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HYDROLOGIC RESPONSES TO FUELWOOD HARVEST AND SLASH DISPOSAL ON A PINYON-JUNIPER DOMINATED GRASSLAND SITE IN THE GILA NATIONAL FOREST

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INTRODUCTION

Pinyon-juniper woodlands extend over an area of more than 19 million hectares in the western United States. In New Mexico alone, pinyon-juniper covers an area of 7 million hectares. Much of this land was once grass and shrubland which was later invaded and eventually dominated by pinyon-juniper as a consequence of man's activities, particularly overgrazing and fire suppression (Evans 1988). Pinyon-juniper woodland has its own place in the ecosystem where it is climax on hillslopes too rocky to have enough understory to carry a fire. Pinyon-juniper woodlands offer certain benefits to man and animals, including firewood, fence posts, poles, pinyon nuts, Christmas trees, outdoor recreation, livestock grazing, and an important habitat for elk and mule deer.

To sustain the supply of pinyon-juniper benefits, a scientifically proven management scheme is necessary. One way to promote these products is by maintaining the health of the land resource by preserving a balance of vegetation types. Also, a greater emphasis on the livestock and wildlife in-

dustries encouraging economic returns would essentially require type conversion from pinyon-juniper woodlands back to grasslands. This would not mean the total elimination of pinyon-juniper, but rather, the creation of a mosaic of vegetation that bears proportionate amounts of grassland and pinyon-juniper woodland to satisfy the legitimate needs of humans and animals.

When considering vegetational conversion, hydrological responses must be given particular attention. Replacing vegetation is a very sensitive operation from a hydrological standpoint (Wood 1988). The aim of vegetation conversion should always be soil and water conservation.

This study reflects an effort to reduce soil erosion and improve other hydrological attributes through the simple techniques of slash disposal associated with tree harvesting. Hydrologic responses to fuelwood harvest and slash disposal under natural conditions in a pinyon-juniper woodland will be studied. The project will quantify over time the effects of fuelwood harvesting and slash disposal on runoff, sediment concentration, sediment production, and bedload. Inferences drawn from this

study will help determine the most reasonable management strategies to minimize accelerated soil erosion and increase phytomass production.

STUDY AREA

Location and Configuration

The study site is in the commercial fuelwood harvesting area of the pinyon-juniper woodland on Spring Mesa in the Black Range District of the Gila National Forest. Specifically, this area lies in Section 36, T9S-T10S, R12W, Catron County, New Mexico. The average elevation is 2245 meters. The experimental site extends over an area of about 20 hectares on three north to south ridges that join on the north end with Spring Mesa. In 1986, four replications of five runoff plots, each 22.1 meters long and 3.6 meters wide, were established to measure hydrological responses to fuelwood harvesting. The slope of runoff plots (5% - 8%) was quite uniform within the blocks but varied slightly among the blocks.

Soil

Site soils have been described as the Lonti-Poley-Rough Broken Land Association. The study site is characterized generally by a thin surface layer of reddish-brown non-calcareous gravelly loam over reddish-brown gravelly clay or heavy gravelly clay loam to a depth of 30 cm to 90 centimeters (Javed 1991). These soils are Lithic Haplustalfs. The sparse understory cover and the high proportion of bare soil contribute to highly erodible soil conditions.

Climate

Climatological data from the nearby Beaverhead Ranger Station show mean maximum and minimum temperatures of 19°C and -1.68°C. Mean annual precipitation according to records of the last 20 years is 319 mm with about 111 frost-free days from June 5 through September 24. Limited precipitation in the form of snow is experienced during December and January. Substantial precipitation is received as short-lived summer rains of mild to moderate intensity (Javed 1991).

On-site climatic data for the growing season during 1989 and 1990 were collected for rainfall, temperature, and relative humidity. The rainfall

data indicated a mean annual rainfall of 325 mm for a total precipitation of 269 mm and 382 mm during 1989 and 1990, respectively. The mean annual maximum and minimum temperature for the growing seasons of 1989 and 1990 were 26°C and 10°C, respectively. The average monthly humidity percentage collected at the research site during the growing seasons of 1989 and 1990 was as low as 37% in the daytime and as high as 82% at night. The humidity was lowest during May and June. It started rising in July when summer rains began and reached a maximum in August. The humidity again showed a gradual decline in September.

Vegetation and Distribution

The study area's vegetation consists of a moderately low tree density of the two-needle pinyon (*Pinus edulis*) and alligator juniper (*Juniperus deppiana*) (Javed 1991). Both pinyon pine and alligator juniper tend to be active reproductively. Scattered throughout, gray oak (*Quercus grisea*) is the only shrub species. The herbaceous growth comprises a variety of grass and forb species. Among grasses, the most plentiful species is blue grama (*Bouteloua gracilis*). Mountain muhly (*Muhlenbergia montana*), wolftail (*Lycurus phleoides*), and squirreltail (*Sitanion hystrix*) are other grasses commonly found in the area. Golden eye (*Viguiera dentata*), Bahia spp., and a few Chenopods are some eye-catching forbs in the area.

MATERIALS AND METHODS

Pre-Treatment Description

In 1986, twenty experimental plots were established in an area where commercial fuelwood harvesters remove pinyon and juniper. Five plots were located in each of four blocks. These experimental units were 25×12 meters and contained runoff plots which were 21.1×3.6 meters or 0.081 hectare. The plot size is the same length and twice as wide as plots used to develop the Universal Soil Loss Equation (Wischmeier 1966). The plots were arranged in a Randomized Complete Block Design. Prior to assigning the intended treatments, these plots were used to collect preliminary data on runoff, sediment yield, and phytomass production during the summers of 1987 and 1988. The objective was to determine variations among the plots under undisturbed natural conditions. The data showed no significant

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differences within the blocks but some slight differences among blocks.

The treatments in addition to the control were:

- clear cut in June 1989 with slash uniformly scattered and burned in October 1989
- clear cut in June 1989 with slash uniformly scattered
- clear cut in June 1989 with slash uniformly scattered and lopped at 60 centimeter height
- clear cut in June 1989 and slash removed

Each experimental unit included a runoff plot and an adjacent 4-meter-wide strip to allow destructive sampling.

RESULTS AND DISCUSSION

Runoff

Seven runoff storms were received in 1989 and nine in 1990, with most storms occurring during July, August and September. Only rainstorms having intensities higher than 25 mm hr⁻¹ produced runoff.

The treatment comparisons by year (Figure 1) revealed that the slash-removed treatment produced significantly higher runoff depth in 1989 compared with control, slash-scattered, slash-lopped, and slash-burned (essentially the same as slash-scattered in 1989) treatments. In 1990 a dramatic increase in cumulative runoff depth was observed for the slash-burned treatment when burning took place at the end of the previous year's growing season. The runoff resulting from the slash-burned treatment was almost 2.5 times more than the control treatment and was also significantly higher than other treatments.

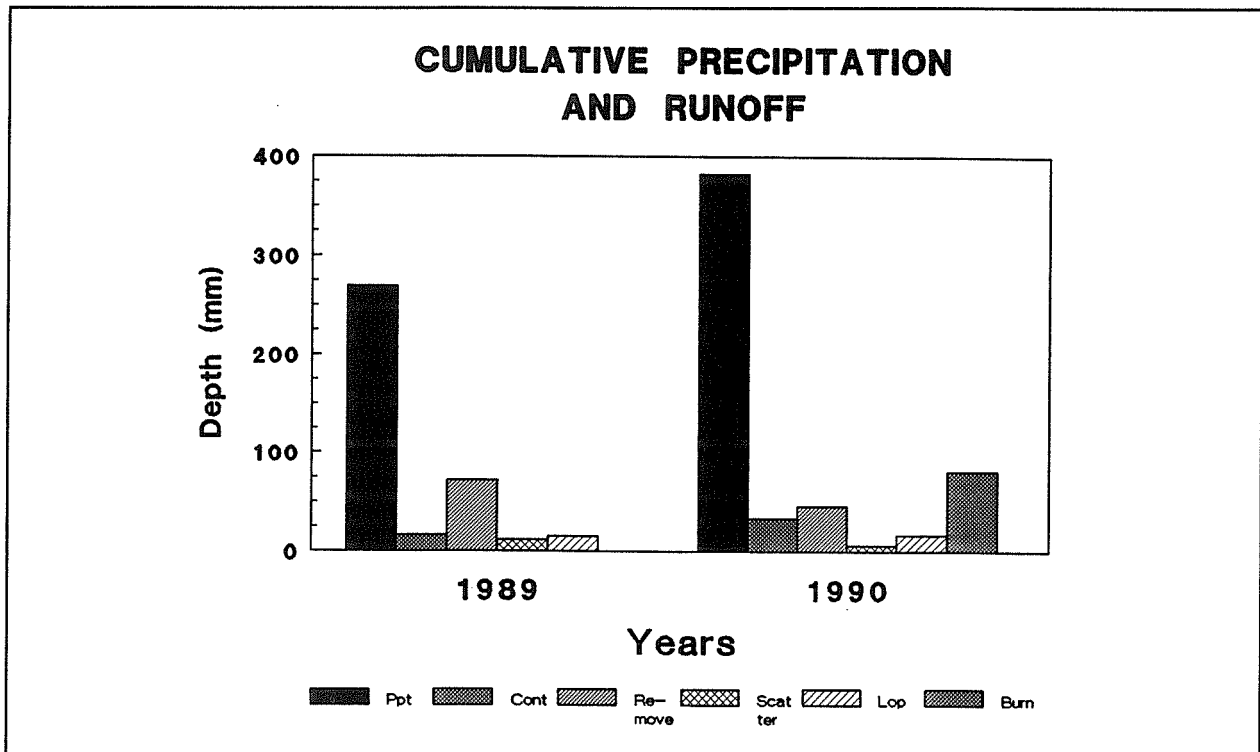


Figure 1. Cumulative precipitation and mean cumulative runoff for each treatment in 1989 and 1990.

The slash-removed treatment was next in runoff magnitude. The obvious reason for increased runoff from the slash-removed treatment in 1989 and slash-burned treatment in 1990 was the absence or small amount of vegetation cover due to complete removal and burning.

The mean runoff depth from the control treatment was higher in 1990 than that in 1989 (Figure 1). This is attributed to the high amount and frequency of precipitation in 1990. The slash-removed treatment responded very differently in 1990 and resulted in lower runoff depth despite a high amount of precipitation compared to 1989. A probable reason for lower runoff in 1990 is again the increased vegetal and litter cover which were negatively correlated with runoff as reported in the aforementioned studies. The slash-scattered treatment exhibited the lowest values in both years from the standpoint of runoff control.

Mean runoff depth was the highest for the slash-removed treatment followed by the control where the slash-lopped and slash-scattered treatments showed roughly the same responses during 1989.

The runoff magnitude was highest for the slash-burned treatment in the subsequent year followed by the slash-removed treatment on all dates. The slash-scattered treatment responded almost the same on all dates in both years and ranked lowest in producing runoff. The slash-lopped treatment was statistically and practically no different than slash-scattered treatment on any of the dates. The treatment by date interaction was also statistically significant in both years. This indicated inconsistency between the mean runoff response of different treatments over dates under the combined effect of precipitation amount and intensity.

Sediment Concentration

Sediment concentration is a measure of water quality. It is a function of runoff and is an important determinant of suspended sediment production.

The overall mean treatment responses were significantly different when the data were combined for the whole growing season (Figure 2). The results were consistent with the runoff variable. In

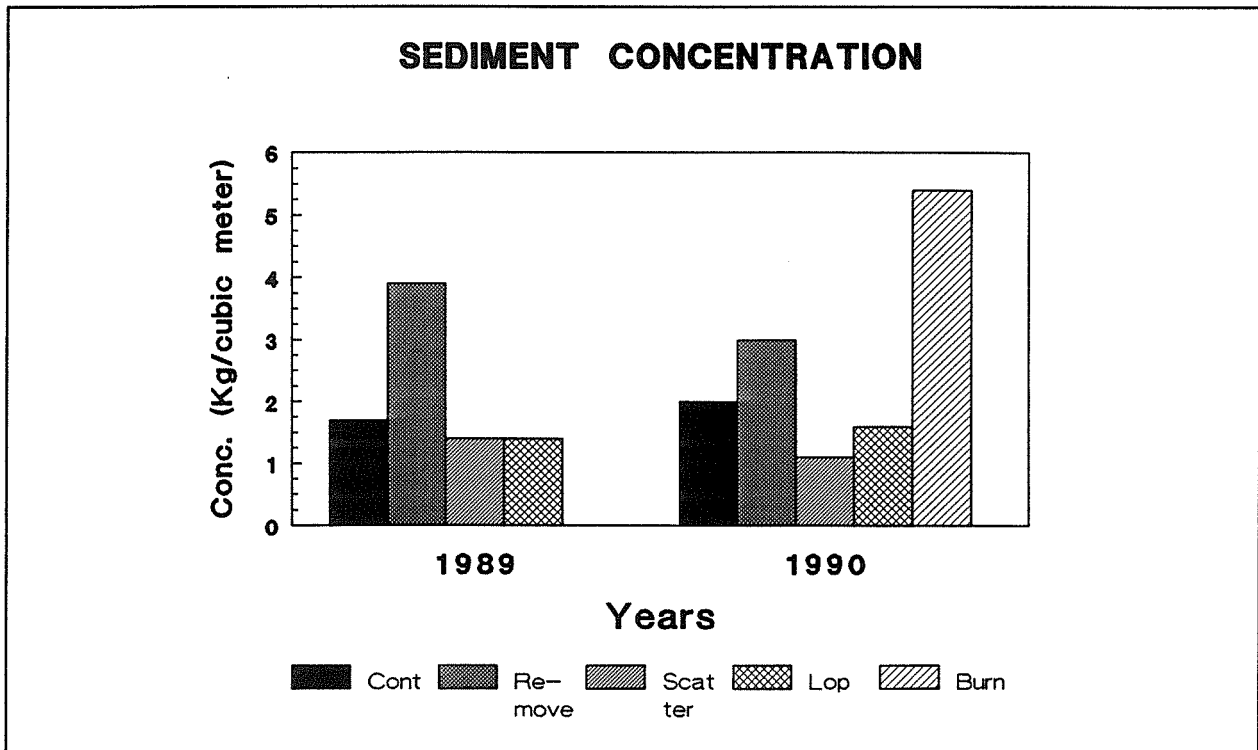


Figure 2. Mean sediment concentration for each treatment in 1989 and 1990.

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1989 the slash-removed treatment was characterized by relatively higher sediment concentration and was found significantly different from the other treatments. The apparent reason for the high sediment concentration was the removal of vegetation cover that exposed the soil to direct rainfall.

The other reason could be greater soil disturbance due to the harvesting and logging operation. The slash-lopped, slash-scattered, and control treatments were not significantly different ($P < 0.10$) from one another. Unlike 1989, the slash-removed treatment in 1990 was also statistically similar to the slash-scattered and the mean sediment concentration was less than the preceding year despite higher precipitation. The major reason for reduced sediment concentration in 1990 was the relatively higher vegetal and litter cover that impeded soil erosion.

The sediment concentration yielded by the slash-burned treatment during 1990 was surprisingly high (Figure 2). Sediment concentration under the slash-burned treatment was significantly higher than all other treatments. In 1990 the control, slash-

removed, slash-lopped, and slash-scattered treatments resulted in nearly the same mean sediment concentration and were statistically no different from one another ($P < 0.10$).

Bedload

Bedload refers to coarse sediments that are rolled along the soil surface by the driving force of runoff during stormflows. This is also a measure of soil erosion. The bedload data were collected and analyzed yearly for each growing season during 1989 and 1990 (Figure 3). Significant differences in mean bedload production were noticed between different treatments in 1989. The slash-removed treatment ranked the highest producing sediments 1.5 times more than the control and approximately 4 times more than the treatments with slash-lopped and slash-scattered treatments. The treatments having slash were also significantly lower from the control treatment in magnitude of bedload. In 1990 the slash-burned treatment produced 3 times more bedload than the control and 11 times more than the slash-lopped or slash-scattered treatment.

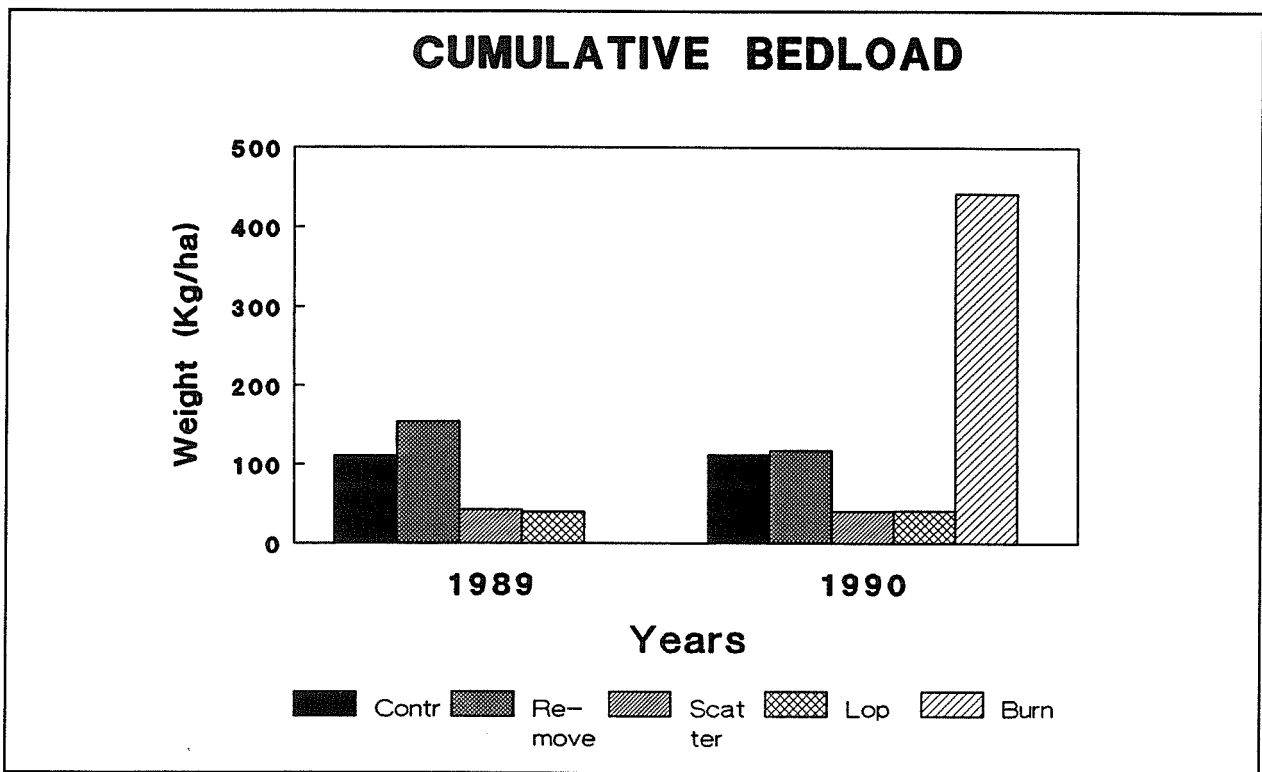


Figure 3. Mean cumulative bedload for each treatment in 1989 and 1990.

When the treatment effects were compared over time, their responses were apparently similar excluding the slash-burned treatment. During 1990 the bedload amounts did not differ statistically ($P < 0.10$) from 1989 except for slash-burned, in spite of the fact that precipitation was 113 mm more in 1990 than during 1989. This stability is attributed to higher phytomass production and more vegetal and litter cover that helped control excessive erosion. The slash-lopped and slash-scattered treatments were similar in both years and ranked the lowest in bedload production. The slash-burned treatment exhibited a geometric increase followed by the slash-removed treatment. This comparison suggests that slash-in-place treatments conserve soil better than the other slash disposal treatments.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results and discussion, the following inferences can be drawn from this study.

- Among the five treatments used to determine the hydrologic responses following tree harvesting, the slash-scattered treatment was found to be the most desirable. The slash-scattered treatment resulted in:
 - the least surface runoff and sediment loss;
 - relatively higher soil moisture;
 - best vegetational response from the standpoint of the highest amount of grass production (this will promote infiltration besides increasing the carrying capacity for grazing purposes); and
 - plentiful vegetal and litter cover to help increase infiltration, impede runoff, and control soil erosion.
- The slash-lopped treatment was found to be as desirable as the slash-scattered treatment but it is more time consuming and expensive.
- Complete removal of slash was harmful from a hydrologic standpoint. It resulted in higher runoff, higher sediment loss and low herbage yield.
- The slash-burned treatment was even more detrimental for all hydrologic variables listed against the slash-removal treatment. Complete removal and the slash-burned treatments are therefore, not recommended. In the long-run these differences would, however, diminish due to more soil stability and higher vegetation cover. Therefore, fire effects must be

monitored in the long-run for soil moisture, sediment loss and vegetational responses.

REFERENCES

- Evans, R.A. 1988. Management of Pinyon-Juniper Woodlands. U.S. Department of Agriculture Forest Service General Technical Report INT-249, Ogden, UT.
- Javed, N. 1991. Hydrologic Responses to Fuelwood Harvest and Slash Disposal on a Pinyon-Juniper Dominated Grassland site in the Gila National Forest, New Mexico. Ph.D. dissertation, Department of Animal and Range Sciences, New Mexico State University, Las Cruces, NM.
- Wischmeier, W.H. 1966. Relation of Field-Plot Runoff to Management and Physical Factors. In *Soil Sciences Society of America Proceedings*. 30:2:272-277.
- Wood, M.K. 1988. Rangeland vegetation - Hydrologic interactions. In *Vegetation Science Applications for Rangeland Analysis and Management*. Edited by P.T. Tueller. London: Klumer Publications.