A Simulation Study of Runoff and Soil Loss from Riparian Zone using Answers Model

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Abstract

Riparian areas are important ecosystems in rangelands. Surface runo and soil loss from the ungrazed and grazed areas of sheep Creek Colorado, U.S.A. were simulated using the Areal Non-Point source Watershed Environment Response Simulation (ANSWERS) model. The ANSWERS model parameters were estimated from eld measurements and published literature. The mean runo, soil loss, maximum erosion and maximum deposition rates simulated by the ANSWERS model were signicantly higher ($P \leq 0.05$) for the grazed areas than for the ungrazed areas. Evidence indicated that livestock grazing in the sheep Creek riparian zone reduced inltration, which, in turn, increased runo and soil loss but of minimal biological importance.

Introduction

Mountain riparian areas are multiple use areas. They are the source of water, provide refuge to wildlife and produce palatable forage for livestock and wildlife. Cattle concentrate in summer and graze there untill fall. Detrimental impacts of heavy grazing on vegetation, species composition, bank stability, channel widening, inltration and soil bulk density are often apparent and have been reported by various researchers (Branson *et. al.*, 1981, Kauman *et. al.*, 1983, Kauman and Kruger 1984 and Skovlin 1984, Leininger and Trlica 1986; and Schulz and Leininger 1990). Increasing stocking rates often increases runo and soil loss. Giord and Hawkins 1978, Branson et. al., 1981 and Blackburn *et. al.*, 1982. Runoff and soil loss increase with increase in slope (Meeuwig 1971 and Schumm 1977).

Availability of high speed computers and improved solution techniques made it possible to simulate watershed behaviour. The ANSWERS model is a physical-based distribution model (Beasley 1977, Beasley and Huggins 1980.) It simulates runo and soil loss in a watershed and considers spatial and temporal variations. However, to-date, it has not been applied to simulate responses of riparian areas, This model was applied to simulate runoff and soil loss using data from ungrazwd and grazed areas of Sheep Creek (Colorado, U.S.A) riparian zone, to determine eects of season-long grazing on them. Flow diagram of ANSWERS model is shown in Figure 1.

Material and Methods

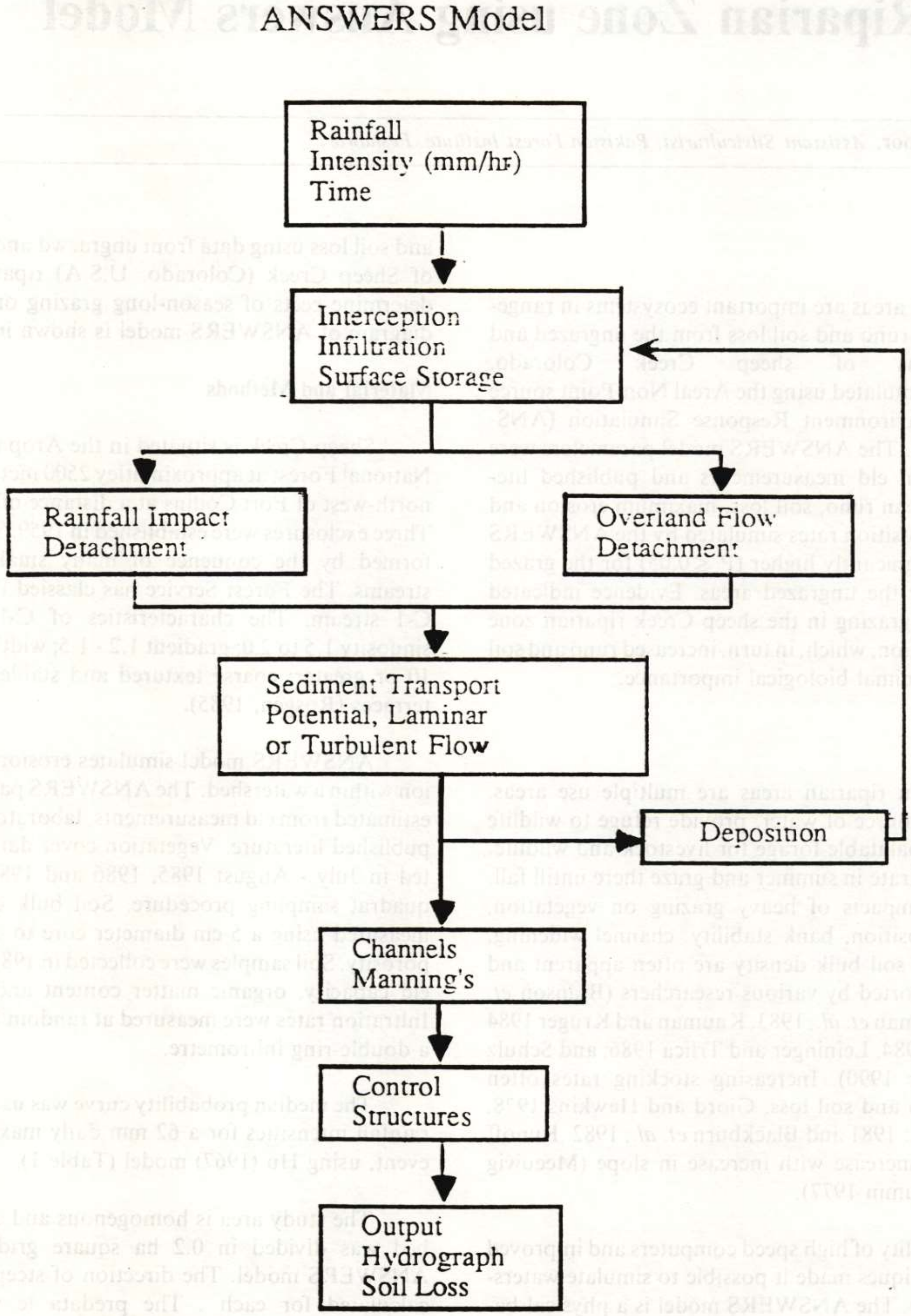
Sheep Creek is situated in the Aropaho-Roosevelt National Forest at approximatley 2500 metre elevation in north-west of Fort Collins at a distance of 80 kilometre. Three exclosures were established in 1959. Sheep Creek is formed by the conuence of many small head water streams. The Forest Service has classied this creek as a C-1 stream. The characteristics of C-1 stream are: sinuosity 1.5 to 2.0; gradient 1.2 - 1.5; width/depth ratio 10 or greater; coarse textured and stable high alluvial terraces (Rosgen, 1985).

ANSWERS model simulates erosion and deposition within a watershed. The ANSWERS parameters were estimated from eld measurements, laboratory results and published literature. Vegetation cover data were collected in July - August 1985, 1986 and 1988 following a quadrat sampling procedure. Soil bulk densities were measured using a 5 cm diameter core to calculate total porosity. Soil samples were collected in 1985 to determine eld capacity, organic matter content and soil texture. Inltration rates were measured at random locations with a double ring inltrometre.

The median probability curve was used to calculate rainfall intensities for a 62 mm daily maximum rainfall event, using Hu (1967) model (Table 1).

The study area is homogenous and at. the watershed was divided in 0.2 ha square grids to run the ANSWERS model. The direction of steepest slope was calculated for each . The predata le was prepared following guide lines given in the manual Information on one (clay loam) soil and two crops (willow and herbaceous) was placed in each cell of the predata le. The same element le was used in all simulations to avoid area eect, as runo and soil loss data are not recorded. ANSWERS

Fig. 1. **Flow diagram of ANSWERS model showing various processes on an element.**



parameters for both ungrazed and grazed area are shown in Table 2. Simulations were run separately for each of the three values of total porosity (TP), field capacity (FP), plant cover (PER), steady state infiltration rate (FC) and the maximum infiltration rate in excess of steady-state infiltration rate (A), estimated from the on-site data.

A paired t-test (Steel and Torrie 1980) was applied to determine significant differencs ($p \leqslant 0.05$) between simulated average values of runoff, soil loss, mazimum erosion and maximum deposition rate from the ungrazed and grazed areas.

Results and Discussions

The statistical analysis (t-test) of the measured parameters showed (Table 3) that the steady-state infiltration rate and plant cover were higher on the ungrazed area when compared with grazed area ($P \leqslant 0.05$). However, the maximum infiltration rate in excess of FC, field capacity and soil bulk density were not significantly different between ungrazed and grazed areas.

Higher infiltration rates and plants cover on the ungrazed area are in agreement with prior research studies (Gamougoun *et. al.*, 1984 Schulz and Leininger 1990). This finding is consistent with the observation of Abdel-Magid *et. al.* (1987) that soil bulk densities were not affected by livestock grazing.

Table 4 gives means, standard deviations and t-values for runoff , soil loss, maximum erosion and deposition rates simulated by ANSWERS model. Both runoff and soil loss were significantly higher ($P \leqslant 0.05$) on the grazed than on the ungrazed area. These differences are attributed to decreased infiltration on the grazed area. The maximum erosion and deposition rates were greater ($P \leqslant 0.05$) on the grazed than on the ungrazed area of Sheep Creek.

The ANSWERS-simulated runoff and soil loss were significantly lower from the ungrazed than on the grazed area. Estimated values are consistent with field measurement; i.e., the higher the infiltration rate the lower the runoff and soil loss (Meeuwig 1971, Gifford and Hawkins 1978, MeGinty et. al., 1979).

The soil at Sheep Creek is classified in the A hydrologic group (USDA, SCS, 1980) and is a deep clayey loam and has very high organic matter content (12 percent). Clayey loam soil with high organic matter content have high infiltration rates and low potential for erosion (Lusby 1970, Branson et. al., 1981). Because infiltration rates were high for both the sites, little runoff was available to transport detached soil particles.

The relation between plant cover and erosion is logistic. The vegetation cover on the ungrazed and grazed area was greater than 70 percent and increase in plant cover beyond this amount will not significantly reduce erosion and soil loss from a watershed (Copeland 1965, Schumm 1977 and Kirkby and Morgan 1980). Apparently livestock grazing did not reduce plant basel cover, which provided appreciably greater protection to soil against the erosive forces of rainfall and surface runoff.

Conclusion

The ANSWERS model simulations gave significantly greater runoff, soil loss, and maximum erosion and deposition rates from grazed areas of Sheep Creek than from the ungrazed sites, although of minimum biological importance. This reflects reduction in infiltration rates in the grazed area by livestock.

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Table 1

Synthetic intensities of a 62 mm daily rainfall event at different time intervals, Red Feather Lakes, Colorado, (1950-1989), using the median probability curve (Huff, 1967) for use in ANSWERS simulations.

Time (min)	PPT(mm)	Rainfall intensities (cm/hr)
0	0.00	0.00
5	8.61	95.75
8	16.61	199.75
11	25.83	184.50
15	37.52	167.00
22	47.36	82.00
42	57.20	29.50
60	62.00	14.50

Fig. 2. Sheep Creek riparian study area (lower exclosure) divided into 0.2-ha elements with channel elements shaded.

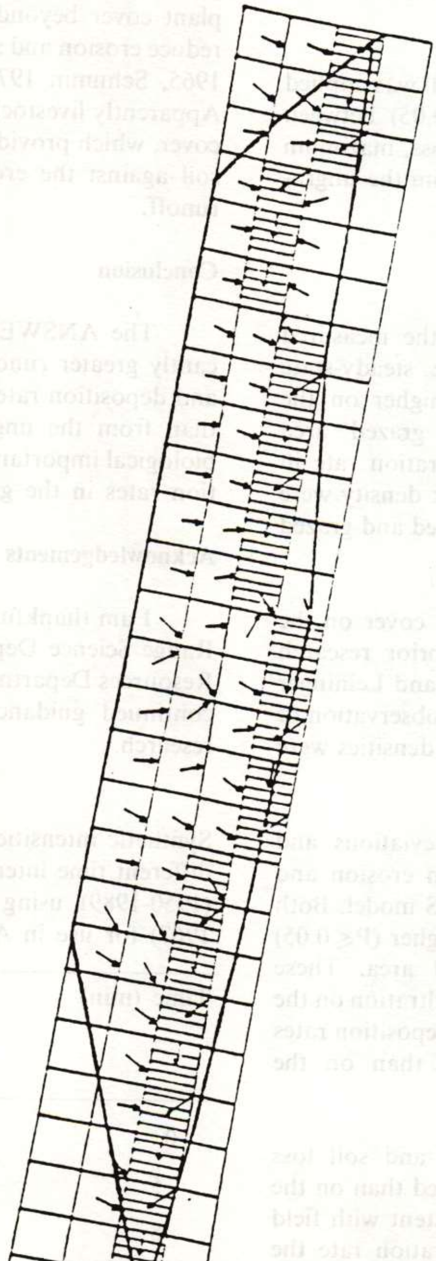

Table 2

Parameter values estimated from field data at Sheep Creek (1988. 1989). All remaining parameters were equal for both ungrazed and grazed simulations.

Parameter	Ungrazed area			Grazed area		
	1	2	3	1	2	3
TP(%)	53.00	58.00	52.00	53.00	51.00	52.00
FP(%)	40.00	31.00	35.00	34.00	33.00	33.00
FC(cm/hr)	16.18	9.33	16.23	5.13	2.10	3.15
A(cm/hr)	4.78	5.75	3.88	1.78	1.53	3.65
PER(%)	95.00	96.00	97.00	85.00	76.00	89.00

(Table 2 continued)

Parameters estimated from the literature and used in the ANSWERS simulations Sheep Creek riparian zone.

Parameters	Ungrazed area		Grazed area	
Antecedent soil moisture(%)	37.000		35.000	
Control zone depth (cm)	15.000		15.000	
Soil erodibility factor (K)	0.240		0.240	
Exponent for decrease in infiltration	0.650		0.650	
Channel width (m)	1.818		1.818	
Manning's (n) (Channel)	0.025		0.025	
	Willow	Herbaceous	Willow	Herbacous
Pot. interception (PIT) (mm)	1.25	1.25	1.25	1.25
Plant cover percent (PER)	22.000	96.000	5.000	83.000
Roughness coefficient (RC)	0.600	0.400	0.600	0.400
Max. roughness height (HU)(mm)	37.500	4.000	37.500	4.000
Manning's(n)	0.150	0.385	0.150	0.385
Cropping and management factor(C)	0.150	0.010	0.150	0.010

Table 3

Results of t-tests for parameters from ungrazed and grazed areas of Sheep Creek riparian zone.

Parameter	Treatment	df	Mean	Stdev	t-value
Plant cover (%)	Ungrazed	2	96.00	1.00	3.26*[1]
	grazed		83.33	6.66	
Field capacity (%)	ungrazed	2	35.00	4.51	1.58 NS[2]
	grazed		33.33	0.58	
Bulk density (gm/cm³)	ungrazed	22	1.26	0.17	0.80 NS
	grazed		1.20	3.33	4.27*
Steady-state infiltration rate (cm/hr)	ungrazed	10	14.00	6.48	4.57*
	grazed		3.56	2.24	
Difference between maximum and steady-state infiltration rate (cm/hr)	ungrazed	11	4.89	4.62	1.32 NS
	grazed		2.67	2.06	

1. Significant at $P \leqslant 0.05$
2. Not significant.

Table 4

Results of simulations using data collected from Sheep Creek riparian zone

Response	Treatment	df	Mean	Stdev	t-value
Runoff (mm)	Ungrazed	2	0.12	0.20	3.14*[1]
	grazed		0.28	0.09	
Soil loss (Kg/ha)	Ungrazed	4	0.37	0.65	5.81*
	grazed		5.23	1.30	
Max. erosion rate (Kg/ha)	Ungrazed	2	25.81	41.80	3.80*
	grazed		478.24	201.75	
Max. deposition rate (Kg/ha)	Ungrazed	4	22.40	35.89	4.95*
	grazed		156.80	30.32	

1. Significant at $P \leqslant 0.05$.

Assumption: No overland flow occurs in the study area from adjoining areas.

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