Alternative Skid Trail Retirement Options for Steep Terrain Logging

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ABSTRACT

In winter 1999-2000 trials of deep tillage and recontouring of skid trails were implemented on three sites in northeastern Kentucky, USA to examine their potential as skid trail retirement options. While effective, current Best Management Practices (BMPs) for trail retirement do not address two potential benefits of retirement: recovery of normal hill slope hydrology and amelioration of soil compaction. Subsoiling and recontouring both significantly reduced soil compaction compared to the control. Preliminary data from runoff sampling indicated none of the treatments were similar to the undisturbed hillside, but recontoured treatments had surface runoff 77% of the control and sediment yield 41% of the control. Subsoil treatments results for sediment yield and runoff volume were between the control and recontour treatments. Production levels from research application of deep tillage showed that the cost could be competitive with conventional BMPs. The recontouring treatment was three to five times the cost of conventional BMPs. General application of deep tillage and site-specific application of recontouring may be cost neutral or reduce net cost of BMPs if treatments increase tree growth or significantly improve water quality.

INTRODUCTION

In the Appalachians, ground-based logging on the steep terrain results in a network of bladed trails on hillsides. These trails are a primary source of erosion and commonly cover from 10-25% of the harvest area (Stuart and Carr 1991; Miller and Sirois 1986; Kochenderfer 1977). The Best Management Practices (BMPs) for trail retirement following the harvest are installation of cross drainage and establishment of vegetative cover. There are two limitations to conventional BMPs: 1) the areas with soil damage (erosion, compaction, destruction of surface soil) continue to accumulate with successive stand entries and 2) the trails disrupt the normal hillslope surface and subsurface water flow leading to increased long-term erosion and potential changes in watershed hydrology.

Addressing these limitations, may provide opportunities for alternative methods for trail retirement including the restoration of the hillslope to the original profile or deep tillage of the trail running surface. While a tracked excavator was the obvious choice for recovery of the fill slope, choices for deep tillage of the trail surface are varied (Andrus and Froehlich 1983). The goals for tillage on these trails include: 1) ameliorate soil compaction, 2) increase infiltration, 3) enhance germination and growth of ground cover and tree growth, 4) avoid acceleration of erosion through trail surface disturbance, and 5) maintain or enhance trail surface drainage.

The entire study was designed to evaluate seedling growth and soil water, surface water and sediment movement across the profile of trails treated with water bars and revegetation (control), recontouring and revegetation (recontour), and subsoiling and revegetation (subsoil). Here we report on the implementation of the recontouring and subsoiling, soil conditions immediately following implementation, and preliminary data from water volume and quality measurements.

METHODS

The research sites were located in northeastern Kentucky, USA in the Cumberland Plateau Physiographic Province. The Cumberland Plateau is characterized by short, steep sloped hills with relatively narrow ridges. The area is generally considered part of the Appalachian region. Two of the sites, Moore Branch and Road Branch were within 3 miles of the other and had similar soil texture (sandy loam). The Fuller Branch site was about 25 miles away and had loamy soils.

For subsoiling applications we chose the Tilth Self-Drafting Winged Subsoiler (subsoiler). Characteristics of the subsoiler were described by Andrus and Froehlich (1983), and its application was described in Andrus and Froehlich (1983), Davis (1990), De Long et al. (1990) and Hogervorst and Adams (1994).

Trials of the subsoiler were completed on trail segments on side hills and ridge tops on the three research sites. The prime mover or tractor was a Caterpillar D6R XL. University of Kentucky staff operated the tractor with the subsoiler. The operator was an experienced tractor operator but had no previous experience with the subsoiler. The manufacturer provided support for subsoiler operation during the study.

The subsoiling was completed in early December 1999 about one week after 25-mm of rainfall. Light rain fell (12-mm)

after the completion of the Fuller Branch Site and before starting operations on the Road Branch and Moore Branch sites. Soils were dry in spite of the rain since extreme drought conditions prevailed for the area throughout the summer and fall 1999. We hired a local contractor with a Caterpillar E120B to complete the fill slope recovery and re-contour on sections of side slope roads. Recontouring occurred during moist soil conditions in late February 2000. We took continuous timing measurements on the subsoiler from video recordings. The excavator was videotaped on three of the six trail sections.

To maintain a complete randomized block design for the experiment, the excavator walked over the subsoiled plots to get to the recontour plots. The excavator compacted surface soil in subsoiled treatments about 3-cm under the track. Scrap lumber was placed every 60-80-cm perpendicular to the trail to distribute the weight of the excavator more evenly across the trail. Soil was compacted about 7-10-cm under the lumber.

Following the application of the treatments we took penetrometer readings in the inner track, middle, and outer track locations at three systematic locations in the treated plot. Readings were taken with a Rimik recording penetrometer with a 130-mm^2 cone according to ASEA Standard: ASAE S313.2 (ASAE 1989). Slopes of the resistance profiles were computed using ordinary least squares. In some control locations the penetrometer could not be inserted because the soil strength exceeded the capacity of the penetrometer. For those locations we estimated the slope using a regression developed from bulk density, soil moisture, and clay content (R^2=0.29). The slopes were modeled using ANOVA with a complete randomized block design.

In Spring 2000 we planted each of the treatments with 20 eastern white pine and 20 tulip poplar bareroot (1-0) seedlings. For three treatments on each site and an undisturbed reference location we installed TDR probes for soil moisture data above the trail, on the trail surface, and below the trail and runoff collection plots on the trail surface. Runoff data presented here were collected from June to August 2000.

RESULTS

Soil

Recontour and subsoil treatments were significant in reducing soil strength on the trail running surface (P=0.0001). Recontour and subsoil treatments were significantly different from the control (P<0.05), but the recontour treatment was not significantly different from subsoil treatments. Figure 1 shows the mean slopes for each of the sites and treatments. The control on the Fuller Branch site was significantly less compact than the other two controls.

Water and sediment

Preliminary analyses revealed that the recontour treatments had the lowest volume runoff and the lowest sediment runoff (Table 1). None of the treatments were similar to the undisturbed hillslope (reference).

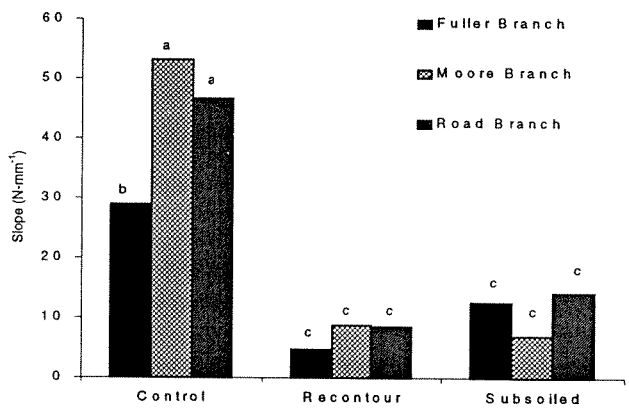

Figure 1. Slopes of the penetrometer profile for control, recontour, and subsoiled treatments for each site. Letters represent significant differences at P<0.05.

Table 1. Summary of preliminary runoff and sediment data. Letters indicate significant diffences at P<0.05.

	Runoff volume (L m^{-2})	Sediment (g m^{-2})
Subsoil	8.5 a	31.40 ab
Recontour	5.9 b	14.18 b
[illegible]	[illegible]	[illegible]

Control	7.6 ab	34.74 a
Reference	0.04 c	0.06 c

Production

The timing data for the subsoiled trail sections are presented in Table 2. Delay times were large due in part to an inexperienced operator. Most frequently delays were caused when the operator tried to avoid creating soil disturbance and to avoid damaging standing trees. Some delays were produced when the operator attempted to minimize damage to the subsoiler and minimize disturbance by not moving large rocks with the subsoiler. Delays for maneuvering, avoiding stumps, and debris comprised over 78% of the total productive delay time. The operator often received instruction about how to deal these problems increasing the length of the delay.

Travel time to the location was not included in the subsoiling data since a) we were using the dolly mounted configuration which required backing down some trails and b) machine speed was reduced to minimize damage to the experimental plots prior to treatment.

Delay free production ranged from 0.59 to 2.31 km-hr^{-1} and production including productive delays only ranged from 0.42 to 1.75 km-hr^{-1} (Table 3). A treatment width of 4-m (the width of the trail running surface) yielded production with productive delays 0.17-0.70 ha-hr^{-1}. For ridges and benches the actual treated width could be up to 50% wider (Andrus and Froehlich 1983).

Table 2. Subsoiler production and delay times (seconds) for each site and trail segment

	Site								
	Road				Moore		Fuller		
Trail segment	1	2	3	4	1	2	1	2	3
Length (m)	197	182	33	42	26	57	64	321	318
Productive time (sec)	530	283	144	256	73	102	170	767	535
Delay (sec)									
Stump	108	88	0	37	0	0	0	26	192
Tree	89	12	0	0	49	0	0	0	0
Debris	49	21	29	37	0	0	0	0	225
Rock	20	0	0	0	0	0	0	0	13
Maneuver	0	56	27	0	0	0	46	212	0
Waterbar	0	0	0	0	0	0	0	146	0
Other	0	0	45	0	0	15	130	1188	302
Total	266	177	101	74	49	15	176	1572	732

Table 3. Subsoiler production estimates and mean production in kilometers per hour and hectares per hour for each trail segment.

			Production (delay free)		Production (productive delays)	
Site	Trail seg.	Length (m)	Km-hr^{-1}	Ha-hr^{-1}	Km-hr^{-1}	Ha-hr^{-1}
Road	1	197	1.34	0.54	0.89	0.36
Road	2	182	2.31	0.93	1.42	0.57
Road	3	33	0.82	0.33	0.48	0.19
Road	4	42	0.59	0.24	0.42	0.17
Moore	1	26	1.29	0.51	0.77	0.31
Moore	2	57	2.01	0.80	1.75	0.70
Fuller	1	64	1.35	0.54	0.67	0.27
Fuller	2	322	1.51	0.60	0.49	0.20
Fuller	3	318	2.14	0.86	0.90	0.36
Mean			1.48	0.59	0.87	0.35

The recontouring treatments took from 18 to 25 minutes for each 25-m plot. No significant delays were experienced

during the completion of any of the six plots. The contractor we employed indicated that his production including travel out would be 0.1-km-hr^{-1} on sites similar to the research sites. Using the same 4-m width for the trail surface yielded production rate of 0.04 ha-hr^{-1}. Using the distance from the inside of the cut slope to base of the fill slope (6-m), the production increases to 0.06 ha-hr^{-1}. The local contractor rate for this size machine was about $120 per hour yielding a cost of $1200 per kilometer of trail or $3000 per hectare (4-m wide trail).

DISCUSSION

Both treatments significantly reduced compaction. Recontouring had an advantage in this regard since the penetrometer sampled an upper layer of the soil profile. In the subsoil and control treatments the penetrometer sampled subsoil that was at least 0.5-m below the original soil surface. The result was considerably higher rock content in addition to penetrometer resistance. In addition the penetrometer results of the subsoil treatments were probably affected by excavator traffic following the subsoil treatment. The importance of the differences won't be known until tree growth, infiltration, and runoff data are collected from these treatments.

Recorded production of the subsoiler was slower than production speeds previously recorded because the operator had only one day of training prior to the trial and was relying on instructions from the manufacturer and the researchers. Using one pass to clear slash and the second pass to subsoil De Long et al. (1990) recorded production of 0.29 ha-hr^{-1}. The most recent published costs are from Davis (1990) of $160 per hour for both crawler tractor and subsoiler. Delong et al. (1990) predicted ownership and operating costs for the subsoiler at $5.88 (Canadian) per hour. Subsoiler costs may differ slightly in the Appalachians due to operator proficiency and local terrain and soil conditions. Local contractor rates for a 180 Hp crawler tractor at the time of the study ranged from $150 to $200 per machine hour. Rates quoted to us may have been inflated because contractors did not have a good sense of how the tractor would be used and the amount of downtime that would be experienced. In De Long et al. (1990) the first pass was used to clear slash from the subsoiled areas and took 60% of the productive time. Total productivity would be sensitive to slash cover on the trails. In the Appalachians fellers and skidders combined have considerable control over how much slash is on the trails following harvest. Using a rate of $175 hr^{-1} for the prime mover and subsoiler, the average productivity of subsoiling from this study (0.35-ha-hr^{-1}), and a first pass that consumes 0.5-ha-hr^{-1}, the treatment cost equals $850-ha^{-1}. Doubling the productivity of the subsoiling but with the slash removal production at 0.5-ha-hr^{-1} decreases costs to $600-ha^{-1}.

While much of the value of these two techniques has yet to be determined by tree growth and runoff results, the costs estimated are not that different from present retirement costs. Assuming that 1 water bar would be installed every 18-m which relates to an average trail slope of 15% (Stringer et al. 1997), the cost of recontouring equals conventional retirement at $21.60 per waterbar. At the low (0.17-ha-hr^{-1}) and high (0.70-ha-hr^{-1}) productivity levels from the subsoiler (0.50-ha-hr^{-1} for the first pass), the cost of subsoiling equals conventional retirement at $9.92 and $4.31 per waterbar, respectively. From survey results Shaffer et al. (1998) found average waterbar costs at $15 each. A production study gave the cost per water bar at this density $3.34 per waterbar (Hewitt et al. 1998).

The ability to put a larger dozer on the harvest for tillage should have production benefits in all phases of retirement. Most loggers that have dozers have smaller dozers since their primary function is bunching and skidding and not earth moving. In addition the cost of assigning a productive machine to a retirement task is probably somewhat higher than the machine rate or even the contractor rate for a comparably sized dozer. Both recontouring and subsoiling are likely to increase the success of revegetation through seedbed preparation and may allow increased mechanization of seeding, mulching, and fertilizing through equipping the prime mover with bulk spreaders. A limiting factor for both recontouring and subsoiling would be the area treated at one location. Small harvests with only a few hectares to treat would drive up the costs per hectare because of transport costs and poor machine utilization.

Current investments in trail retirement through BMPs may represent an under investment in retirement to ameliorate soil damage or planning to reduce area impacted. Stewart et al. (1988) showed that several methods used to decrease the compacted area in harvests of forests in the Pacific Northwest, including tillage, yielded positive returns. In hardwood forests our understanding of the growth losses due to trails is extremely limited and such a comparison would be difficult. Adding the cost of amelioration to the cost of ground-based harvesting in this steep terrain likely represents the true opportunity for aerial logging systems or other ground-based systems that minimize trail density and trail slope.

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