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Hydrological Behaviour of a Mini Agricultural Watershed in a High Rainfall Area of the Himalayan Region

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SYNOPSIS

The paper presents the research experience on the development of a selected watershed including the measurement of runoff, soil and nutrient losses. The watershed management practices implemented enable in checking the runoff effectively within the areas thereby reducing soil erosion much below the permissible limits. Runoff and sediment yield mainly depends upon the characteristics of rainfall and the watershed characteristics which can be influenced by the soil conservation measures taken on the catchment. A watershed consisting 26 hectares in area was developed and put to scientific use. Three parameters, namely runoff, soil and nutrient losses before and after the treatment of the basin were studied and compared for a rainfall period of June to September for continuously ten years (1979-1988).

INTRODUCTION

A watershed implies a natural hydrological drainage unit having distinct boundaries which produces water as an end product by interaction of rainfall and watershed factors and contributes runoff water towards a particular single point or channel. It is not only a water yielding area, but is also a social and economic unit for community development and conservation of water, soil, forest and related sources. The area of a watershed may vary from a few hectares to thousands of square kilometers. There is a significant difference between the hydrology of small and large watersheds. For small watersheds the rates and amount of runoff are influenced by the condition of the soil and vegetative covers, over which man has some control and thus watershed factors are more important. For large watersheds the channel storage effect becomes very pronounced, and more attention is given to the hydrology of streams.

Hydrological behaviour of Himalayan Region

The objective of watershed development is to improve the soicio-economic well being of the people in the basin and the nation through proper soil and water conservation, increasing irrigation facilities, improving drainage, checking flood and sediment damages, etc. Watershed management is an important component for agricultural prosperity in every part of the country but most essential in hills.

Hydrologists engaged in soil and water conservation planning require information on such parameters as runoff, soil and nutrient losses in planning water resource development programme. These losses are dependent upon many factors such as climate, soil type, land use, topography and the presence of reservoirs.

Agricultural activities in the hill areas are generally hazardous and associated with continued degradation of the production base i.e. land. In hilly areas, maintenance and monitoring of management activity is very essential. The submountaineous terrain experience acute shortage of water at the cessation of monsoons or their early withdrawal. Proper land and water management is thus required to keep the resource degradation within permissible limits and ensure sustained agricultural production. Storage is an important part of water harvesting system because of the intermittent nature of runoff from precipitation. Flood in the country and silting of reservoirs are the direct result of soil erosion in the Himalayas which is one of the most outstanding ecological problems.

Location

The 26 ha watershed selected for the present study is hydrologically isolated and runoff and sediment from surrounding areas do not enter into it. The general slope of the watershed is 1-10 percent. It is located at Palampur in Himachal Pradesh (India) at an elevation of 1300 m above the mean sea level. It has a latitude of 32.6 and longitude of 77.2 . The areas fall under the 'mid-hills subhumid' agro-climatic zone of the state (Fig.1.)

Rainfall Pattern

The annual rainfall of the region is about 3000 mm. More than 80% of the rainfall is received in the monsoon season from mid June to mid Septemsber and a major portion of it goes waste as runoff. Torrential and high intensity storms during monsoon create serious problems of soil erosion and nutrient losses. On the other hand, short duration dry spells at later stages of Kharif (rainy season) crops and long dry periods during winter (rabi) crops result in severe moisture stress to the crops. The ground water potential of the region is generally poor. Canal lift irrigation systems are not economically feasible due to the rolling and undulating topography. The maximum rainfall occurs during July and August and monsoon recedes in Septemsber. The rainfall is extremely low from October-December for rabi crops.

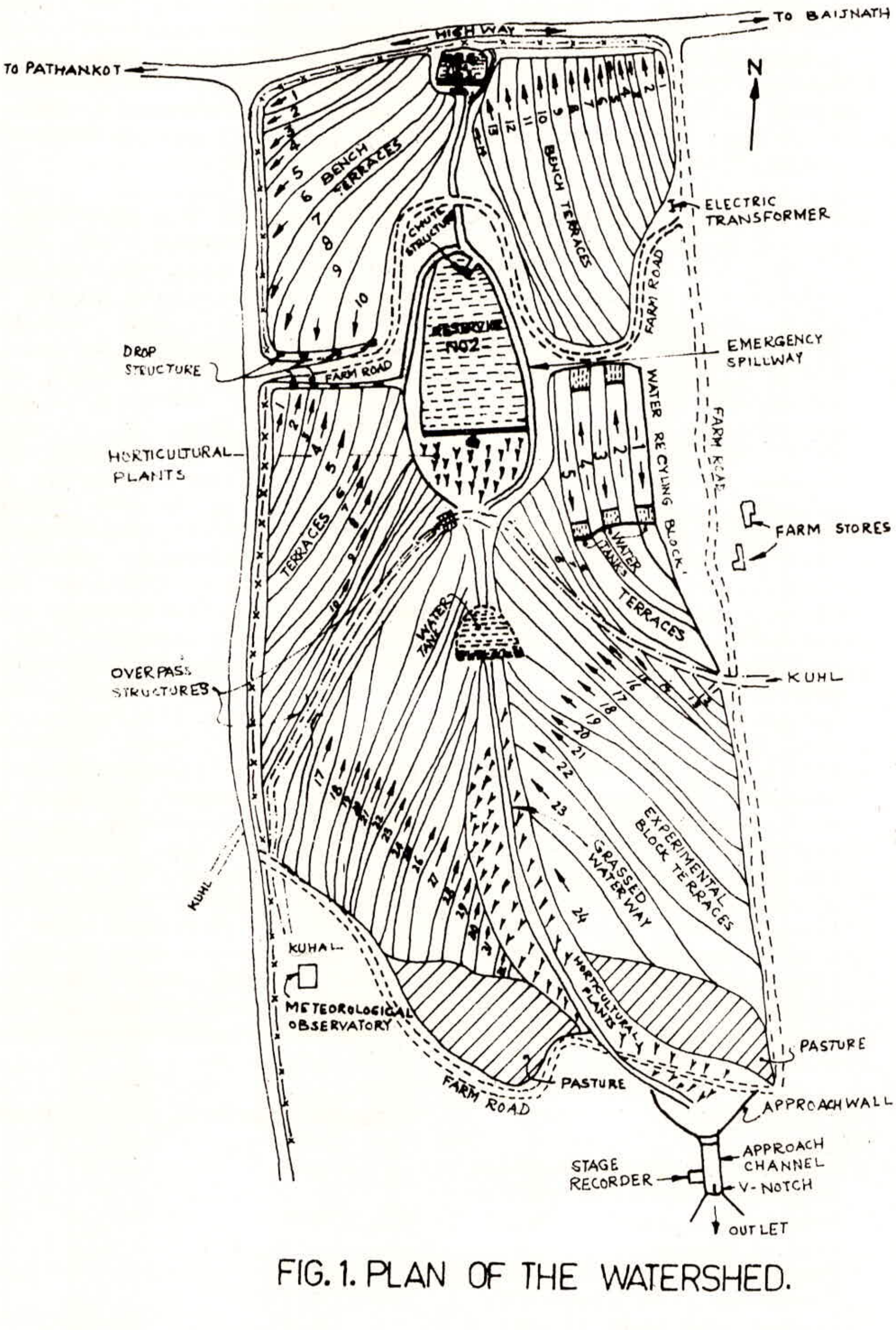

FIG. 1. PLAN OF THE WATERSHED.

MATERIALS AND METHODS

The study is based on the observations and experience of a research watershed developed in the high rainfall belt at Palampur in Himachal Pradesh (India). Now the watershed, 26 hectares in area, is in fully developed stage and being put to scientific use. During the period of study, the area earmarked for different crops and other uses during the rainy season was paddy (4 ha), maize (6 ha), maize + soyabean (4 ha), sugarcane (0.5 ha), horticultural plants (2.5 ha), grasslands (5 ha) and others (4 ha).

After the reconnaissance survey of the selected area, land use planning was done as per the land capability classification of the basin. The land use treatments were applied in the micro watershed with a view to manage the rainfall water within the area and study the resultant runoff, soil and nutrient losses. Bench terraces and contour bunds were designed in such a way that the vertical interval remained between 1.0 - 1.5 m and all the terraces drained their excess runoff into a common grassed waterway. Since the watershed is located in a high rainfall belt, the area to be used for growing crops was put under inward sloping bench terraces having longitudinal and cross slope of 0.5 percent. To bring the catchment to a stable situation, the watershed was treated with integrated soil conservation measures like field bunding, terracing, checkdams, drop and chute structures, spillways, grassed waterways, raising horticultural plants and pasture development etc. Horticultural plants like almond, peach, plum, pear etc. were planted in the areas unsuitable for crops. However, the area close to the waterways and unsuitable even for fruit trees were developed into pastures. Natural depressions in the valley within the basin which could not be utilized for any profitable use, were selected as the sites for water harvesting reservoirs. Construction of small storage structures is an important component of soil conservation measures and these hold sediments from entering the main drainage system, improve soil moisture regime of the downstream area and also stabilize the watershed to bring down the siltation rate to a tolerance limit. Apart from the smaller structures, two main homogeneous type earthen dams were designed and constructed within the catchment for harvesting excess runoff for use during the scarcity periods for stabilizing crop production. The reservoirs now have the potential of recycling the stored water on community system basis. The details of these two reservoirs are as follows :

Particulars	Reservoir No.1	Reservoir No. 2
Length of embankment (m)	30	60
Height of embankment (m)	3	5
Storage capacity (Cu m)	660	6300
Top width (m)	3	3
Free board (m)	0.5	0.5
Upstream side slope	3:1	3:1
Downstream side slope	2:1	2:1

A vegetated emergency spillway was constructed by the side of each dam which diverts the excess runoff at safer velocity when the reservoir is full to its capacity. Across the embankment of each reservoir, 15 cm diameter pipe supported with anti-seep collars was fixed at the bed level. A sluice valve was made to regulate the outflow from the dam to irrigate the fields on the downstream side by gravitational flow.

Depth gauges were installed along the upstream surface of the embankment to estimate the inflow or outflow/seepage volumes. To determine the water-spread-areas at different elevations, contours were drawn after every 10 cm drop from free board level upto the maximum depth of reservoirs.

To recycle the water on small farm system basis, a separate block was developed in the watershed. In this block, slope of two consecutive terraces was given in the opposite directions. Brick masonry tanks, each having a capacity of 30 cu.m were constructed in these terraces to store runoff water for irrigation. Each tank has the dimensions of 6 m x 4 m x 1.25 m and may harvest excess water of the respective terrace.

At the end of the watershed, the point through which the entire runoff passes out, a broad-crested masonry triangular weir with 2:1 side slope was fabricated. In order to minimise turbulance effects, the weir has straight reach of an approach channel 15 m long, 1.35 m base width and 1.5:1 side slope. The overland flow of water directly enters into the approach channel. The channel has a sedimentation tank at the inlet. The gauging station was constructed at a distance of 3 m on the upstream side of the weir and included a head-gauge, recorder housing, stilling well and automatic water-level-stage-recorder of Steven's A-35B type. The zero of the head-gauge coincided with the zero of the crest of the weir. The fluctuations of water level in the stilling-well actuate the pen-carriage in the recorder through the float and pulley arrangement. The recorder automatically produces a curve called the stage-graph which is the graphic record of the stage of flow over the control with respect to time. The stage was analysed to determine the rate, duration and amount of runoff. A weir rating curve and the rating table was prepared to estimate the discharge at different stages of flow. The gauge scale of the recorder was 1:6. Runoff and sediment samples were collected in bottles at 30 minutes interval from the jet falling into the sunken sedimentation basin. Analysis of these samples gave an estimation of soil and nutrient losses from the watershed. Rainfall data were obtained from the meteorological observatory of the local Agricultural University, located close to the watershed.

In order to assess the effectiveness of various soil conservation and water management treatments, the following basic research needs for the watershed programme were taken-up under different precipitation, soils cover and fertilizer conditions :

i) Accurate measurement of runoff from the watershed. The data are essential for efficient planning and design.
ii) Field measurement of sediment yields from the basin.
iii) Measurement of nutrient (nitrogen) losses.

The above losses were gauged during the period of main rainy season from June to Septemsber each year from 1979-88.

RESULTS AND DISCUSSION

The observations revealed that approach to the development of watershed lies in the integrated use of the total water available according to the best possible coordinated programme, taking into consideration all the present and future uses of water in that watershed. The basic nature of development should be to retard the flow of water throughout the year as well as from one wet season to the next-one so as to meet the varying needs and for all this the knowledge of the working of the watershed as it is and its resources is essential. Each watershed must be studied in the light of its individual characteristics before predicting its behaviour. The principal factors which affects the operation of the individual watershed and need to be studied before commencing the programme are i) shape of the watershed, ii) topography and slope of the land, iii) amount of precipitation and storm patterns, iv) land use, v) type and quality of vegetative cover, vi) type of soil and vii) size of watershed.

Watershed development should include the aspects of land use planning, soil conservation and water management. Vegetative and structural measures may be utilized for the purpose of erosion control, sediment control, flood prevention, ground water recharge and water supply.

The desire and willingness of the local land owners to install the programme is an important factor in planning a watershed project. No project can be successful unless it provides the type of control wanted by the local people. Programmes of demonstration farms to convince the other farmers in the region about the feasibility of some recommended techniques of water management needs to be taken up.

Proper budgeting of the project is also essential. In case the project requires technical services or equipment that can not be easily obtained, it is better to discuss this during the planning stage rather than half-way through the project.

Watershed management must have definite plan of activity and specific objectives. Precautions should be exercised to ensure that the study is not so elaborate that it includes numerous variables which become difficult to control and the sensitivity of measurement of the most important factors is weakened by attempting to include too much in the study. The runoff, soil and nutrient losses observed from the watershed consisting of 26 ha in area during the main rainy seasons from 1979-88 have been summarized in Table 1.

Table 1 :Runoff, soil and nutrient losses from the watershed (June-September)

Year	No. of flows	Runoff (m)	Runoff (%)	Runoff duration (hrs.)	Soil loss (t/ha)	Nitrogen loss (kg/ha)	Rainfall (mm)
1979	29	259685.40	65.0	624	22.50	3.80	1535.6
1980	35	301113.17	60.2	740	18.45	4.00	1923.8
1981	33	269766.12	53.4	775	6.65	4.20	1943.0
1982	22	157505.40	47.7	240	3.08	2.25	1270.0
1983	27	184522.65	43.5	818	4.74	3.10	1631.5
1984	22	156251.68	43.0	543	4.50	4.00	1397.6
1985	18	203058.38	38.6	231	4.63	4.10	2023.3
1986	37	189584.61	33.2	891	4.27	4.00	2196.3
1987	19	79455.37	30.8	334	3.62	3.56	992.2
1988	55	244362.11	34.3	1293	4.32	4.12	2740.1

As indicated above, the runoff, soil and nutrient losses from the watershed were found to have decreased over the period of study on account of the implementation of soil conservation and water management measures as elucidated earlier. The total percent of runoff during the initial years when no soil conservation treatments were followed was about 65%. However, later on it stabilized between 30-34% approximately. The soil losses came down from 22.5 t/ha in 1979 to between 3.0-4.4 t/ha in 1987-88. No sharp reduction in the rate of nutrient losses (ammonical and nitrate nitrogen) was evident. Such losses figured in the range of 2.25-4.20 kg/ha in different years and the enhanced values were followed by higher totals seasonal precipitation.

The results demonstrate the effectiveness of small soil conservation structures and other measures for tapping eroded materials and overland flow. The small storage structures also restore some of the degraded lands to provide new production base. In order to obtain the maximum dividends from the investment on these structures, these should have sufficient capacity and reasonably long useful life. The water harvested in the reservoirs was usefully recycled during the scarcity periods for irrigation purposes. It was seen that the expenditure on water harvesting could be repaid in 7-8 years. The seepage losses of water from the earthen reservoirs also stabilize in a period of 8-10 years because of gradual sitation. The interplay of climate and watershed parameters produce runoff water and determine its quantity and quality. While one has no control over climate, one can control to a considerable extent some watershed parameters through planned constraints in the watershed which influence the hydrological and sedimentation characterisitcs.

Besides soil erosion, land use activities are adversely affecting the availability of water in the hills. Depletion and drying-up of springs and streams are becoming evident in these areas. Thus watersheds are not static but are relatively in a state of transition. Unless and until each and every individual land user contributes towards effective management of the land he cultivates, it will not be possible to achieve desired objectives of good watershed management.

Thus, watershed can form the base for implementing various soil and water management practices to optimize the use of resources for sustained production within permissible limits of degradation of the production base (land and water). With the use of the local resources based water storage and soil conservation measures, efforts have to be made to ensure maximum retention of rainfall within the catchment and ensure adequate protection of land against soil erosion.

CONCLUSIONS

The observations have revealed that watershed development in the hills helps in checking runoff, soil and nutrient losses besides the proper water management for augmenting agricultural production. From conservation point of view, mechanical soil and water conservation measures are an essential part of any intensive agricultural activity in mountainous regions. After the adoption of proper watershed management practices, the runoff declined from 65 to between 30-34 percent. The soil losses dwindled from 22.5 t/ha to about 3.0-3.4 t/ha in a period of ten years. No sharp reduction in the nutrient losses was observed. Due to gradual siltation, the seepage losses in the earthen dams stabilize in a period of 8-10 years and the expenditure on water harvesting could be repaid in about 8 years. Small storage works are very effective in reducing sediment yield, preventing gullying, restoring degraded lands and creating mini commands.

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