in rehabilitation of degraded catchments. Awareness and motivation are needed both among the local people, NGOs and public functionaries.

3. RESULTS AND DISCUSSION

The study area is suffering from land degradation problem of one or other type and about half of the problematic area was degraded by soil erosion. The cost effective technology for resource conservation is effective in channelizing the flow of runoff water, which rehabilitated about 75 acres of land. Farmers diversified their agricultural activities including cash crops and vegetables. It was observed that 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 of impact of human and cattle population on vegetative cover. There are 90 families/housesholds in the watershed where they are categorized as marginal (74%), small (18%), medium (5.1%) and large (3%) farmers.

D-50 Analysis

D-50 analysis of torrent bed sediment deposition was carried out at three different places of torrent bed *i.e.* upper; middle and downstream. The D-50 of bed material on upstream, middle stream and downstream was found 3.5, 3.70 and 3.1mm, respectively**.** D-50 values of deposited sediment were found 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.

Channelization of Stream Flow

The flowing water channel course changes their path every year and lot of land was degraded every year. Keeping in view behavior of torrent different engineering as well as biological activities were carried out for channelization of stream flow. Different types of mechanical and vegetative spurs were constructed. About 43 ha area of torrent bed and surrounding affected area is reclaimed through different bio-engineering measures (Fig. 2). It was observed that vegetative measures were most effective in channelizing the water flow and converting the naked bed to green belt.

The low cost bio-engineering measures using local

Fig. 2. Vegetative spur comprising of different species

grass (*Saccharum munja*), shrubs (*Vitex negundo* and *Ipomea spp.*) and trees (*Acacia nilotica* and *Acacia catechu*) along with loose boulder structures (spurs, check dams and gully plugs) of suitable design and dimensions were very effective in channelizing the torrent water flow towards central line and its stabilization. Quite good volume of sediment was trapped by vegetative measures. The sediment deposition varied from 0.06 to 14 t at a maximum depth of 1.2 m at distance of 1.1 m away from the spur. The deposition varied from 0.07-16.66 t and at the upstream, it was found 1.0-21.0 and 0.09-14.0 t in downstream, respectively. It was observed that the mechanical as well as vegetative measures helped in reducing sediment deposition and channelization of water course towards the central line with the tune of 10-40 m.

Impact Evaluation on Socio-Economic Status

The various measures for non-arable and arable lands were undertaken. At farmers field fruit crops was replaced with high yielding varieties of vegetables. The drainage line was treated with vegetative as well as mechanical measures. The socio-economic status was analyzed by adopting suitable statistical and economic techniques. The plantation activities (fruits and forest 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 was increased of about 7% each. The irrigation status in the area with respect to percentage response of the availability of water/irrigation by the farmers also increased. Percentage plants survival of horticultural plants rate at Johranpur watershed is shown in Fig. 3.

The net return from project, total cost, total returns, net revenue and total benefit- cost ratios of important food crops as well as live-stock were determined. The benefit- cost ratios of 2.20, 1.98 and 2.47 was achieved in wheat, maize and tomato crops, respectively. The benefit-cost ratio of live-stock after the project was 3.76. As per the socio-economic survey, a positive impact was observed on shifts in the land-use, increased in productivity of crops, increased assets and increased 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 to 40 m and trapping sediments through gully plugs and vegetative measures. The positive impact was found leading to conserve the natural resource in the watershed area. In addition, other activities for increasing productivity of the area were undertaken for crop improvement. The details of benefit-cost ratio of different crop interventions are shown in Table 1.

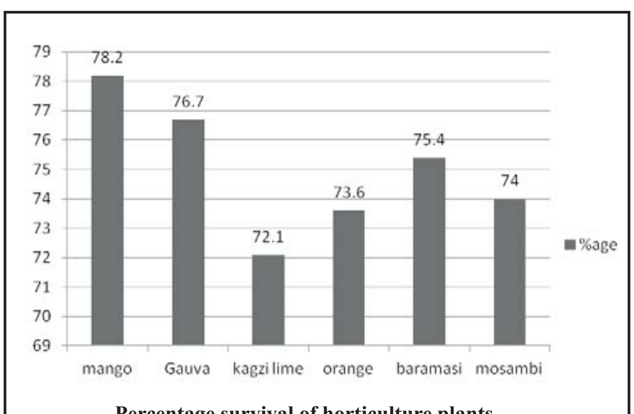

Fig. 3. Percentage plants survival of horticultural plants rate at Johranpur watershed

Table: 1
B:C ratio of different crops grown in watershed

S.No.	Crops	B:C ratio
1.	Wheat	2.20
2.	Maize	1.98
3.	Tomato	2.47
4.	Livestock	3.76
5.	Water storage structures	1.71

4. CONCLUSIONS

The cost effective technology for treatment of torrent is useful in channelizing of runoff flow, which reclaimed the affected area. The farmers diversified their agricultural activities towards cash crop and vegetables. The bio-engineering measures are viable and relevant in conserving soil and water conservation for sustainable crop production. In the catchment, the gullies which were small to medium in size, treated with gully plugging by erecting loose boulder check dams, erected with different species of plants. Agroforestry plant species with combination of engineering measures was effective for stabilizing the nala bank, torrent bed, attenuating soil erosion and runoff loss. Therefore, the mechanical measures in conjunction of vegetative interventions helped in the channelization of water course towards the central line and to stabilize the torrent bed and reclamation of degraded land. The study helped in reducing seasonal migration of landless people in search of work in the nearby areas by providing higher on-farm employment opportunities and enhancing the value of land.

ACKNOWLEDGEMENTS

The project was funded by National Agricultural Technology Project (NATP) in village Johranpur-Kulahriwala during 2001-2005, Govt. of India. Authors are highly thankful to Dr. V.N. Sharda, Dr. A.K. Tiwari and Dr. I.P. Sharma for their inspiration, encouragement and guidance.

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