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Estimating sedimentation from an erosion-hazard rating

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Data from two watersheds in northern California were used to develop an interpretation of the erosion-hazard rating (EHR) of the Coast Forest District as amount of sedimentation. For the Caspar Creek Experimental Watershed (North Fork and South Fork), each EHR unit was estimated as equivalent to 0.0543 cubic yards per acre per year, on undisturbed forest. Experience within the District provided estimates of average excess sediment produced by logging: 17.5 cu. yd/acre for tractor yarding, and 6.3 cu. yd/acre for cable yarding. These estimates based on limited data should be supplemented by additional research to cover wide variations in conditions.

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Retrieval Terms: erosion-hazard index; Caspar Creek Experimental Watershed.

Since November 1974, timber harvests in the Coast District of California have been regulated by State forest practice rules which include an erosion-hazard rating system.[1] The system attempts to produce a scale which measures the relative vulnerability of forested sites to erosion. Ratings are based- upon slope, soil series (or geology, soil depth, and soil texture) and a climatic stress factor which is a function of mean annual precipitation.

The roles of slope, geologic parent material, and climatic stress factor in computing an erosion-hazard rating were derived from analyses by Anderson.[2] Colwell and Zinke[3] determined the effect of differences in soil depth and texture on the relationship between these three variables. The erosion-hazard system now in use also includes a table of potential erosion hazards based upon the modal condition of each slope and soil series. An erosion-hazard rating is the potential erosion hazard multiplied by the climatic stress factor.

To be fully useful, an erosion-hazard rating should be interpretable as a quantity of erosion or sedimentation. In this study, sedimentation data from the Caspar Creek Experimental Watersheds, Jackson State Forest, have been used to develop a quantitative relationship between erosion-hazard ratings and sedimentation. Ideally, such an appraisal should be conducted on a wide variety of areas. Unfortunately, however, Caspar Creek is the only north coast area we know of where sedimentation has been measured under undisturbed conditions.

METHODS

Mean annual sediment production was estimated from data collected between 1962 and 1971 on the north fork of Caspar Creek, and between 1962 and 1967 (before disturbance) on the south fork of Caspar Creek.[4] Suspended sediment discharge was estimated for a normalized streamflow expectancy.[5]

The measured reservoir deposition was adjusted to a long-term normal based upon the mean annual discharge of the nearby Noyo River. Tile adjustment factors were the ratios of the square of the long-term mean annual discharge of the Noyo to the square of its mean annual discharge during the two sampling periods. This mode of adjustment was suggested by H. W. Anderson (pers. commun.) because an earlier analysis[6] indicated that differences in annual suspended sediment loads were proportional to the square of the ratio of their respective mean annual discharges. Suspended sediment was converted to a volumetric measure using a volume weight of 70 pounds per cubic foot (1121 kg/m^3). The sum of the adjusted mean reservoir deposition and the, mean of the normalized suspended sediment load estimates was taken as the mean sediment production of each of the study watersheds. This gives an annual rate of 0.693 cubic yards per acre (1.31 m^3/ha) for the north fork and 0.474 cubic yards per acre (0.896 m^3/ha) for the south fork.

The basic data for computation of the erosion hazard ratings consisted of the U.S. Geological Survey Glen Blair southwest advanced 7th-minute quadrangle; California soil-vegetation survey maps 45A-2, 45A-3, 45B-1, and 45B-4.; and an isohyetal map of northern California.[7] Each map was enlarged by a Zeiss Stereoprett[8] to an approximate scale of 1 inch 1100 feet (1 cm: 132m), and plotted on clear mylar drafting film. This composite map, covering the north fork and south fork watersheds, was then broken into homogeneous units according to mean annual precipitation, slope class (as contained in the Coast District rules), and soil series (fig. 1).

Area determinations were made by tracing each watershed onto a 10-mil plastic sheet; these outlines were then cut from the sheet and weighed on an analytical balance. Each of the homogeneous units within the two watersheds was similarly traced, cut, and weighed. Acreage was determined by cutting and weighing a rectangular piece of plastic of known map area. This yielded a factor which could be used in converting weight of plastic to map area.

Only three soils were found on the experimental watersheds: the Caspar (7.61 percent), the Mendocino (10.98 percent), and the Hugo (81.41 percent). Three slope classes were represented: less than 30 percent, 30 to 50 percent, and 51 to 70 percent. All sites had a mean annual precipitation of either 45 or 50 inches (1143 or 1270 mm). In spite of this rather narrow range of fundamental variables, erosion hazard ratings computed ranged from 1.7 to 113.4 for the North Fork and 1.7 to 97.2 for the South Fork (*table 1*).

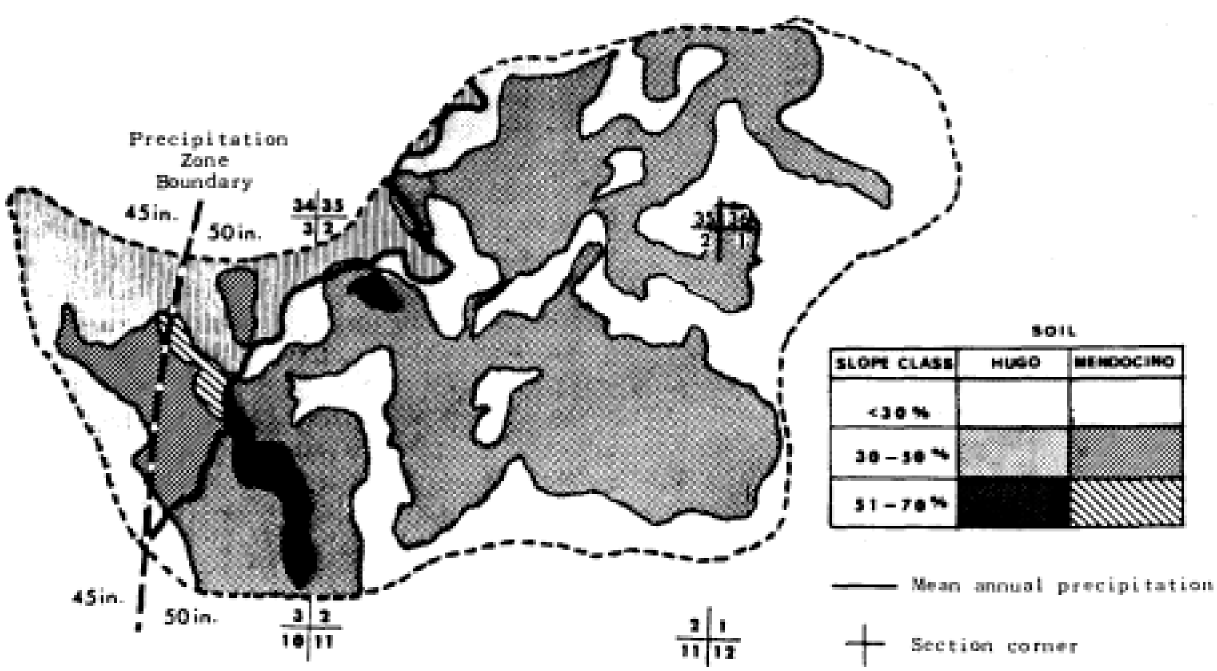

Figure 1-Homogeneous soil and slope classes were mapped as shown here for the north fork of Caspar Creek.

Table 1-*Erosion-hazard rating, Caspar Creek, Jackson State Forest, California*

Area (Acres) (1)	Proportion of watershed (2)	Soil series (3)	Slope (4)	Mean annual precipitation (5)	Potential erosion hazard (6)	Erosion-hazard rating (7)	Proportional erosion-hazard rating (col. 2 x col. 7)' (8)
			Percent	*Inches*			
North fork:							
103.37	0.08133	Mendocino	<30	45	16	27.2	2.21
56.53	.04448	Mendocino	<30	50	16	43.2	1.92
27.17	.02138	Mendocino	30-50	45	24	40.8	.87
42.82	.03369	Mendocino	30-50	50	24	64.8	2.18
15.56	.01224	Mendocino	51-70	50	42	113.4	.79
412.87	.32484	Hugo	<30	50	1	2.7	.88
586.90	.46176	Hugo	30-50	50	2	5.4	2.49
22.78	.01792	Hugo	51-70	50	4	10.8	.19
South fork:							
83.20	.08627	Hugo	<30	45	1	1.7	.15
255.00	.26442	Hugo	<30	50	1	2.7	.71
120.17	.12461	Hugo	30-50	45	2	3.4	.42
264.40	.27417	Hugo	30-50	50	2	5.4	1.48
49.44	.05126	Hugo	51-70	45	4	6.8	.35
22.13	.02294	Hugo	51-70	50	4	10.8	.25
83.15	.08622	Caspar	<30	45	6	10.2	.88
24.54	.02544	Caspar	<30	50	6	16.2	.41
16.94	.01756	Caspar	30-50	45	18	30.6	.54
45.38	.04705	Caspar	51-70	50	36	97.2	4.57

[1] Mean erosion-hazard rating: North fork, 11.53; South fork, 9.76.

Table 2-*Estimates of increased erosion from skyline-logged areas*

Location	Silvicultural method	Measure of erosion	Ratio, logged to unlogged
Idaho[1]	Clearcut	Debris dams	1.6
Oregon[2]	Clearcut	Total sediment load	3.3
Idaho[3]	Group selection	Infiltrometer	3.8
Oregon[4]	Clearcut	Landslide inventory	9.8

Sources:

[1] Megahan, W. F. 1972. *Logging, erosion, sedimentation - are they dirty words? J.* For. 70 (7):403-407.

[2] Fredriksen, R. L. 1970. *Erosion and sedimentation following road construction and timber harvest on unstable soils in three small western Oregon watersheds.* USDA Forest Service Res. Paper PNW-104, 15 p. Pacific Northwest Forest and Range Exp. Stn., Portland, Oreg.

[3] Bethlahmy, Nedavia. 1967. *Effect of exposure and logging on runoff and erosion.* USDA Forest Service Res. Paper INT-61, 7 p. Intermountain Forest and Range Exp. Stn., Ogden, Utah.

[4] Dyrness, C. T. 1967. *Mass movements in the H. J. Andrews Experimental Forest.* USDA Forest Serv. Res. Paper PNW-42, 12 p., Pacific Northwest Forest and Range Exp. Stn., Portland, Oreg.

RESULTS AND CONCLUSIONS

The mean erosion-hazard rating of the north fork was 11.53. Calculation (0.693 yd/ac ÷ 11.53) yielded mean annual sedimentation of 0.0601 cubic yards per acre per EHR unit (0.114 m^3/ha/EHR unit). The mean erosion-hazard rating for the south fork. was 9.76, yielding 0.04860 cubic yards per acre per EHR unit (0.092 m^3 /ha/EHR unit). They average 0.0543 cubic yards per acre per EHR unit (0.103 m^3 /ha/EHR unit).

This factor of approximately 1/18 cubic yard of sediment per acre per year per unit (1/10 m^3/ha/yr/EHR unit) is a first approximation to the significance of erosion-hazard ratings for undisturbed watersheds. What then might be the expected erosional cost of timber harvest? Increased sedimentation and erosion have been reported in numerous studies of the effects of logging (*table 2*). Undoubtedly, the magnitude of the increase depends on the individual logging operation as well as on the elements that go into the computation of the Coast District erosion-hazard rating. The most important considerations probably are the yarding method used, the amount of roads, and the magnitude of storms actually experienced following the harvest. The average increase over the undisturbed value in the harvest studies shown in *table 2* is a factor of about 4.6. The data are for skyline yarding, however, whereas tractors are still the norm in the Coast District. A preliminary analysis of erosion (as distinct from soil displacement by yarding) in the Coast District has revealed that tractor operations result in about 2.8 times more erosion than cable yarding. Combining these two factors, we conclude that the typical Coast District harvest would result in about 13 times the erosion that would occur on undisturbed forest.

If this is true, then the total erosional "cost" of the timber harvest would be estimated at 0.7 cubic yards per acre per EHR unit (1.3 m^3/ha/EHR unit). If cable yarding rather than tractor yarding is used, the amount would be reduced to about 1/4 cubic yard per acre per EHR unit (1/2 m^3/ha/EHR unit). Because the median erosion-hazard rating in the Coast District[9] is about 25, these estimates suggest that the average cable yarding area produces 6.3 cubic yards per acre (11.9 m^3/ha) excess sedimentation and the average tractor-yarded operation produces 17.5 cubic yards per acre (33.1 m^3 /ha). These estimates include neither the soil displacement resulting from skid trails or yarding disturbances, nor the erosion resulting from the accompanying road network.

The relationship developed here, though useful as a first approximation of quantification of the Coast District erosion-hazard rating, is limited in that it is based on data that represent only a meager portion of the variability found in the District. It would be highly desirable to have a large number of similar estimates, covering the full range of the important variables making up erosion-hazard rating. Only after erosion-hazard ratings have been quantified will it be possible to begin making realistic economic choices concerning the regulation of forest practices.

NOTES

[1] California State Board of Forestry. 1974. *Initial forest practice rules, Coast Forest District*. 45 p.

[2] Anderson, H. W. 1972. *Evaluating sedimentation and stream flow turbidity hazards in wildland use*. Report on file, Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 48 p.

Anderson, H. W. 1974. *Sediment deposition in reservoirs associated with rural roads, forest fires, and catchment attributes*. Proc. Int. Symp. on Man's Effect on Erosion and Sedimentation, UNESCO-IAHS, Paris, Sept. 1974. p. 87-95.

[3] Colwell, Wilmer L. (State Cooperative Soil-Vegetation Survey) and Dr. Paul J. Zinke (Department of Forestry and Resource Management, University of California, Berkeley) supplied most of the soils expertise used by the group which prepared the first draft of the Coast District's erosion-hazard rating. H. W. Anderson and R. M. Rice were the other members of the group.

[4] Krammes, J. S., and David M. Burns. 1973. *Road construction on Caspar Creek watersheds-l0-year report on impact*. USDA Forest Service Paper PSW-93, 10 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

[5] Anderson, H. W. 1971. *Relative contribution of sediment from source areas and transport processes*. Proc. Symp. Forest Land Use and Stream Environment, Corvallis, Oreg. 1970:55-73.

[6] Wallis, James R., and Henry W. Anderson. 1965. *An application of multivariate analysis to sediment network design*. Inst. Assoc. Sci. Hydrol. Pub. 67, p. 357-378.

[7] Rantz, S. E. 1969. *Mean annual precipitation in the California region*. U. S. Geological Survey Publ. 1020-01. (2 maps).

[8] Trade names are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

[9] Gagne, Raoul W. 1975. *The erosion hazard rating system of the Coast Forest District*. M.S. thesis. Humboldt State University, Arcata, Calif. 59 p.

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