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The Effect of Check Dams and Changing Land Uses on the Productivity of Catchment Sediments in Yusmerg(Jammu and Kashmir)

Dr. Bashir Ahmad Pandit
Associate Professor, Division of irrigation & Drainage Engineering, SKUAST-K, Shalimar Srinagar, Jammu and Kashmir

Abstract: Reforestation and the cessation of agricultural activity have resulted in significant changes to land use in several parts of Jammu and Kashmir. on parallel, the Administration invests a significant amount of money on hydrological control projects to lessen silt transport and erosion. Nevertheless, it is still unknown how these significant changes in land use will impact catchment-scale erosion processes and whether effective hydrological control will lessen the export of silt. To assess the effects of land use scenarios with and without sediment control facilities (check-dams) on sediment yield at the catchment scale, a combination of field work, mapping, and modeling was employed. The study catchment is in Kashmir, where there have been significant changes in land use that have resulted in a decrease in agricultural area and an increase in forest cover. In addition, as part of the related reforestation efforts, numerous check-dams were built in the watershed.

Applying the erosion model WATEM-SEDEM, six land use scenarios—each with and without check-dams—were used. Upon calibration, the model yielded an absolute sediment yield model efficiency of 0Ð84. The implementation of the model demonstrated that the changes in land use led to a steady decline in sediment output in a scenario without check dams. About 69% of the sediment production was retained behind check dams in a situation where there were no changes to land use. Although their effects on sediment control are transient, check-dams can be effective techniques. They have significant adverse effects, like downstream channel erosion. Changes in land use can have significant long-term effects on sediment output, even though they can also have negative effects. The goal of management and the unique environmental circumstances of each location determine whether to apply check dams or land use changes, such as reforestation, to regulate sediment yield.

Key Words: Land use change, geomorphological impact, sediment yield, check dams, management, and reforestation

I. INTRODUCTION

Reforestation and the building of check dams on rivers and streams are two often used soil conservation techniques in temperate regions. Land use changes (including reforestation) and hydrological correction projects are known to significantly alter a catchment's sediment delivery and water discharge, affecting the morphological processes occurring in the river bed and occasionally causing processes that are undesirable for river management (Kondolf et al., 2002). However, the consequences of altered land use patterns and the implementation of hydrological correction projects on catchment-scale sediment output have received very little attention up until now. To better understand sediment dynamics and allocate resources, evaluation of commonly used management methods in mountain streams is required.

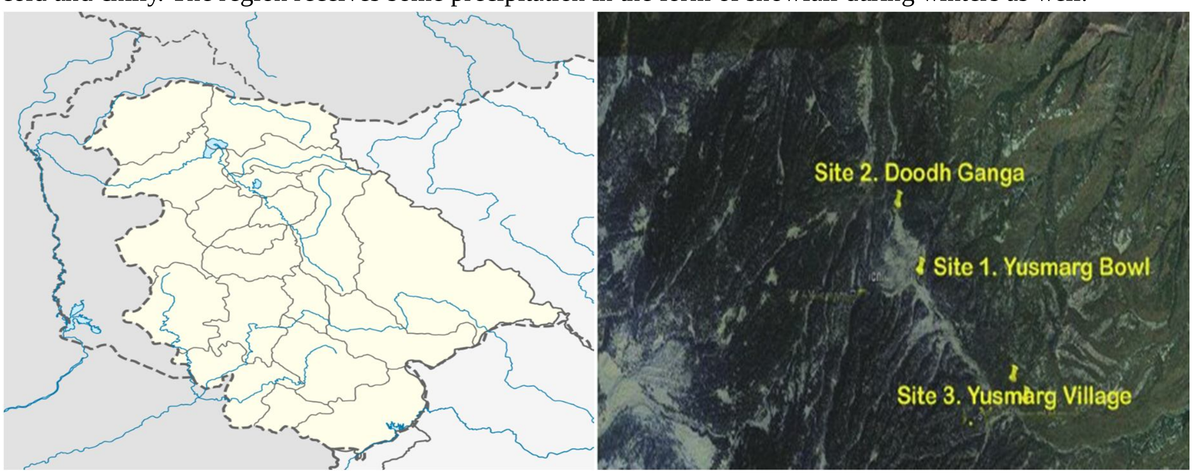
According to Wohlberg (2006), in-channel devices like check-dams disrupt the longitudinal transport of nutrients and aquatic animals, produce segmented longitudinal profiles, change sediment dynamics, bed and bank stability, and change how flood waves pass through the channel. Check-dams alter the hydraulic behaviour of the flow in extreme events (Conesa Garc§ıa et al., 2004) by causing significant morphological and granulometrical impacts in the river bed (Boix-Fayos et al., 2007). In addition to the fact that check-dams reduce the sedimentary load, as documented in various contexts (Simon and Darby, 2002; Mart´ın-Rosales et al., 2003; Surian and Rinaldi, 2003), there is evidence that check-dams also cause local erosion processes (Gomez-Villar and Mart.

Because of their intimate coupling with neighbouring hillslopes, mountain streams are especially susceptible to changes in hillslope dynamics. Changes in land use can easily affect hillslope processes. According to García-Ruiz et al., 1996a; Beguer´ıa et al., 2006, an increase in plant cover generally results in a decrease in runoff generation and sediment detachment, which stabilizes sedimentary structures at the catchment scale over the medium term. Regional rates of soil erosion can occasionally be significantly impacted by a relatively small change in land use (Van Rompaey et al., 2002). But changes in the composition of various land uses do not alone impact sediment yield; shifting the topography of the landscape also has a significant impact on sediment yield.

Changes in the combined effects of land use and field sizes (Vanacker et al., 2005; Van Rompaey et al., 2007), changes in the temporal patterns of cultivation practices (Vezina et al., 2006), changes in the spatial connectivity between sediment-producing areas and the river network (Vanacker et al., 2003; 2005), and changes in the location of field boundaries (Van Oost et al., 2000) are just a few examples of the notable effects on sediment yield. So even though it is commonly recognized that changes in land use have an impact on sediment output and erosion, Therefore, even though it is commonly known that changes in land use have an impact on erosion and sediment yield, there hasn't been a comprehensive analysis of check-dam effectiveness and impacts in comparison to reforestation and other land use changes. Large reservoirs, small farm dams, and changes in land use have all recently been evaluated for their effects on sediment output in watershed. The question of how much check-dams and/or changes in land use are to blame for the lower sediment output at the catchment scale is brought up in this research. Finding out how well check dams and land use modifications work as management tools to regulate sediment output at the watershed scale is the major goal.

II. STUDY AREA

Yusmarg or Yousmarg (meaning 'Meadow of Jesus') is a hill station in the western part of the Budgam district of Jammu and Kashmir, India. It is situated 53 km (33 mi) south of Srinagar, the summer capital of the state. It lies at an altitude of 2,396 m (7,861 ft.) above sea level. It lies between the geographical coordinates of 33.8316° N, 74.6644° E. It is located in the Pir Panjal peaks, a sub range of Himalaya. Yusmarg of district Budgam experiences temperate climate, where summers are mild while winters are extremely cold and chilly. The region receives some precipitation in the form of snowfall during winters as well.



The terrain is a combination of woodlands, shrublands, walnut plantations, and dryland farming, primarily focused on barley. Since the latter part of the 20th century, significant changes in land use had an impact on the catchment. The primary components of these changes are an increase in the amount of forest cover and a gradual cessation of dryland farming operations. Pinus nigra salzmanii dominates the forest, but the lower basin also has some Pinus pinaster and Pinus halepensis. Due to heavy wood and charcoal production as well as past removal for agriculture, Quercus rotundifolia was diminished. Erinacea anthyllis dominates the shrublands higher up in the watershed, whereas Cytisus reverchonii, Rosmarinus officinalis, Thymus vulgaris, and Genista scorpius are found at lower elevations.

Area covered by different land use in 1981, 1991 and 2001 and ratio between years

	Area			Ratio		
	1981Km^2	1991 Km^2	2021 Km^2	1981/2001	2001/ 1991	2001/1981
High density forest	1.02	3.02	4.21	2.966	1.39	4.12
Medium density forest	2.56	5.14	8.32	2.00	1..61	3.25
Low density forest	5.69	2.41	3.12	0..42	1.29	0.54
Shrubland	1.61	2.83	1.03	0.01	0.36	0.63
Pasture land	1.02	0.83	1.16	0.81	1.39	1.13
Dry land agriculture	8.04	5.23	3.45	0.65	0.65	0.42

The three main components of the methodological approach used for this work were: (i) field surveys to characterize the soils within the catchment and estimate sediment yields at the sub-catchment level; (ii) GIS analysis to calculate various model input parameters; and (iii) a modeling exercise using the spatially distributed soil erosion model WATEM-SEDEM (Van Oost et al., 2000; Van Rompaey et al., 2001; Verstraeten et al., 2002).

A first field study was conducted to identify every check-dam built within the catchment. With differential correction, a GPS Trimble GeoXM was used to locate and georeference 14 check-dams. Each dam's height, length, and sediment wedge locations were measured, and each dam's sediment wedges were meticulously mapped. By measuring the height and area of the alluvial wedges in the field, the volume of sediments was estimated on the assumption that the wedges have the shape of a prismatic channel with a rectangular section (Prosser and Karssies, 2001; Lien, 2003; Castillo et al., 2007). The average bulk densities of preserved sediments were determined by undisturbed sampling of a few chosen sediment wedges. At the front and rear of each of the seven sediment wedges, two sampling locations were selected for each wedge. At each sampling location, two replicates with 7 cm depth intervals down to 35 cm depth were taken in addition to bulk samples of 100 cm3 obtained at intervals of 7 cm to a maximum depth of 25 m. 189 undisturbed samples in all were gathered. These figures were used to determine the mass of sediment that each check-dam could hold. A second field investigation was conducted to identify the soil texture in various catchment areas. 50 sample locations in all, spread out throughout the catchment from upstream to downstream, were taken at depths of 0–5 and 5–10 cm. The soils were allowed to air dry, the organic matter was removed using H2O2, the samples were chemically dispersed using hexametaphosphate, and the Coulter LS200 was used for laser diffraction to determine the particle size distribution. For every sample, three laboratory replicates were performed.

For every sample, three laboratory replicates were conducted. Together with the geometric mean size of the particles, the percentages of coarse and fine sand, fine and coarse silt, and clay were also determined. The results were utilized to create a soil erodibility map (K factor).

Several model input parameters were derived using GIS analysis. First, a digital elevation model (DEM) of the catchment was used to compute the catchment area draining to each check-dam. The digital elevation model (DEM) was derived from digitized topographic maps (10 m interval) that were acquired from the Indian National Geographic Institute. The maps were based on photogrammetric data from a trip in 1988 and were released between 2000 and 2002. Using the Idrisi program, a 30 m resolution DEM was produced from these maps. The initial volume of every check-dam was used to calculate the trap efficiency for each one, in accordance with Brown (1943). This approach is helpful for estimating mid- and long-term trap efficiencies, particularly in the absence of inflow data, as it calculates the efficiency of the trap based on the structural capacity and watershed area ratio (Verstraeten and Poesen, 2000). The amount of sediments kept by each check dam, the bulk density of the sediments, the trap efficiency of the check dams, and the drainage area of each check dam were used to determine the specific sediment yield data (SSY, t ha~1 yr~1) and absolute sediment yield (SY, t yr~1). Many writers have documented using comparable methods to calculate sediment yield information behind check-dams or small dams (Verstraeten et al., 2007; Romero-D´ıaz et al., 2007).

In addition, a number of GIS layers were ready to be used as input for the RUSLE erosion model. For the model application, every layer was resampled at a resolution of 30 meters.

The fragmentation index and the perimeter to area ratio (Monmomier, 1974, Eq. (1)) were also applied in GIS analysis to characterize the land use pattern for 1981, 1991, and 2001:

$$F = \left(\sum_{i=1}^{m} \left(\frac{c-1}{n-1} \right) / n \right) \qquad (1)$$

Where c D is the number of cells taken into consideration in the 5 by 5 pixel kernel,
m D is the number of pixels in the picture, and
n D is the number of distinct classes included in the kernel.

A more fragmented land use pattern with more tiny, isolated pockets of distinct land use is indicated by a high perimeter to area ratio and a high fragmentation index.

The land use at the time the hydrological control works were installed was not depicted in the land use maps from aerial photographs that are currently available (1981, 1991, 2001). Therefore, a classification of a historical Landsat Multispectral Scanner (MSS) satellite image was done in an attempt to characterize land use conditions for this time period.

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Two bands in the visible and two in the infrared portions of the electromagnetic spectrum were captured by the MSS sensor. A supervised classification of land uses was carried out using a false colour image based on the combination of bands 4, 2, 1. Two of the original land use classes—high and medium density forests—were combined in this categorization due to the relatively low level of detail in the Landsat MSS photos (spatial resolution 75 m). The satellite image was only used to define the land use at the time the control works were being built, not as a land use scenario for modeling purposes, due to its poorer spatial resolution when compared to aerial photographs.

The sediment output at the catchment's outlet under various land-use scenarios was estimated using the regionally distributed model WATEM-SEDEM (Van Oost et al., 2000; Van Rompaey et al., 2001; Verstraeten et al., 2002). Long-term mean annual soil erosion rates by water and sediment yield are provided by WATEM-SEDEM. Previous papers (e.g., Van Oost et al., 2000, Van Rompaey et al., 2001, Verstraeten et al., 2002, de Vente et al., 2007b) provided a detailed description of the model. Sediment transport capacity, sediment routing, and soil erosion evaluation are the three primary components of the pixel-by-pixel computing model. A modified version of the revised universal soil loss equation (RUSLE; Renard et al., 1997), which was put forth by Desmet and Govers (1996a, b), is used within WATEM-SEDEM to forecast mean annual soil erosion.

$$E = R \times K \times LS_{2D} \times C \times P \qquad (2)$$

Where LS2D is the two-dimensional topographic factor,
C is the crop and management factor,
P is the erosion control practice factor, and
E is the mean annual soil erosion (kg m}2 yr~1).
R is the rainfall erosivity factor (MJ mm m~2 h~1 yr~1),
K is the soil erodibility factor (kg h MJ~1 mm~1), and

The rill and inter-rill erosion potential are multiplied by a constant known as the transport capacity coefficient in the original WATEM-SEDEM model to determine the sediment transport capacity. Here, we calculated transport capacity using an altered version of Verstraeten et al. (2007)'s formula:

$$TC = KTC \times R \times K \times A^{1.4} \times S^{1.4} \qquad (3)$$

Where A is the upslope area (m2),
S is the local slope gradient (m m^1),
R and K are the rainfall intensity and soil erodibility factor of the RUSLE, and
TC is the transport capacity (kg m~2 yr~1).

Change in landscape metric indicators between the studied periods

	Perimeter to area ratio (Km^2)			Fragmentation index		
	1981	1991	2001	1981	1991	2001
High density forest	6.05	3.01	2.86	0.001	0.011	0.014
Medium density forest	4.67	2.38	2.02	0.012	0.232	0.021
Low density forest	1.51	1.43	2.31	0.011	0.041	0.024
Shrubland	2.31	2.02	3,14	0.012	0.031	0.042
Pasture land	3.54	3.61	3.16	0.026	0.028	0.027
Dry land agriculture	2.43	5.62	5.87	0.036	0.028	0.029
Mean value	3,41	3.05	3.22	0.98	0.066	0.022

In basins where gully erosion is a significant erosion process, this equation differs from the original formulation of sediment transport capacity in that it permits a high transport capacity throughout zero-order basins (de Vente et al., 2007b, Verstraeten et al., 2007).

III. RESULTS AND DISCUSSION

A. *Scenarios of Land use and Data on Sediment Yield*

There were significant shifts in land usage between 1981 and 2021. There was a 24% decline in the land used for agriculture and an increase in the area covered by medium density and high density forests. The land use map created from the 1981 satellite image provides a picture of the environment shortly before the hydrological rectification projects (check dam construction and reforestation) got underway. The fragmentation index and the perimeter to area ratio show that during the course of the study, there were significant changes in the spatial pattern of land use. Agricultural land has the lowest perimeter to area ratio, whereas high and medium density forests have the highest ratios. High-density forests have the highest fragmentation rating, whereas agricultural land has the lowest. In comparison to 1981, the fragmentation index for agricultural land has somewhat increased in 2001. These metrics collectively demonstrate that in 1981, agricultural land was highly interconnected and had minimal fragmentation. Nonetheless, compared to 1981, the land use mosaic from 2001 depicts a smaller area of agricultural land with more fragmentation. There is a little rise in SSY in the downstream direction; as has been noted in other examples, this may be due to the introduction of substantial sediment yields in the main channel by other erosion processes, such as channel erosion and bank erosion from a particular threshold.

IV. CONCLUSIONS

Although they operate at rather different temporal scales, check dams and changes in land use are both useful techniques for reducing the amount of sediment production in catchments. Although check dams are quite effective in the short term, they may cause erosion to worsen in the long run. Land use changes in the examined catchment, primarily the reduction of agricultural activity and the expansion of forest cover, had the impact of lowering the sediment output by 28% in 30 years and 42% in 40 years. In comparison to the 1981 scenario, 43% of the sediment yield in the study area was regulated by the installation of check dams without affecting land use. In the watershed, it appears that the 40% reduction in sediment yield may have already occurred due to the change in the spatial structure of land use at the time of check-dam construction. Check-dams and modifications in land use are both useful strategies for reducing In contrast to check dams, which are an effective short-term sediment control measure, land use modifications are long-term maintained sediment control measures. The area's environmental features and the particular goals of the management project should influence how each of them is used. Check-dams can be useful in places with high erodibility and poor vegetation establishment for lowering the amount of silt produced. Check-dams can be limited to significant sediment source regions, and land use adjustments that increase plant cover are sustainable ways to minimize sediment yield in places with favourable conditions for vegetation establishment.

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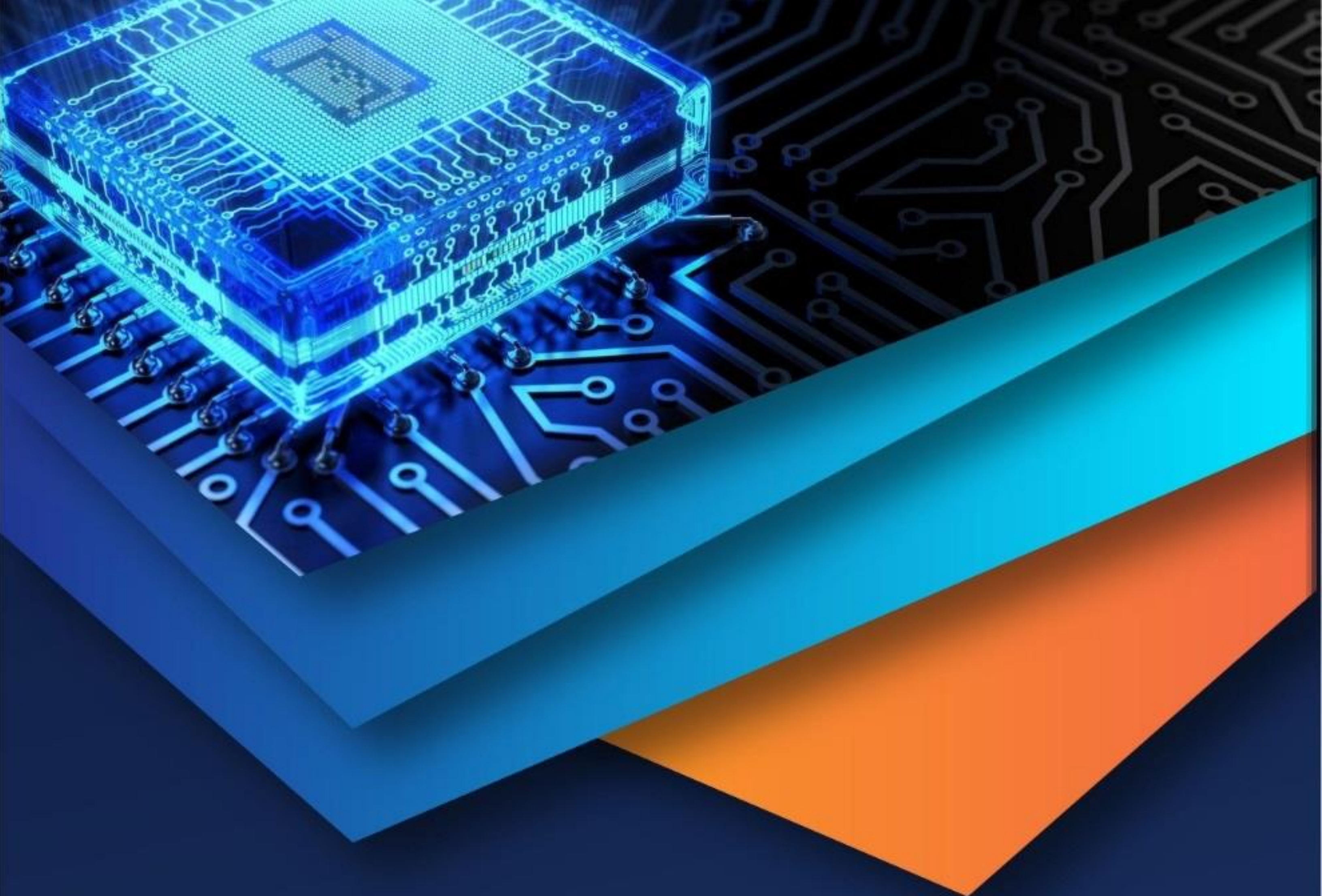

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