BRAIN STORMING SESSION

ON

HYDROLOGICAL PROBLEMS AND PERSPECTIVES

IN

WESTERN HIMALAYAN REGION

MARCH 14, 1997

Erosion and Sedimentation Studies using WEPP in Baira Watershed, HP, India

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ABSTRACT

The software Water Erosion Prediction Project (WEPP 95.7) developed by U.S. Department of Agriculture - Agriculture Research Service was applied in Baira Watershed, H.P., India. The WEPP input files were developed for a steep slopes with 3 overland flow elements (OFEs) e.g. forest, pasture and wheat. WEPP was run for ten years for a climate typical of Northern India. The result have shown that about half of the eroded sediment deposited on the hillslope. Once the channel elements were incorporated, then about 90 % of the sediment that entered the channel was deposited. A simplified discussion of a sub watershed as a hillslope with 4 OFEs predicted about 50% greater sediment delivery than did the watershed run with the model.

INTRODUCTION

Soil erosion is universally recognized as a serious threat to human welfare. It is defined as the removal of surface material by wind or by water (Kirkby et al 1980). This paper emphasizes soil erosion caused by water. Soil erosion is a natural process, but it is greatly accelerated by human activity and results in a greater soil loss rate than the rate of soil formation. Vegetation, rainfall, soil and slope are the main factors involved in the erosion process and disturbance of any one of them causes erosion to become a highly significant problem(Sbaa, M., 1990).

Soil erosion is the greatest natural destroyer of land resources. In addition to losses of soil, many other problems are created by soil erosion like siltation of reservoirs, canals and rivers, deposition of unfertile material on cultivated lands, harmful effects on water supply, fishing, power generation and most important the destruction of fertile agricultural land (Singh et al., 1981).

Reliable soil loss estimation is a valuable design, extension and planing tool. Its most immediate advantage is that a well defined conservation objective can be formulated, namely, to reduce estimated soil losses to specified acceptable levels and thereby ensure the maximum safe economic use of each piece of land. The present paper deals with predicting erosion and sedimentation for a Western Himalayan watershed in India.

REVIEW OF LITERATURE

Attempts have been made for many years to quantify the erosion effect of cropping practices in numerical form which could allow erosion prediction for a given circumstances (Hudson, 1971). The

soil erosion research on rangelands was initiated in 1912 by Sampson and associates (Renard and Foster, 1985). However, the systematic study on the soil loss prediction from agricultural fields was conducted in the United States beginning around in 1930's. Data for derivation and field use of equations were obtained from the field runoff plots. Zingg (1940) proposed a relationship of soil loss to slope length raised to a power. In 1947 a committee chaired by Musgrave proposed a soil loss equation having some similarity to the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith in 1965. This equation was later refined with more recent data from runoff plots, rainfall simulations, and field experience (Wischmeier and Smith, 1978).
The USLE has been the workhorse of erosion prediction and conservation planning technology in the United States and even worldwide (Renard et al., 1994; Nicks and Lane, 1989; Simanton et al., 1987). The USLE is an empirical factor-based Equation. The equation has served and continues to serve our needs in erosion prediction well. However, like most technology that are at least 30 years old- with components that are similar to those derived nearly 50 years ago- there are some shortcomings. A major limitation is the effort needed to apply the USLE to new crops and management techniques and inability to satisfactorily apply the USLE to different situations than those for which it was developed (Laflen et al., 1991).

The R1R4SED model was intended for modeling erosion and sedimentation from the forested mountainous watersheds. However, the channel routing component of this model was a weakest link in attempting to model the erosion and sediment transport processes. Secondly, the model was not extensively tested for the larger watersheds. The performance evaluation of the model was limited to the smaller watersheds (0.1-2.5 square miles) on Idaho Batholith watershed. Therefore, the performance evaluation of this model on other watersheds was recommended (Hennes and Potyondy, 1985).

The Ephemeral Gully Erosion Model (EGEM) was good for smaller ephemeral gullies developed in agricultural areas. The model is good for gullies up to the tillage depth with a maximum depth of 18 inches. The erosion component in this model was a combination of empirical relationships and physical process to compute the width and depth of the ephemeral gully based on hydrology input (Laflen., J.M. 1988).

Agricultural Non Point Source Pollution Model (AGNPS) is intended to provide basic information on water quality for classifying non-point-source pollution problems in agricultural watersheds. The model provides output on hydrology, with estimates of both volume and peak runoff, and on sediment, with estimates of upland erosion, channel erosion, and sediment yield. Along with these, the model will give estimates of the pollutants nitrogen (N), phosphorus (P), and chemical oxygen demand (COD), in units of concentration and mass, contained in the runoff and the sediment. The outputs can be examined for either a single cell or for the entire watershed. This information may then be used to rate the watershed objectively against other watersheds, to further pinpoint water quality problems, and to investigate possible solutions to these problems (Young, et al., 1991).

A recent erosion prediction technology is the Water Erosion Prediction Project (WEPP). It is based on fundamentals of stochastic weather generation, infiltration theory, hydrology, soil physics, plant science, hydraulics, and erosion mechanics. The model is process based and can be extrapolated to a broad range of conditions (D.C. Flanagan et al., 1995). Ellison (1947) hypothesized that soil erosion is a process of detachment and transport. However, in the WEPP model there are three processes of erosion: detachment, transport and deposition. The WEPP uses the rill-interrill concept of describing sediment detachment (Foster et al., 1981).

Interrill erosion is the detachment and transport by raindrops and very shallow flow, such as occurs on row side slopes. Interrill erosion is estimated as a function of interrill slope and of the square of rainfall intensity, modified by surface cover and crop canopy. Rill erosion is the detachment by flowing water. Rill erosion is estimated as a linear function of excess hydraulic shear (Laflen et al., 1991). The Yalin sediment transport equation (Yalin, 1963) is used to estimate sediment transport in channels and rills. Deposition in flowing water is computed on the basis of sediment load, transport capacity, and the fall velocity of the transported sediment. Deposition in impoundments is computed similarly to that in the CREAMS model (USDA, 1980; Laflen et al., 1991). Research for estimating soil erodibility has been carried out with rainfall simulation on 36 tilled cropland soils, 20 untilled rangeland soils (Laflen et at., 1991 a; Elliot et al., 1993a), and eight forest roads (Elliot et al., 1993b; Foltz, 1994).

STUDY AREA

The present study was conducted on sub watershed basis for Baira Nalla above Tissa, district Chamba (H.P.), India. The study area is between latitudes 32^0 47' and 33^0 02', and longitudes 75^0 57' and 76^0 23' (Fig.1). The study area is on the southern slopes of Pir Panjal range in the Western Himalayas. The area of Baira Nalla is 585 km^2 . In this study the model was applied for Balsio sub watershed of Baira Nalla and accounts about 1/3 rd of the watershed area. The elevation varies from 1600 m to 4400 m above mean sea level. The study area has steep slopes with "V" shaped valleys.

There are two types of soils dominate in the area. The upland soil is derived from quartzite parent material and is sandy with moderately high infiltration rates. At lower elevations old river terraces contain more clay and have lower infiltration rates than uplands. The soil depths on the upper slopes are shallow and depth varies from 45-60 cm. The main rock types occurring in the study area are dolomite, limestone, philates, mica, schist, and quartz (gray). The Rocks are highly fractured and planes are developing probably due to instability.

Rain occurs mainly during July and August. The area is also affected by Western disturbances during the winter and the precipitation is then mainly in the form of snow at higher elevations. Annual rainfall of 1034 mm, 886 mm, 1433 mm, and 1136 mm was reported during 1980, 1985, 1986, and 1987 respectively for the Chamba district, HP. The temperature during winter is low and remains below freezing for most days from December to February.

ANALYSIS

In an analysis of the Baira watershed, the WEPP input files were developed for a steep hillslopes with 3 overland flow elements (OFE's). These include forest on the top, pasture in middle and wheat at lower elevations in the watershed (Table 1). WEPP was then run for 10 years for climate typical of Northern India. The results are given in Table 2. The average annual precipitation was 1082 mm, including some snow events. The major locations of erosion on the hillslopes were at the upper parts of the pasture where slope was still 60%, and at the upper part of the wheat element where the slope was still 20%.

Table- 1 Upland OFE Summary

Attributes	OFE 1	OFE 2	OFE 3
Vegetation	Forest	Pasture	Wheat
Length	160 m	180 m	160 m
Steepness	60%	20%	10%

The three hillslope elements (size 1000 m*500m on top, 2500 m * 500 m on both sides of the channel) were then combined with a channel element into a sub watershed. The channel had a gradient of 9 % and relatively non erodible soil. To model a larger watershed this entire sub-watershed was then modeled as a hillslope with 4 OFE's. The final OFE representing a channel element with a slope of 10% at the top and 9% at the bottom. The soil developed for the sub watershed channel was used for the fourth element. Subsequently, the model was then run for large Balsio sub watershed representing 8 large hillslope elements and 4 channel elements. Hillslope element lengths varied from 1500 m to 8000 m for the 19500 ha sub watershed. The gradient of the channel was set at 8 %. WEPP was run for 10 years for this large sub-watershed.

RESULTS AND DISCUSSION

The results from the hillslope, the small sub watershed, and the large sub watershed were analyzed and a summary is presented in Table-2. The results for all three cases have shown that about half of the eroded sediment was deposited on the hillslope. Once the channel was incorporated, there was considerably more deposition in the channel, or about 90 percent of the sediment that entered the channel.

Table-2 Results of Baira Watershed, HP, India

Item	Hillslope	Small sub-watershed	Large sub-watershed
1. Area, ha	50	301	19560
2. Storm Runoff, mm	81.7	78.9	40.6
3. Average upland erosion, t/ha	187.00	137.00	21.00
4. Average sediment delivery, t/ha	80.5	10.0	1.38
5. Sediment Delivery Ratio	0.43	0.076	0.066

The small sub watershed delivered about 3000 t/yr of sediment, or about 3 tonne of sediment for every meter width. When the complex 4 OFE hillslope was developed for the large sub -watershed scenario (Balsio sub watershed), the predicted results show that about 32% of the detached sediment was delivered into the main channel, which was about 4.6 t/yr/m width. Hence, the 4 OFE hillslope model appears to be over predicting the small sub-watershed yield by about 50%. As the sediment delivery from the main river is limited by the transport capacity of the main channel, the prediction of upland erosion is not so critical as the dominant process is channel transport capacity. With further calibration, it may be possible to adjust the hillslope geometry to get a better prediction from the hillslope modeling the sub watersheds.

The rate of soil erosion in the study area is very high. Therefore, it is need to evolve an appropriate methodology to minimize the soil erosion rate in the watershed. In this connection, integrated approach for land and water management should be adopted in the study area. The major attention should be given on applying appropriate vegetation cover and Erosion Control Blankets specified for the study area. The bare soil should be kept protected with an appropriate vegetation cover. Grazing, agricultural and deforestation activities should be performed with care. The major construction activities including roads, dams and buildings should be accomplished with specified erosion control blankets. The agricultural activities should be performed on contours.

CONCLUSIONS

The USDA-WEPP model is a suitable tool available today to model erosion and sediment problems successfully almost from every land . The WEPP was applied to fairly large heterogeneous mountainous watershed dominant with forest, pasture and wheat in Northern India. The results have shown that about half of the eroded sediment was deposited on the hillslopes. However, while incorporating channel element with the hillslopes, the sediment deposition was considerably increased in the channel. This channel deposition was about 90% of the sediment that entered the channel.

ACKNOWLEDGMENT

This paper was initiated and developed to its draft form when the first author was a Visiting Scientist at the University of Idaho, Moscow, USA. The first author of this paper would like to thank to Dr. S. M. Seth, Director, and Dr. P.V. Seethapathi, Scientist F & National Project Coordinator (UNDP), National Institute of Hydrology, Roorkee, U.P., India for sponsoring and funding support to visit the University of Idaho to pursue the advanced training in the area of forest hydrology. The author is also thankful to Dr. K.S. Ramasastri, Scientist F, Dr. S.K. Jain, Scientist E, and Dr. D.K. Agrawal, Scientist C, National Institute of Hydrology, Roorkee, U.P., India for guidance and cooperation.

REFERENCES

Elliot, W.J., J.M. Laflen, and G.R. Foster. 1993a. Soil Erodibility Nomographs for the WEPP model. ASAE Paper No. 932046, St. Joseph, MI.

Elliot, W.J., R.B. Foltz, and C.H. Luce. 1993b. Validation of the WEPP model for Forest Roads. ASAE Paper No. 932502, St. Joseph, MI.

Ellison, W.D. 1947. Soil Erosion studies, Part 1. Agr. Eng 28: 145-146.

Flanagan, D.C., J.C. Ascough II, A.D. Nicks, M.A. Nearing and Laflen. 1995. Chapter 1, NSERL Report No. 10, USDA-ARS-MWA, 1196 Soil Building, West Lafayette, Indiana, USA.

Foltz, R.B. 1994. Sediment Reduction from the use of Lowered Tire Pressures. ASAE Technical Paper No. 942244, Warrendale, PA.

Foster, G.R., L.J. Lane, J.D. Nowlin, J.M. Laflen, and R.A. Young. 1981. Estimating Erosion and Sediment Yield on Field Sized Areas. Trans., ASAE 24: 1253-1262.

Hennes, R.W. and J. P. Potyondy. 1985. A Computerized Version of the R1/R4 Sediment Yield Model- Users Guide, Intermountain Region, USDA- Forest Service.

Hudson, N. 1971. Soil Conservation. B.T. Batsford Limited, London WI.

Kirkby, M.J. and R.P.C. Morgan. 1980. Soil Erosion. John Wiley and Sons Ltd, 109-124.

Laflen, J.M. 1988. Ephemeral Gully Erosion Model- User Manual, USDA- Agricultural Research Service.

Laflen, J.M., L.J. Lane, and G. R. Foster. 1991. WEPP : A New Generation of Erosion Prediction Technology. J. Soil and Water Conservation, Jan-Feb: 34-38.

Laflen, J.M., W.J. Elliot, J.R. Simanton, C.S. Holzhey, and K.D. Kohl. 1991 a. WEPP Soil Erodibility Experiments for Rangeland and Cropland Soils. Jour.of Soil and Water Cons. Soc., 46 (1), 39-44.

Nicks, A.D., L.J. Lane. 1989. Weather Generator. In L.J. Lane and M.A. Nearing (Eds.) USDA-Water Erosion Project: Hillslope Profile Model Documentation. NSERL Report No.2, National Soil Erosion Res. Lab., USDA, West Lafayette, Indiana.

Renard, K.G., and G.R. Foster. 1985. Managing Rangeland Soil Resource: The Universal Soil Loss Equation. Rangelands, 7 (3), 118-122.

Renard, K.G., J.M. Laflen, G.R. Foster, and D.K. Mc Cool. 1994. The Universal Soil Loss

Equation, Chapter-5, In Soil Erosion Research Methods, 2 nd Ed., 1994, Edited by R. Lal, St. Lucie Press, Delray Beach, Florida, USA.

Sbaa, M. 1990. Evaluation of Runoff and Erosion Prediction by WEPP on Sagebrush Rangelands. Masters Thesis , Civil Eng.. Dept., University of Idaho, Moscow, USA.

Singh, G., R. Babu, and S. Chandra. 1981. Soil Loss Prediction Research in India. Bulletin No. T-12/D-9, Central Soil & Water Conservation Research & Training Institute, Dehradun, UP, India.

Simanton, J.R., L.T. West, and M.A. Weltz. 1987. Rangelands Experiments for the Water Erosion Prediction Project. Paper No. 87-2545, ASAE, St. Joseph, Mich.

United States Department of Agriculture. 1980. CREAMS- A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. Cons. Res. Rpt. 26, Sci. Edu. Admn., USDA, Washington, D.C.

Wischmeier, W.H., and D.D. Smith. 1965. Predicting Rainfall- Erosion Losses from Cropland East of the Rocky Mountains- Guide for Selection of Practices for Soil and Water Conservation, Agr. Handbk. No. 282. USDA, Washington D.C.

Wischmeier, W.H., and D.D. Smith. 1978. Predicting Rainfall Erosion Losses. Agr. Handbk. No. 537. USDA, Washington D.C.

Yalin, Y.S. 1963. An Expression for Bed Load Transportation. J. Hydraulics Div., Proc. ASCE. 89 (HY3): 221-250.

Young, R.A., C.A. Onstad, D.D. Bosch, and W. P. Anderson. 1991. AGNPS- Users Guide, USDA-ARS, Morris, Minnesota, USA.

Zingg, R.W. 1940. Degree and Length of Land Slope as it affects Soil Loss in Runoff. Agril. Eng.. 21: 59-64.

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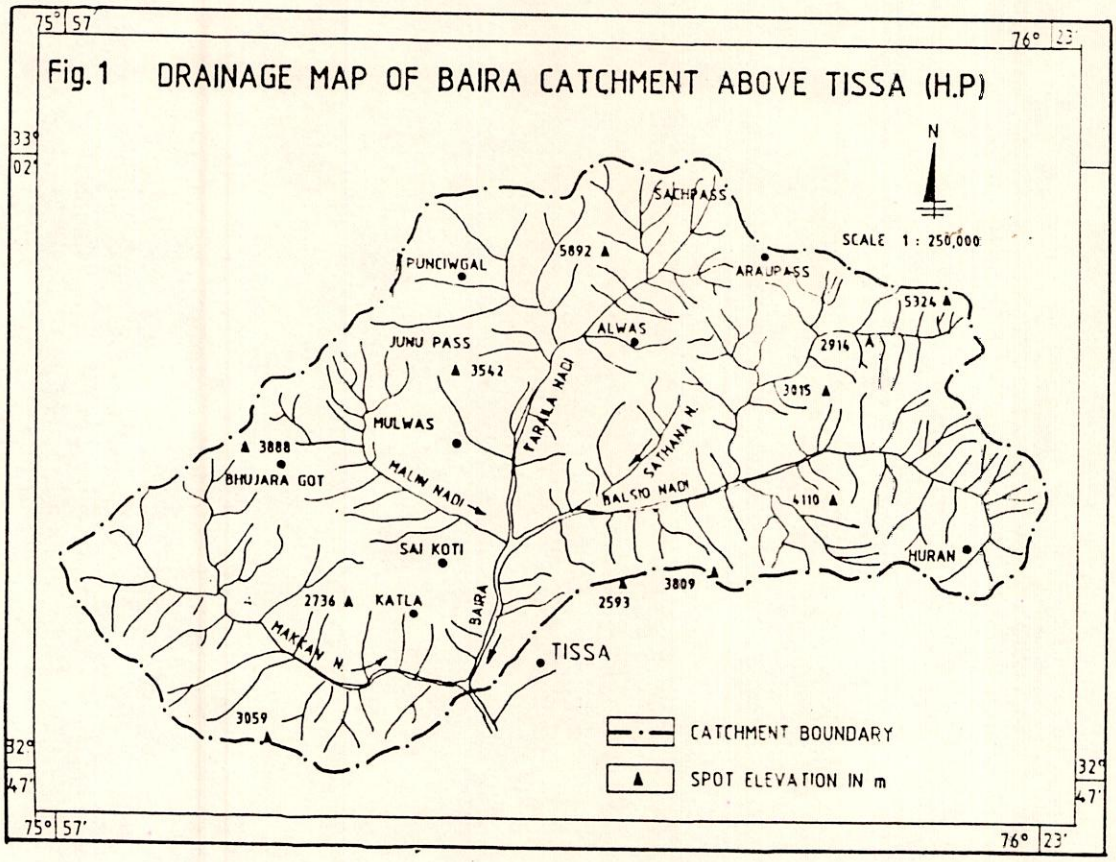
Fig. 1 DRAINAGE MAP OF BAIRA CATCHMENT ABOVE TISSA (H.P)
75° 57'
76° 23'
33° 02'
32° 47'
N
SCALE 1 : 250,000
SACHPASS
5892
PUNCIWGAL
ARAUPASS
5324
ALWAS
JUNU PASS
3542
2914
3015
MULWAS
FARALA NADI
SATHANA N.
3888
BHUJARA GOT
MALNI NADI
BALSIO NADI
4110
HURAN
SAI KOTI
3809
2593
2736
KATLA
BAIRA
MAKKAN N.
TISSA
3059
CATCHMENT BOUNDARY
SPOT ELEVATION IN m