Decommissioning Unpaved Forest Roads: Alternatives and Effectiveness

Lee H. MacDonald

Natural Resource Ecology Lab, Colorado State University, Fort Collins, Colorado

Gabriel Sosa-Pérez

Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, Aldama, Chihuahua, México

Increased runoff, sediment production and sediment delivery from unpaved roads are a major concern for National Forests. Key issues are the large number of such roads, their substantial impacts on runoff and erosion, and limited funds for maintenance. Unpaved roads typically have infiltration rates of less than 5 mm/hr, so even low or moderate intensity rainstorms can generate Horton (infiltration-excess) overland flow (Figure 8; Ramos-Scharrón and LeFevor 2016). The low infiltration rates and lack of surface cover make unpaved roads highly susceptible to surface erosion by rainsplash, sheetwash, and rilling or gullying. In hilly areas road cutslopes can further increase runoff by intercepting subsurface flow and converting this to road surface runoff (Wemple and Jones, 2003), which further increases road surface erosion. The concentrated runoff from roads is a particular concern when the runoff and sediment are delivered to a stream, wetland, or lake, with potential adverse effects on water quality and aquatic habitat. Stream crossings also can be a major source of sediment if a culvert fails by plugging or excessive runoff, which results in erosion of the stream crossing, potential diversion of the stream down the road, and/or the creation of rills and gullies as the diverted water flows back to the stream. Roads are also a major cause of landslides in sloping terrain due to the increase in pore pressures from road surface runoff, reduction in hillslope strength due to the cutslope, and increased loading due to the fillslope (Ochiai and Sidle, 2006).

In many National Forests there are numerous legacy roads that are no longer needed and may be adversely affecting other resources, such as wildlife and ecosystem services. Road decommissioning is a common tool to reduce or eliminate the adverse effects of roads. Decommissioning techniques range from simply closing a road to traffic to complete removal by ripping, recontouring, and revegetating (Switalski et al., 2004; Weaver et al., 2015). In addition to treating the road surface it is critical to remove culverts and associated road fills to prevent crossing failures. An intermediate approach is to rip the roadbed with a bulldozer or other machines to reduce surface compaction and increase infiltration (Luce, 1997; Weaver et al., 2015).

This article summarizes current information on the short- and long-term effects of three decommissioning treatments on infiltration, road surface erosion, and road-stream connectivity. We draw upon our recent research in the Arapaho-Roosevelt National Forest where we conducted plot-scale rainfall simulations, measured segment-scale sediment production using sediment fences, and conducted pre- and post-treatment surveys of 12 km of unpaved roads that were decommissioned in early fall 2013. To maximize utility we also present results from other studies and take a process-based approach to help the reader adapt the information to their specific conditions. The three treatments discussed here include road closures, ripping, and ripping plus mulching.

Figure 8: Overland flow on the road surface due to a low infiltration rate. Road runoff also can be enhanced by the exfiltration of water from a cutslope. Note the small fillslope failure caused by the road surface runoff and the suggestion of older cutslope failures on the left-hand side of the picture. Photo courtesy of Drew Coe.

Effectiveness of Road Closure, Ripping, and Ripping plus Mulching

Road Closure

Road closure is the simplest and least costly decommissioning technique, but how much and how quickly does closing an unpaved road reduce surface runoff and erosion? A study in Idaho showed that the saturated hydraulic conductivity of an abandoned road after 30 years with no traffic was still only 7-28 mm (0.3-1.1 inches) per hour (Foltz et al., 2009), which is much lower than the typical value of 40-80 mm/hr for an undisturbed forest. Our rainfall simulation experiments on 1 m^2 plots showed that the infiltration rate for roads closed to traffic for at least 25 years rapidly declined to only 5 mm/hr (Figure 9; Sosa-Pérez and MacDonald, 2017a). Higher infiltration rates could be expected where there is more rapid vegetative regrowth, as root growth and increased biological activity will help reduce soil compaction. However, in peninsular Malaysia a logging road that had been abandoned for 40 years still had a saturated hydraulic conductivity that was only 9% of the value from adjacent hillslopes (Ziegler et al., 2007).

While road closure does not rapidly restore infiltration rates, closure is relatively effective at reducing road surface erosion. Rainfall simulations on an abandoned road in Idaho with 98% ground cover yielded a mean sediment concentration that was only 14% of the value from a similar road that had been subjected to logging traffic two years earlier (Foltz et al., 2009). At the road segment scale median sediment production rates from unpaved roads with no traffic were 6-10 times lower than segments with either low or high traffic (Sosa-Pérez and MacDonald, 2017b).

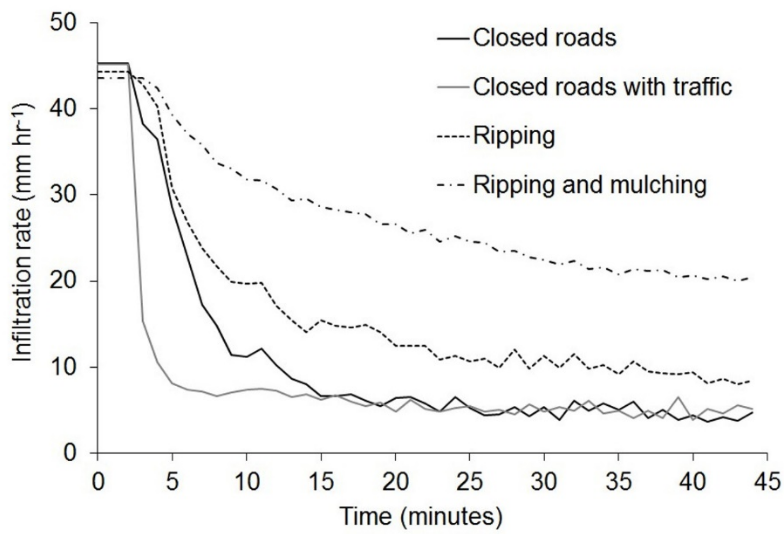

Figure 9: Mean infiltration rates over time for closed roads, closed roads with 80 passes of an OHV, ripped roads, and ripped roads with mulch (n=4 for each treatment). Rainfall was applied on 1 m^2 plots for 45 minutes at 45 mm (1.8 inches) per hour (modified from Sosa-Pérez and MacDonald, 2017a).

There are two main reasons for the much lower sediment production from abandoned or closed roads. First, the surface cover shifts from bare soil (and rocks) to litter and live vegetation. This cover will largely eliminate rainsplash, which is a dominant source of sediment on unpaved roads (Ziegler et al., 2000). Any surface cover also helps slow overland flow, which will reduce particle detachment and sediment transport capacity. The amount of surface cover is arguably the predominant control on surface erosion at the hillslope scale (Larsen et al., 2009; Robichaud et al., 2013). Second, the elimination of traffic greatly reduces the supply of readily-erodible fine sediment because it eliminates the crushing of larger particles by passing vehicles. The passage of vehicles also can pump the finer particles to the surface where they can be more readily eroded by rainsplash and sheetwash (Reid and Dunne, 1984). Our rainfall simulations showed that just 80 passes of an OHV caused a three-fold increase in sediment production (Sosa-Pérez and MacDonald, 2017a).

Ripping

Ripping is the breaking of the road surface by pulling metal tines through the soil with a bulldozer (Figure 10; Luce, 1997; Weaver et al., 2015). Typically there are three vertical tines spaced about 0.7 m (30 inches) apart, and this creates a furrow and ridge topography (Figure 11) without turning over the soil. In some cases the tines have a lateral “wing” at the end to help break up the subsurface compaction. Our data show that ripping can slightly increase the amount of bare soil (Figure 11a, b).

The effectiveness of ripping is controversial in terms of its persistence and the extent to which it may channel surface runoff to create rills or gullies. In Idaho ripping initially decreased the bulk density to 1.50 Mg/m^3 and increased the hydraulic conductivity from 8 to 30 mm/hr, but after 90 mm of simulated rainfall the bulk density increased back up to 1.70 Mg/m^3 and the hydraulic conductivity dropped by half to 15 mm/hr (Luce, 1997). On the Payette National Forest the surface cover was only

Figure 10: A bulldozer with three winged metal tines used for ripping skid trails (left). A close up of a winged tine (right); for scale the black and white squares are 2 x 2 cm. Photos courtesy of Will Olson.

8-27% three years after ripping and the saturated hydraulic conductivity was only 9 mm/hr (Foltz et al., 2007). We also found that infiltration rates on ripped roads dropped to less than 10 mm/hr after about 30 minutes of simulated rainfall (Figure 9; Sosa-Pérez and MacDonald, 2017a), with more infiltration in the furrows.

In our rainfall simulations mean sediment production from the

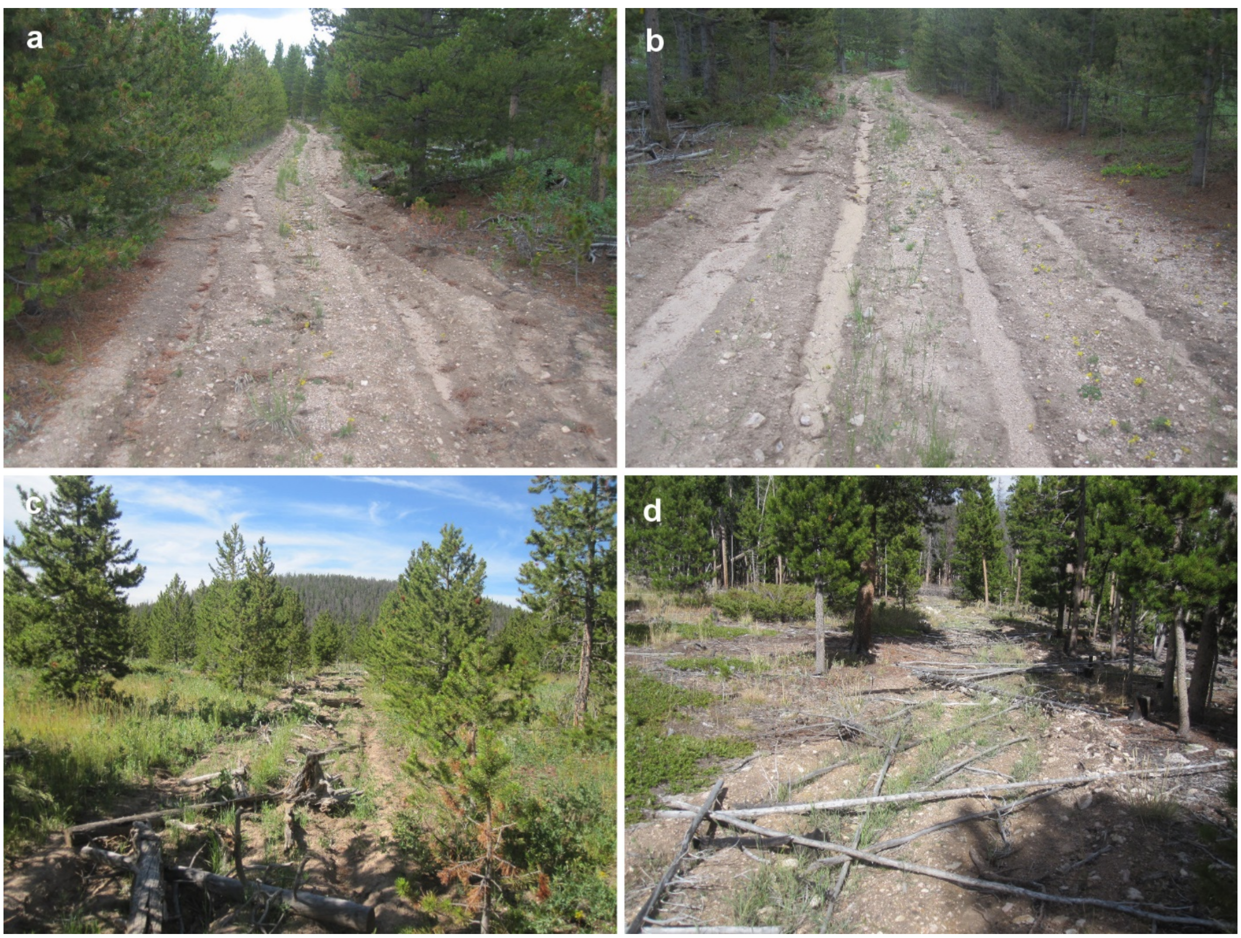

Figure 11: Typical road segments one year after decommissioning. a) Segment with 4% slope that was only ripped. The road surface shows evidence of erosion, but all of the eroded sediment was trapped in the furrows created by the ripping. b) Segment with 9% slope that was only ripped, showing much more eroded, transported, and deposited sediment. c) and d) Road segments that were ripped and mulched showing much less erosion due to the combination of the mulch, greater vegetative regrowth, and greater wood cover compared to the segments that had only been ripped.

ripped plots was 72 g/m², and this was 40% higher than the closed roads (Figure 12). Since sediment production did not decline over time and was strongly correlated to runoff (R^2=0.67, p<0.0001), we infer that sediment production from the ripped plots was not supply limited (unlike the closed roads) (Sosa-Pérez and MacDonald, 2017a). At the road segment scale we found that only three of the 19 ripped segments generated measurable amounts of sediment, and each of these segments were exceptionally long and/or steep (Sosa-Pérez and MacDonald, 2017b). Our road survey showed that most segments had some evidence of surface erosion after ripping—especially the steeper segments—although most of the runoff and sediment was trapped in the furrows (Figure 11a, b).

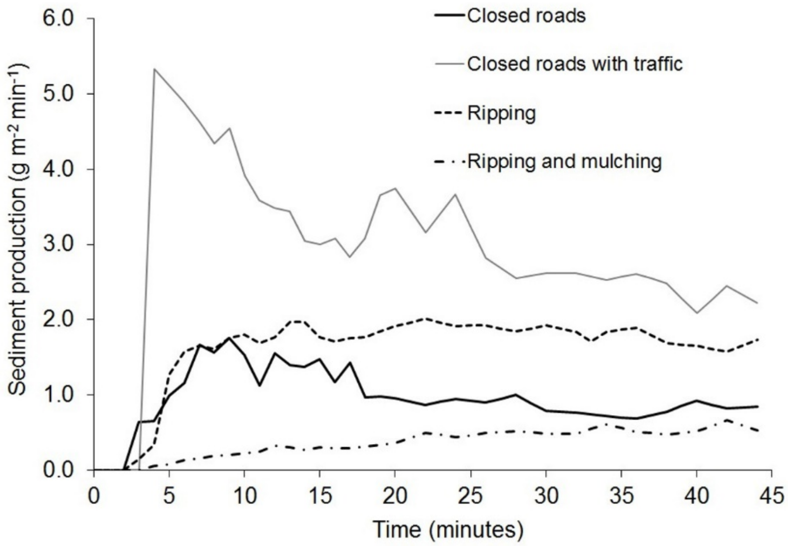

Figure 12: Mean sediment production in grams per minute for 45 minutes of simulated rainfall on closed roads, closed roads with 80 passes of an OHV, ripped roads, and ripped roads with mulch (n=4 for each treatment).

Ripping plus Mulching

There are fewer studies and relevant field data on the effectiveness of ripping plus mulching for road decommissioning. Our study showed that after nearly a year and an exceptionally large storm the mulched segments averaged less than just 30% bare soil, and this was significantly less than the segments that had only been ripped (Figure 11a and b, versus c and d; Sosa-Pérez and MacDonald, 2017b). In our rainfall simulations mulching significantly increased infiltration compared to just ripping, but the infiltration rate on the mulched plots continued to decline and by 45 minutes the infiltration rate was only 20 mm per hour (Figure 9; Sosa-Pérez and MacDonald, 2017a).

Mulching was much more beneficial in terms of reducing mean sediment production from 72 g/m² for the ripped plots to only 16 g/m². However, mean sediment production from the mulched plots did slowly increase over time, indicating a decreasing effectiveness of mulch for reducing sediment production at the plot scale (Figure 12; Sosa-Pérez and MacDonald, 2017a). Mulch effectiveness also was evident at the road segment scale, as none of the nine ripped and mulched segments generated and delivered measurable amounts of sediment to the sediment fences.

The same general results and principles for road decommissioning should also apply to ripping skid trails. Unpublished results indicate that rilling can develop on ripped skid trails in burned areas once slopes exceed about 5-8% (Demirtas, 2017), which is similar to the threshold where we identified extensive rilling on roads after a fire (Sosa-Pérez and MacDonald, 2016). The placement of logging slash or mulch can reduce sediment production and rilling depending on the percent surface cover, amount of ground contact, and the amount and intensity of rainfall and snowmelt.

Road-Stream Connectivity

Prior to decommissioning our road survey documented that 55% of the 185 road segments had a sediment plume, but the mean plume length was only 13 m. These generally short plume lengths can be attributed to the low mean annual precipitation of 460 mm and the relatively gentle mean hillslope gradients of 11% (Sosa-Pérez and MacDonald, 2017b). Thirty percent of the road length was within 10 to 100 m of a stream, but only 10% of the segments (12% of the total road length) had sediment plumes that could be traced to within 5 m of a stream (“connected”).

After ripping or ripping plus mulching only 11 segments had any new deposition on a pre-existing sediment plume, but in each case the segments had been subjected to illegal OHV traffic that flattened the ridges and furrows. This reduced the on-segment storage capacity and allowed the runoff and sediment to flow off the road segment (Sosa-Pérez and MacDonald, 2017b). After decommissioning only four segments (2% of the total road length) were connected to the stream, and the mean length of the sediment plumes for these segments was only 7 m. The short plume lengths and limited connectivity indicate that the primary control on road-stream connectivity is the proximity of a road to the stream. Overall, we found that ripping was effective in trapping much of the sediment on the road surface due to the ridge-and-furrow topography, but this trapping efficiency will most probably decrease over time depending on the amount and intensity of rainfall versus the rate of vegetative regrowth.

Acknowledgements

The authors are very grateful to the US Forest Service's National Stream and Aquatic Ecology Center and the Arapaho-Roosevelt National Forest for their financial and logistical support. We would like to thank Consejo Nacional de Ciencia y Tecnología (CONACYT) and Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP) for their support of Gabriel Sosa-Pérez during his stay at Colorado State University. Steven Yochum and Carl Chambers provided encouragement and helpful comments on an earlier draft of this manuscript.

References

Demirtas, I. 2017. Effects of post-fire salvage logging on compaction, infiltration, water repellency, and sediment yield and the effectiveness of subsoiling on skid trails. M.S. thesis, Michigan Technological University, 100 pp.

Foltz, R.B.; Copeland, N.S.; Elliot, W.J. 2009. Reopening abandoned forest roads in northern Idaho, USA: Quantification of runoff, sediment concentration, infiltration, and interrill erosion parameters. Journal of Environmental Management 90, 2542-2550. DOI: 10.1016/j.jenvman.2009.01.014.

Foltz, R.B.; Rhee, H.; Yanosek, K.A. 2007. Infiltration, erosion, and vegetation recovery following road obliteration. American Society of Agricultural and Biological Engineers 50(6), 1937-1943.

Larsen, I.J.; MacDonald, L.; Brown, H.E.; Rough, D.; Welsh, M.J.; J.H. Pietraszek, J.H.; Libohova, Z.; Benavides-Solorio, J. de Dios; Schaffrath, K. 2009. Causes of post-fire runoff and erosion: water repellency, surface cover, or soil sealing. Soil Science Society of America Journal 73(4): 1393-1407.

Luce, C.H. 1997. Effectiveness of road ripping in restoring infiltration capacity of forest roads. Restoration Ecology 5(3), 265-270.

Ramos-Scharrón C.E.; LaFevor, M.C. 2016. The role of unpaved roads as active source areas of precipitation excess in small watersheds drained by ephemeral streams in the Northeastern Caribbean. Journal of Hydrology 533: 168-179.

Reid, L.M.; Dunne, T. 1984. Sediment production from forest road surfaces. Water Resources Research 20(11), 1753-1761.

Robichaud, P.R.; Lewis, S.A.; Wagenbrenner, J.W.; Ashmun, L.E.; Brown, R.E. 2013. Post-fire mulching for runoff and erosion mitigation, part I: effectiveness at reducing hillslope erosion rates. Catena 105: 75-92.

Sidle, R.C.; Ochiai, H. 2006. Landslides: processes, prediction and land use. American Geophysical Union, Washington, D.C. 312 pp.

Sosa-Pérez, G.; MacDonald, L.H. 2017a. Effects of closed roads, traffic, and two road decommissioning treatments on infiltration and sediment production: a comparative study using rainfall simulations. Catena 159:93-105.

Sosa-Pérez, G.; MacDonald, L.H. 2017b. Reductions in road sediment production and road-stream connectivity from two decommissioning treatments. Forest Ecology and Management 398: 116-129.

Switalski, T.A.; Bissonette, J.A.; DeLuca, T.H.; Luce, C.H.; Madej, M.A. 2004. Benefits and impacts of road removal. Frontiers in Ecology and the Environment 2(1): 21-28. DOI: 10.1890/1540-9295(2004)002[0021:BAIORR]2.0.CO;2

Weaver, W.E.; Weppner, E.M.; Hagans, D.K. 2015. Handbook for forest, ranch and rural roads: a guide for planning, designing, constructing, reconstructing, upgrading, maintaining and closing wildland roads (Rev. 1st ed.). Mendocino County Resource Conservation District, Ukiah, California.

Wemple, B.C.; Jones, J.A. 2003. Runoff production on forest roads in a steep, mountain catchment. Water Resources Research 39(8): 1-17.

Ziegler, A.D.; Negishi, J.N.; Sidle, R.C.; Gomi, T.; Noguchi, S.; Nik, A.R. 2007. Persistence of road runoff generation in a logged catchment in Peninsular Malaysia. Earth Surface Processes and Landforms 32(13): 1947-1970. DOI: 10.1002/esp.1508.

Ziegler, A.D.; Sutherland, R.A.; Giambelluca, T.W. 2000. Runoff generation and sediment production on unpaved roads, footpaths and agricultural land surfaces in northern Thailand. Earth Surface Processes and Landforms 25(5), 519-534.

Management Implications

- Decommissioning options range from simply closing a road and removing culverts to ripping or full eradication. Treatment choice is largely a function of objectives and cost.
- Road closure can rapidly reduce sediment production because the elimination of traffic and increase in surface cover greatly reduces the supply of readily-erodible fine sediment. In contrast, compaction and the associated low infiltration can persist for decades. Slope failures can continue to be an issue due to the persistent hydrologic effects of the road along with the instability associated with cutslopes and fillslopes. To be effective road closure must include the removal of culverts and road fills.
- Ripping does not fully restore the roadbed to a properly functioning hydrologic condition and increases the supply of readily erodible fine sediment. Mulching after ripping increases the infiltration rate, reduces road surface erosion, and can facilitate vegetative regrowth. Mulching is particularly beneficial on steeper segments.
- The effects of ripping and mulching on skid trails is similar to unpaved roads, but in burned areas ripping can induce rilling when off-contour gradients exceed about 5-8%.
- Ripping, or ripping and mulching, are generally effective in reducing road-stream connectivity, and most of the residual connectivity is due to road segments in close proximity to a stream.