
How Much Land Is Needed for the Harvest Access System on Nonindustrial Private Forestlands Dominated by Northern Hardwoods?

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ABSTRACT: *Harvest access systems (forest roads, skid trails, and landings) account for 90% of the erosion and sedimentation during harvesting activities. A well-planned harvest access system can reduce the surface area disturbed by logging, thereby decreasing the potential for erosion and sedimentation. Most Best Management Practices (BMP) guidelines suggest that the area disturbed by the harvest access system should range from 10 to 15%. We measured surface area disturbance by the harvest access system on 43 harvest sites on nonindustrial private forestlands in northern hardwood cover types in New York State and found that the average area percent disturbed was 6% with a range of 3 to 13%. The quality of BMP implementation was positively associated with the percentage of surface area disturbed, suggesting that harvests with a low percentage of surface area disturbance do not necessarily exhibit high-quality BMP. North. J. Appl. For. 22(4):243–247.*

Key Words: Best Management Practices, logging, erosion, watershed.

Forest harvesting activities disturb the soil surface, increasing the potential for erosion and sedimentation, which degrade water quality. Forestry's potential to cause water pollution via nonpoint sources is well recognized (Corbett et al. 1978, Loehr et al. 1979, Martin 1988, Scholze and McNeilly 1993, Schuler and Briggs 2000, Ellefson et al. 2001). Section 208 of the Federal Water Pollution Control Act, as amended in 1972, singled out silviculture as a source of nonpoint source pollution. Additional legislation followed the 1972 amendment to improve the reduction of sedimentation and nutrient loading related to forestry activities (Scholze and McNeilly 1993). Much of this legislation directed states to establish programs and protocols—voluntary or involuntary—designed to reduce the degradation of water quality resulting from forestry-related activities. In 1975, the Environmental Protection Agency developed the concept of forestry Best Management Practices (BMP)—a collection of practices that minimize the potential for sedimentation associated with forest harvesting activities (Egan

et al. 1998). If BMP are not adequately implemented, sedimentation can limit the quality and quantity of water from a watershed (Binkley and Brown 1993, Martin and Hornbeck 1994). In response, many states, watersheds, and counties have developed guidelines or regulations for timber harvesting. A few examples of these practices include well-planned skid trails and haul roads, the use of temporary bridges for crossing streams and rivers, and the application of water bars for surface water diversion on trails and roads. Consistent among the guidelines is the importance of planning the access system.

The primary cause of the degradation of water quality associated with harvesting activities is erosion from disturbed areas such as roads, landings, and skid trails. Aside from stream channels, roads, landings, and skid trails are the only places in forests where large areas of soil are exposed (Kochenderfer et al. 1997). The construction and use of forest roads, skid trails, and landings are responsible for 90% of the sediment generated during harvesting activities (Patric 1976, Swift 1984). Runoff from precipitation or snowmelt that would normally travel downhill as shallow subsurface flow may be intercepted by roads and trails and become surface flow, increasing the potential for erosion and sedimentation (Egan 1999a). Inadequate planning of the

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access system can result in more roads, trails, and landings, thereby increasing the likelihood that water will intersect with the access system, contributing to more surface flow and the possibility that sedimentation will exceed normal geologic processes (Reinhart et al. 1963, Patric 1976, Swift 1984).

A review of the literature indicates that the percentage of the harvest area dedicated to the access system ranges from 3 to 30%, depending on the forest type, silvicultural system, topography, type of harvest, and type of equipment (Anderson et al. 1976). Proper planning can reduce the access system area by as much as 40% (Kochenderfer 1970). The USDA Forest Service's standard reference, "Permanent Logging Roads for Better Woodlot Management" (Haussman and Pruett 1978) states that a haphazardly built system of forest roads and skid trails (landings not included) may disturb as much as 20% of the surface area, whereas a well-planned system (landings not included) need not exceed 10% of the land area. Mitchell and Trimble's (1959) work on the Fernow Experimental Forest in West Virginia found that the skid trail area can range from as low as 3 to 7%. In areas of Appalachia, Kochenderfer (1977) found forest roads, skid trails, and landings occupied, on average, 10% of the harvest area. In the northern hardwood forests of New York, Davis and Nyland (1991) reported the surface area impacted by a well-planned access system under uneven-aged management was 14%. The Minnesota Department of Natural Resources monitored harvest sites across the state and reported that landings and forest roads combined to occupy 3% of the harvest area, whereas primary skid trails impacted less than 15% of the harvest area on 75% of the sites. The Minnesota Timber Harvesting and Forest Management Guidelines recommend that 10 to 15% of the harvest area should be impacted by skid trails (Phillips 2000). Because these studies were not conducted and reported uniformly, we must use caution when comparing the percentage of harvest area disturbed. To partially address the uniformity issue, we referenced harvest studies that were conducted in hardwood cover types.

This article revisits the question of how much of the harvest area should be dedicated to the access system, and the relationship between harvest surface area disturbed and BMP implementation. In addition, we examined the effect of a management plan and the involvement of a forester on the aforementioned variables. The study was part of a larger research project studying the diffusion of forestry BMP among nonindustrial private forestland (NIPF) owners in the Catskill region of New York State. The authors visited a total of 43 harvest sites in the study area to measure BMP implementation. The field survey included measuring the surface area of all forest roads, skid trails, and landings. In general, we found the average percentage of harvest surface area disturbed by the access system was well below 10%.

Methods

The larger research project combined a mail survey measuring the dispositions and actions of NIPF owners (owning greater than 10 contiguous acres) relative to BMP, followed

by a field visit of those respondents who had conducted recent forest-harvesting operations. The mail survey was a Likert-type instrument containing questions intended to measure the awareness and knowledge of BMP, as well as the decision to use BMP among Catskill-region NIPF owners. The sampling frame was identified using Environmental Systems Research Institute's ArcView 3.2 Geographic Information System, Year 2000 NYS Office of Real Property tax parcel centroids, and United States Geologic Survey's 1990 1:250,000 land use/cover polygons. Stratified random sampling was used to ensure acreage heterogeneity. This was achieved by stratifying the sampling frame by parcel size. Sample intensity in each stratum was based on the overall distribution of parcel sizes in the sampling frame.

The mailing was conducted in spring 2002, which in turn provided the sample frame for the field survey. NIPF owners who had conducted harvesting operations in the last 3 years (1999–2002) were asked if they would allow a researcher to conduct measurements on their harvested property. Those owners agreeing to a field survey were contacted via telephone to schedule the visit and obtain directions. The field survey was conducted during the summer and fall of 2002.

The field survey was derived from Schuler and Briggs's (2000) BMP compliance evaluation, the NYS BMP field guide, and input from State University of New York–College of Environmental Science and Forestry scientists and Watershed Forestry Program foresters. The survey evaluated BMP implementation by conducting a census of each access system and scoring within five segments: landings, forest roads, forest road stream crossings, skid trails, and skid trail stream crossings. The landings segment focused primarily on the landing's location, condition, and use of water diversion devices. The forest road segment evaluations pertained mostly to the road's structure, condition, and use of water diversion devices. Likewise, the skid trails segment principally measured the trail's structure, condition, and use of water diversion devices. The stream crossings segment for skid trails and forest roads assessed the crossing's condition, location, and use of water diversion devices.

To prepare for the survey, the site's topography, water bodies, and timber sale area were identified using topographical maps. The timber sale area and size were confirmed with the landowner. A clinometer was used to measure slope. Distance and area measurements were taken with a measuring wheel. One investigator conducted all site evaluations. Forest roads were defined as any corridor capable of, at the very minimum, supporting a four-wheel drive vehicle, though most roads encountered were capable of supporting a tri-axle truck. Skid trails were defined by the degree of exposed soil and the clarity with which the trails could be identified. Limiting the evaluation to sites harvested within 3 years of the study increased the accuracy of the evaluation, as most skid trails used within this time frame were easily identified. Minor diversions from the skid trail access system used no more than one or two times to

extract felled timber inaccessible from the skid trail were not classified as skid trails. Landings were characterized as open areas within the timber harvest access system where logs were staged and prepared for removal from the harvest area. The field investigator consulted landowners to obtain descriptions of landing locations within the harvest areas.

The road area was estimated by multiplying the total length of the road or road section of interest by a constant of 15 ft. Taking a cross-section measurement of the skid trail every 300 ft. and multiplying the average by the skid trail's total length determined skid trail area measurements. The last cross-section measurement was completed at the end of the skid trail. The 15-ft. constant for road width and length of 300 ft. for skid trails was selected with guidance from State University of New York–College of Environmental Science and Forestry scientists and the Watershed Forestry Program foresters, as well as numerous field tests.

Individual BMP implementation scores were determined using a three-step dichotomous process. First, the BMP of interest was observed from a technical perspective: Was the BMP applied according to the existing guidelines? If so, the evaluation resulted in a perfect score. If not, by how much did it fall short? The BMP was considered in a broader, pragmatic context in the second step: Is a BMP actually needed? Appraising the topography, locating nearby water bodies, and recounting recent precipitation and comparing it with physical signs of erosion determined the need. The evaluation was skipped if a BMP was not needed, although most BMP were necessary on every occasion. The third step entailed combining the technical and pragmatic considerations to assign an evaluation score: 0 = BMP not used; 1 = BMP used with major deviations; 2 = BMP used with minor deviations; and 3 = BMP used and correctly applied. The surface area disturbed by a skid trail, road, or landing was not considered when assigning BMP implementation scores. Surface area disturbance was used solely as a weighting factor when averaging multiple skid trail, road, or landing scores to determine a comprehensive segment score. We did not attempt to assess the level of silviculture associated with the harvest (i.e., high grading versus a legitimate tending or regeneration cut).

The amount of the harvest surface area disturbed by the access system was related to the following three variables: the overall implementation score of water diversion devices (water bars, broad-based dips, diversion ditches, etc.) as evaluated on skid trails, roads, and landings; forester involvement in the harvest operation; and the use of forest management plans. The term "management plan" was defined only as a written plan and could have been interpreted by respondents to mean a two-page superficial plan or a 20-page comprehensive document. Pearson bivariate correlation was used to examine the relationship between percentages of harvest surface area disturbed and water diversion device implementation scores. *t*-tests were used to identify any differences in disturbance percent means based on the use of a forester, or a management plan. Statistical significance was based on an alpha of 0.05.

Results and Discussion

Eight hundred fifty-three surveys out of a possible 915 were successfully delivered to NIPF owners. Three hundred sixty-five of 853 were returned for an adjusted response rate of 43%, consistent (if not higher) with other NIPF owner surveys (English et al. 1997, Kluender and Walkingstick 2000, Tyson and Worthley 2001). *t*-tests were used to test for nonresponse bias between early and late respondents. The tests revealed no differences among the scale means for each group. Nonresponse bias was ruled out because late respondents are more representative of nonrespondents (Salant and Dillman 1994).

Seventy-nine respondents indicated that they had conducted harvesting operations between 1999 and 2002. Fifty-two of the 79 NIPF owners agreed to allow a field visit. We were able to successfully schedule and complete 43 site visits. An independent samples *t*-test was used to test for bias among this sample of 43 forestland owners. All mail survey mean scores submitted by those who did not agree to a field visit were tested against the responses submitted by those who agreed with respect to the Awareness, Knowledge, and Decision scales. Test results indicated a significant difference between the two groups for Decision mean scores. Landowners agreeing to a field visit had significantly lower Decision mean scores than those who did not, suggesting that the group allowing visits were less confident BMP were used on their harvest. In addition, we used Levene's test for homogeneity of variance to determine whether there are any statistically significant differences in the variability between respondents that agreed to a visit and those that did not. The test indicated that the respondents agreeing to a field visit were significantly more variable than the respondents who marked "no" in the Awareness, Knowledge, and Decision scales. The greater variability and lower means among "yes" respondents removed concern that access to NIPF using the mail survey method would result in a biased evaluation.

All harvesting sites consisted of northern hardwoods, with occasional patches of eastern hemlock. There were no plantations. All harvests were partial cuts, ranging from diameter-limit cuts to silviculturally sound tending operations. There were no clearcuts. The majority of the logging was conducted with rubber-tired skidders. The average slope ranged from 5 to 30%. The results should be interpreted in the context of harvesting activities in northern hardwoods on NIPF.

Surface area measurements were made on a total of 1,574 acres of harvested land. The harvest sites ranged in area from 8 to 150 acres. The average harvest area was 37 acres and the median was 30. (Recall that the sample was limited to NIPF parcels greater than 10 acres.) Of the 43 harvest sites, only nine had forest roads. The average harvest area of sites with forest roads was 63 acres, and the remaining 34 sites without forest roads averaged 31 acres. The low number of harvest sites with forest roads reflects the small woodlot sizes, which often do not justify the expense of constructing and maintaining forest roads. Also

consistent with small woodlots, only four harvest sites required more than one log landing. Again, we attribute this to woodlot size. The four sites with multiple landings averaged 59 acres, whereas the 39 sites with one landing averaged 35 acres. Given that the average NIPF parcel size is approximately 20 acres (based on parcels greater than one acre) in the study region (Brazill 2002, Lapierre and Germain 2004), most harvesting operations can be completed with one landing and a network of skid trails.

The mean percentage of harvest surface area disturbed by the access system across all sites was 6.3%, with a low of 3.1% and a high of 13.0%. Correlation tests revealed that the percentage of harvest surface area disturbed was significantly associated with water diversion device implementation scores (Table 1). As the percentage of harvest area disturbed increases, so do the BMP implementation scores for water diversion devices such as properly installed waterbars, broad-based dips, and culverts at intervals appropriate for slope and soil conditions. This positive association between the quality of BMP implementation and harvest surface area disturbed initially may appear counterintuitive, however, on closer analysis, it is consistent with the range of harvest surface area disturbed percentages we experienced in this study. It is important to note that none of the harvesting sites in the sample exhibited a total disregard for planning the access system that may have produced area disturbance percentages of 20% or more. All 43 harvest sites were in a range consistent with a planned access system. Within this acceptable range, it makes sense that a well-planned access system will accommodate steep topography, numerous stream crossings, or wet areas by actually increasing the harvest surface area disturbed. For example, maintaining an acceptable slope, locating the optimal point to cross a stream, or avoiding a wetland may require extended skid trails. In contrast, a skid trail that takes the shortest route between two points may disturb less area than a skid trail designed to conform to BMP guidelines, but in the process may traverse steep and unstable terrain. Our results suggest that there is a minimum threshold for harvest area disturbance required for proper BMP implementation. Although dependent on many variables such as topography, silvicultural system, harvesting system, and equipment, we expect that this threshold lies between 6 and 10%.

We also examined the ratio of skid trail length to harvest acres. In a study assessing nine timber sales totaling nearly 900 acres of harvested area in the Appalachians, Kochenderfer (1977) reported one mile of skid trails for every 20 acres of harvest area. We observed one mile of

skid trails for every 25 acres of harvested area. The difference in average harvest area, 100 versus 37 acres, may be a contributing factor to the lower ratio on NIPF. Although this comparison is useful, we acknowledge that the two studies used different methods for measuring surface area, and likely differed somewhat on how forest roads and skid trails were defined. To further examine the relationship between harvest area and access system, we examined the ratio of harvest surface area disturbed to harvest area (density) for each of the 43 harvest sites. There was no significant relationship between harvest area and density of the access system (Table 1).

The involvement of a forester or the existence of a management plan had no significant effect on the percentage of harvest surface area disturbed (Table 2). Even when these two variables were combined (forester and management plan), we found no significant difference in the percentage of harvest surface disturbed. This result suggests that the role of foresters is difficult to assess when there is a positive relationship between the surface area disturbed and BMP scores (as previously noted). However, it is important to note that the use of a written management plan significantly increased the overall BMP scores, whereas foresters had no influence (Table 3). This reinforces the role of management plans in the planning and implementation of BMP that includes harvest access systems. We are unable to explain why foresters are not influencing BMP implementation. Given the study area includes the New York City Watershed, an area with significant investment in BMP training programs for loggers, perhaps the region's trained loggers are taking on most of the responsibility for the harvest access system and associated BMP. Egan (1999b) found the involvement of foresters does make a difference. The study, which was based in West Virginia, where BMP compliance is mandated by law and is the primary responsibility of the logger, reported a significant correlation between BMP compliance and forester involvement.

Conclusions

The most significant findings of the study were the overall low mean harvest surface area disturbed across the 43 NIPF harvest sites, as well as the positive association between the quality of BMP implementation and harvest surface area disturbed. Based on previous research and various BMP guides, we were expecting our average to fall closer to Kochenderfer's (1977) 10% figure. Keep in mind,

Table 1. Correlations between the percentage of harvest surface area disturbed in BMP implementation and harvest area.

Independent variable	Pearson correlation	Valid cases	Significance (two-tailed)
BMP implementation	0.347 ^a	43	0.023
Harvest area	-0.270	43	0.080

^a Significantly different ($\alpha = 0.05$).

Table 2. The relationship between the percentage of harvest surface area disturbed and the existence of a management plan and the involvement of a forester.

Management plan	Valid cases	Mean score	SE
Yes	9	0.062 ^a	0.01
No	25	0.075 ^a	0.005
Forester			
Yes	14	0.063 ^a	0.006
No	26	0.062 ^a	0.005

^a Means with the same letter are not significantly different ($\alpha = 0.05$).

Table 3. The relationship between the quality of BMP implementation and the existence of a management plan and involvement of a forester.

Management plan	Valid cases	Mean score	SE
Yes	9	2.27 ^a	0.12
No	26	1.52 ^b	0.06
Forester			
Yes	14	1.80 ^a	0.12
No	27	1.65 ^a	0.08

^{a,b} Means with the same letter are not significantly different ($\alpha = 0.05$).

the consensus for the northern region is that any figure below 15% is considered respectable. Some guidelines (i.e., Minnesota) recommend 10 to 15% for skid trails alone. We suggest that the target threshold of harvest surface area disturbed in northern hardwoods be lowered from 15 to 10%. Equally important, we found that a low percentage of harvest area disturbed does not necessarily reflect high-quality BMP implementation. Proper planning of the access system will require a minimum threshold of area disturbance to accommodate factors associated with topography and density of water bodies.

Initially, the study did not seek to examine the relationship between the harvest access system and harvest area. However, we did find that the harvest area does influence the number of landings as well as the existence of forest roads. Harvest sites with multiple landings and forest roads were twice as large as those with one landing and only skid trails.

This study builds on several decades of research related to forest harvesting and its effects on water quality. It provides a foundation to assess access systems on NIPF, particularly in northern hardwood cover types.

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