SEDIMENT YIELD ALONG AN ACTIVELY MANAGED RIPARIAN BUFFER

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ABSTRACT

High quality water is generally associated with forested watersheds. However, intensive forestry activities within these watersheds can negatively affect water quality. In order to mitigate negative effects of forestry operations on water quality, best management practices (BMPs) are recommended. In this study, effects of silvicultural treatments on water quality are examined by comparing a treatment watershed with an unharvested control watershed. Forested areas created less sediment than open areas. In addition, a partial cut within streamside management zone (SMZ) increased sediment yield.

INTRODUCTION

Clean, drinkable water is becoming one of the most important natural resources for the future. Forested watersheds are the main sources of clean water. In order to insure the sustainability of products and benefits from forested watersheds, some intensive management practices may be essential (Grace 2005). But, these operations can adversely affect water quality without well-designed logging roads and the implementation of mitigating measures such as buffer zones (Saleh 2004). Best management practices (BMPs), such as streamside management zones (SMZs), have appeared to be effective for mitigating the effects of forestry operations on water quality (Norris 1993, Wynn and others 2000, McBroom and others 2007).

A SMZ is one of the most commonly employed nonstructural BMP types. SMZs consist of a strip of land that is managed to protect the surface water and riparian values from silvicultural operations (Alabama Forestry Commission 1999). Although SMZ's need not be excluded from silvicultural activities, these buffers should be carefully designed, and any silvicultural activity within them must be closely supervised and managed. Thinning operations within SMZs will reduce fire and insect hazards, provide some economic return, and improve the effectiveness of SMZs (McBroom and others 2007).

In this study, we intended to regenerate a mature SMZ stand and create an uneven-aged forest with multiple canopy tiers using single tree selection based on the Proportional-B method. During this process, the effects of partial cutting on sedimentation were observed by comparing the study watershed with an unharvested reference site. In addition to determining harvesting effects on sediment yield, the effects of different land uses and a recent clearcut on sedimentation were evaluated; the effect of forest cover on sediment was quantified, and the efficacy of the SMZ at reducing sediment yield from potential source areas was determined.

METHODS

STUDY SITE

The study was conducted on the Mary Olive Thomas Demonstration Forest which is owned and managed by the Auburn University School of Forestry and Wildlife Sciences. Most of the area has slopes of less than 6%; however, steeper slopes are present on some parts of the tract. Pacolet series is the predominant soil type on the property except for narrow bands of Taccoa sandy loam along streams and main drainages (McNutt and others 1981). The average annual rainfall is 148 cm, and 50% of the rainfall occurs during the growing season from April to September. The average daily temperature is 7 °C in winter and 27 °C in summer. The average relative humidity is about 50% in mid-afternoon, and is higher at night. The timber on the property is primarily Loblolly pine (*Pinus taeda L.)*. However, the SMZs (including the study area) are dominated by deciduous species. Average site index for loblolly pine is about 26 m (base age 50 years) on the property. The SMZ stands are well stocked, and are typically wider than required (approximately 20 m) by State of Alabama guidelines (AL Forestry Commission 1999).

Two small adjacent watersheds, treatment (Tw) and control (Cw), were chosen for the study (Figure 1). Each watershed was divided into three sections (Tw1-Tw2-Tw3, and Cw1- Cw2-Cw3 respectively) based on land use or forestry treatment. An intact SMZ borders the stream the entire length of the watershed from sample point T1 south to T3, and from sample point C1 south to point C3. North of T1 on the treatment watershed is an open area, mostly pasture with a pond in the middle of the section. The central

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portion of the study area, Tw2, is entirely forested. On the control watershed (Cw), section Cw1 (north of C1) is mostly residential area with a pond in the middle of the section. The mid- portion of the study area, Cw2, is entirely forested. The property north of T1 and C1 is not owned by Auburn University and no sampling or data collection was conducted in these areas. In Tw3 and Cw3, there is a clearcut area between the two SMZs. The clearcut was harvested in early 2008, site prepared with herbicide in late summer, windrowed with a root rake in the fall 2008 and planted during 2008-09 dormant season (Figure 1). One monitoring station was established on each section (T1, T2, T3, C1, C2, and C3) to sample stream stage. The first stations (T1and C1) were located on the north boundary of the forested area to observe how much water entered the forested area from the pasture and residential area. The second group of stations (T2 and C2) was located at the upstream edge of the clearcut area so that it would be possible to evaluate the effect of intact forest cover on water changes in the stream in comparison to T1. The third stations (T3 and C3) were located at the downstream end of the watershed to evaluate the effects of a clearcut area on water quality through an intact SMZ (Figure 1).

HYDROLOGIC SAMPLING

Water stage measurements were monitored using Solinst Levelogger Gold Model 3001 pressure transducers installed at each monitoring station. In addition to continuous water stage measurements by transducers, stream discharge was measured during storm events (whenever possible, while it was still raining) at each monitoring station. The proximity of the sites to Auburn University allowed for the capture of most rain events (rain events with lighting activities were avoided). Water levels were associated with discharge measurements taken during each site visit to determine water level-discharge relationships. These relationships were used to calculate continuous discharge (for each 15 minute period) by creating rating curves between water levels and discharge data from each station. Water samples were also taken at each monitoring station during rain events. Total suspended sediment (TSS) concentrations were determined from water samples using the SM 2540 D (total suspended solids dried at 103-105 °C) method. The TSS concentrations were also used to estimate sediment loads for each 15 minute period using LOADEST software. LOADEST requires a time series of streamflow, and constituent concentration (sediment concentration) at a time of a day to assist the user in developing a regression model for the estimation of constituent load (calibration) (Runkel and others 2004).

HARVEST OPERATION

The harvest operation was designed to create an uneven-aged SMZ with multiple canopy layers by allocating growing space among three canopy tiers (overstory, midstory, and understory) based on the Proportional-B method. This method is well suited for use within a SMZ as it ensures a continuous canopy cover, maintains full site utilization with approximately 80% of stand basal area allocated to the sawtimber size classes, and allows sufficient growing space for the recruitment of new cohorts as needed (Loewenstein 2005). Cutting and skidding operations were completed during about two weeks, in October, 2009. The harvest was conducted in dry weather to avoid compaction and rutting of the soils. Trees were removed from the SMZ with a rubber-tired John Deere 540 GIII Model Skidder.

STATISTICAL ANALYSIS

Treatment effects for watersheds were determined using the paired watershed approach based on streamflow (Hewlett 1969). Pre-harvest data were used as a basis for developing calibration regression equations between the treatment and control watersheds using paired monitoring stations (e.g. T1 with C1, T2 with C2, and T3 with C3). Post-treatment comparison relies on the high correlation that normally exists between water discharge from treatment watersheds and control watersheds when there is no harvest on either watershed. Given this relationship, the change in water characteristics attributable to the harvest operation could be determined. PASW Statistics 18.0 software was used to determine significant differences between observed and predicted means on the treatment watershed by the Independent-Samples T-Test for all mean comparisons.

RESULTS and DISCUSSIONS

In general, before the harvest operation, the pastoral area generated more sediment yield per unit area during storm events. Because sediment yield from the pasture is higher, this suggests that open areas generate more sediment yield than forested areas during storm events. The forested middle section generated the least sediment per unit area showing the importance of forested areas at reducing sediment yield on the treatment watershed (Figure 2). The sediment rate from section Tw2, which is intact forest, is lower than Tw3, which contains the clearcut and road crossing. We expected that sediment yield from the clearcut would be mitigated by the existing SMZ, but it appears that it was not sufficient to trap all of the sediment yield from both the clearcut area and the roads. It should be noted that we were unable to separate the sediment yield of the road from that of the clearcut. On the control watershed a similar situation was observed; sediment yield per unit area during rainfall events is higher from Cw1 than from further downstream.

In contrast with the pre-harvest results, post-treatment data on the treated watershed shows that the sediment pattern changed after the harvest. Section Tw3 generated significantly higher amounts of sediment per hectare than did the upstream sections (Figure 3). Section Tw2 generated remarkably higher amounts of sediment per hectare after harvest. Section Tw1 produced the least sediment yield per unit area, a complete reversal of the pre-harvest trends. On the control watershed, the sediment pattern did not change (as expected) since this watershed was not affected by harvesting (Figure 3).

Models derived from the calibration data were used to predict response on both treatment and control watersheds for the post-harvest period. Observed and predicted data were compared to determine harvest effects on sediment. There was no change in the sediment yield from section Tw1 on a unit area basis (Figure 4). When looking at the sediment yield on a per unit area basis, the post-harvest effect is quite distinct on Tw2, suggesting that the partial cut within the SMZ caused disturbance of the duff layer and/or vegetation, therefore allowing soil movement (erosion) and an increase in sediment yield during rainfall events (Figure 4). During rainfall events, between 10-15 times more sediment than predicted was generated in Tw2. Sediment yield significantly increased following harvest from Tw3 ($p=0.012$) (Figure 4). As on section Tw2, differences were most notable during rainfall events with sediment yields of 3-4 times what was predicted (Figure 4). Although less obvious, the magnitude of increased sediment yield during dry periods is greater than during storm events.

CONCLUSIONS

Forested watersheds and forested areas on a watershed both play important roles in protecting and maintaining both water quality and quantity. However, any silvicultural operations in forested watersheds must be carefully managed and supervised in order to protect and maintain water quality. During the pre-harvest period, upstream sections Tw1 (pastoral) generated much more sediment yield than downstream forested sections. It is also likely that sediment yields were affected by the ponds in the middle of section Tw1. We cannot determine the actual sediment yield from the upstream section (Tw1) because during all times except rain events, the pond acts as a settling basin. Also, during a rain event, we cannot know how much of the sediment generated from these sections is from that particular event or how much is stored sediment from previous erosion. The least amount of sediment was created by the forested middle section which differed from the downstream forested section in that there was an intact clearcut. The furthest downstream section Tw3, which contained a stream crossing and a two year-old clearcut, created much more sediment than forested section Tw2. This suggests that the SMZs were not sufficient to trap all of the sediment from the clearcut area and forest road, even though the SMZs were often much wider than the minimum guidelines. It may be also suggested that a SMZ may not function at desired level under certain conditions no matter how wide it is.

Following the partial cutting treatment of the SMZ in watershed Tw, it was observed that there was a significant increase in sediment load from the treated sections (Tw2 and Tw3) caused by increased erosion from soil exposed by skidding operations. Higher amounts of sediment were observed on these sections in comparison to the pre-harvest calibration period. Some of this increase is explained by the reduced canopy cover due to the dormant season, and by an increased number of rain events. However, no significant change was observed between the pre-harvest and post-harvest period on the section Tw1. Sediment trends did not differ from the calibration period following harvest on the control watershed.

This study shows the importance of forest cover at reducing sediment yield. The study also shows that season affects sediment and water yield as well. It may be suggested that clearcutting causes at least a temporary increase in sediment load, even with properly managed BMP's and SMZ's. If effective forest road BMPs are not in place then simply focusing on SMZs to reduce sediment yield may not be sufficient. This study also shows the importance factoring in upstream land use and land cover conditions when designing SMZs for sediment trapping.

LITERATURE CITED

Alabama Forestry Commission. 1999. Alabama's Best Management Practices for Forestry Publication. Available at: http://www.forestry.alabama.gov/Publications/BMPs/2007_BMP_Manual.pdf

Grace III, J. M. 2005. Forest operations and water quality in the south. American society of agriculture engineers ISSN 000-235

Hewlett, J. D. 1969. Principles of forest hydrology. University of Georgia press. ISBN: 0-8203-0608-8

Loewenstein, E. F. 2005. Conversion of uniform broadleaved stands to an uneven-aged structure. Forest Ecology and Management. 215: 103.112

McBroom, M.W., Beasley, R.S., Chang, M., Gowin, B., and Ice, G.G. 2007. Sediment losses associated with degree of watershed disturbance resulting from clearcut harvesting with best management practices. ASABE publication number 701P0207

McNutt, R. B., Tuck, M., and Hoyum, R. A. 1981. Soil survey of Lee County, AL. United States Department of Agriculture and Soil Conservation Service. Available at: http://soildatamart.nrcs.usda.gov/Manuscripts/AL081/0/Lee.pdf

Norris, V. 1993. The use of buffer zones to protect water quality. Water resource mgt. 7(4), 257-272

Runkel, R.L., Crawford, C.G., and Cohn, T.A. 2004. USGS Load Estimator (Loadest) Program. Available at:.http://pubs.usgs.gov/tm/2005/tm4A5/pdf/508final.pdf

Saleh, A., Williams, J.R., Wood, J.C., Hauck, L.M., and Blackburn, W.H. 2004. Application of APEX for forestry: Transactions of the ASAE. American Society of Agricultural Engineers. Vol. 47(3): 751−765

Wynn, T.M., Mostaghimi, S., Frazee, J. W., McClellan, P.W., Shaffer, R.M., and Aust, W.M. 2000. Effects of Forest Harvesting Best Management Practices on Surface Water Quality in the Virginia Coastal Plain. Transaction of the ASAE. American society of agricultural engineers 0001-2351/00/4304-927

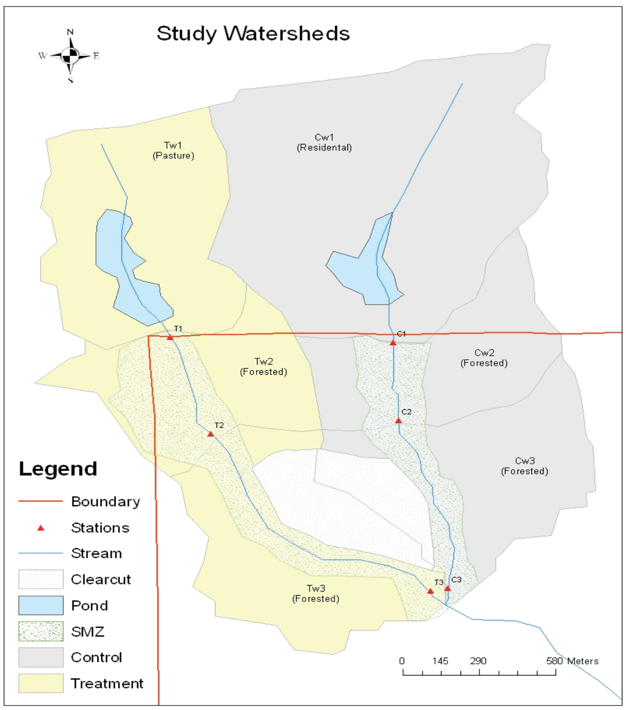

Figure 1—Map of the study watersheds.

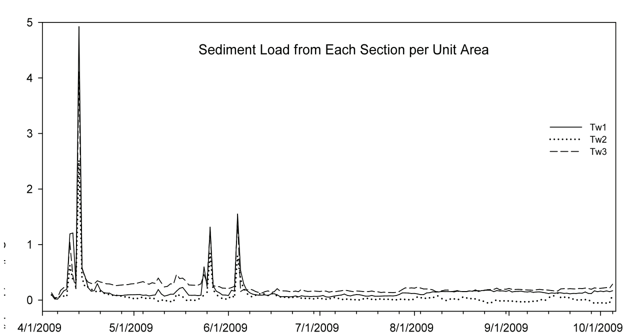

Figure 2—Pre-harvest sediment yield pattern.

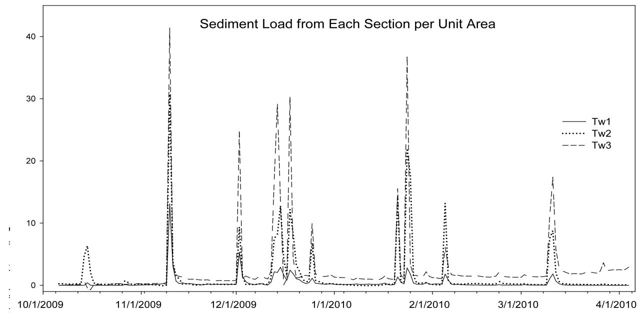

Figure 3—Post-harvest sediment yield pattern.

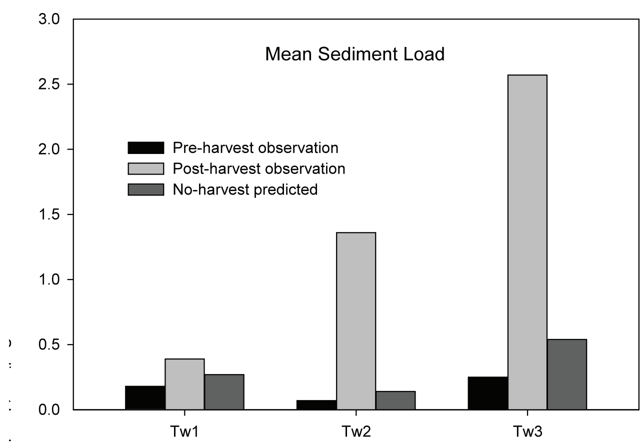

Figure 4—Mean sediment load of each section after harvest operation.