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Sediment production and delivery from unpaved forest roads in the Sierra Nevada, California

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Unpaved roads can be the dominant source of sediment in forested watersheds. An understanding of road erosion rates, controlling processes, and sediment delivery is needed for both prediction and management, but there is a paucity of data for areas Mediterranean climate. The objectives of this study were to: (1) measure sediment production rates from forest roads; (2) determine the key controlling factors; and (3) assess whether the runoff and sediment from unpaved roads is being delivered to the stream network.

The study was conducted over three wet seasons in the mixed conifer zone of California's Sierra Nevada at elevations ranging from 900 to 2000 m. Annual precipitation is about 1300 mm, but this falls predominantly as snow at the higher elevations and at lower elevations during colder storms. Sediment production was measured from 27-65 road segments over three wet seasons using sediment fences. The measured variables for each segment included road surface area, segment slope, road surface type, elevation, precipitation, soil type, estimated usage, and grading. Sediment delivery was assessed by measuring the length of sediment plumes or rills from 285 road segments, and whether these extended to a stream channel. The length of these features and the degree of connectedness was related to the road and site characteristics.

In the first wet season the mean sediment production rate for unpaved roads was 0.81 kg m^{-2}, but this dropped to approximately 0.23 kg m^{-2} in the both the second and the third wet seasons. This decline in the second and third years of the study was due to below-normal precipitation and the large decline in rainfall erosivity because most of the precipitation fell as snow. Sediment production rates were reduced by

at least an order of magnitude by placing approximately 10 cm of coarse gravel on the road surface. Fifty-four percent of the variability in road sediment production can be explained by the product of road segment area and slope, annual erosivity, and whether the road had been graded in the last two years. Midslope roads on sites with shallow soils had higher sediment production rates than road segments on deeper soils, and this presumably was due to the increase in surface runoff induced by intercepting the subsurface stormflow. The survey of 285 road segments showed that 25% of the road segments were delivering runoff and sediment to the stream channels. Stream crossings accounted for about 60% of the segments that were connected to the stream network. Very few rills or sediment plumes extended for more than 40 m.

The results show that road sediment production and delivery can be reduced by providing and maintaining frequent drainage structures, avoiding locations that generate more road surface and ditch runoff, and reducing the frequency of road grading. The sensitivity of road sediment production rates to the amount of rain versus snow makes it difficult to deterministically predict road sediment production. Since global warming will increase the proportion of rain relative to snow, road sediment production and delivery rates may greatly increase in areas that currently have a mixed- or snowmelt-dominated climatic regime.