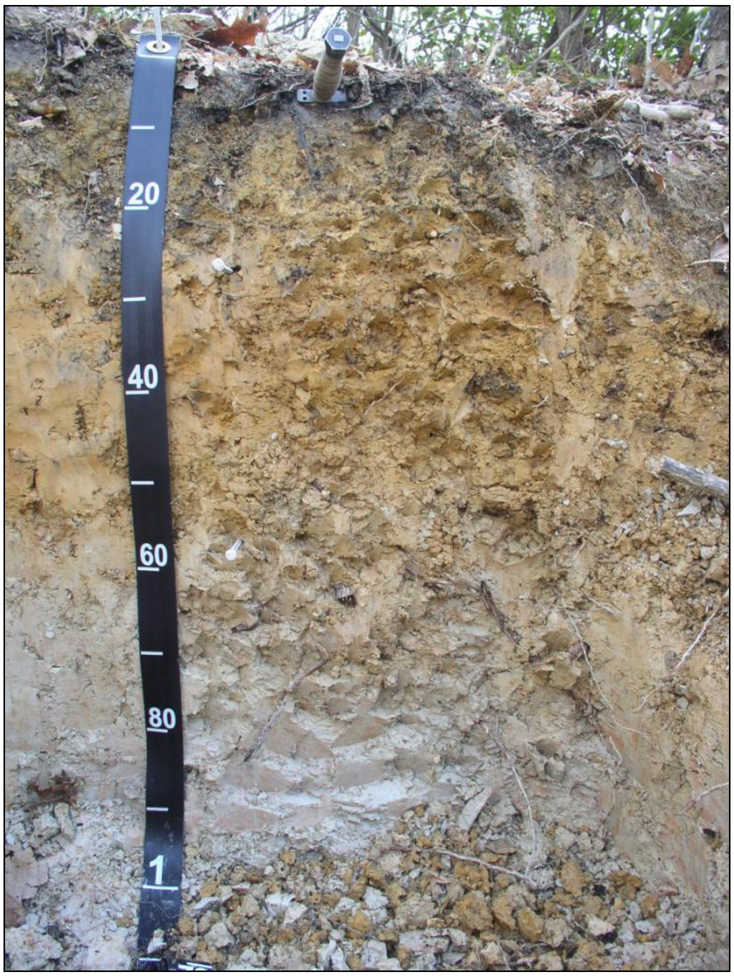
Soils Specialist Report for the Commercial Harvest in Beaver Creek Watershed

Cumberland Ranger District
Daniel Boone National Forest



Prepared by

Claudia Cotton, Ph.D.

Forest Soil Scientist

June 3, 2016

Table of Contents

Introduction

The proposed area for the project "Commercial Harvest in Beaver Creek Watershed" (project) is located on the Cumberland Ranger District of the Daniel Boone National Forest (DBNF). The Forest Service proposes to implement this project to improve the health and vigor of forested communities through stand improvement and stand establishment. This report describes the existing soils environment and environmental effects that may arise from activities within the project.

Included in the project are four alternatives with varying amounts of disturbance (Table 1). The highlighted areas of Table 1 indicate the proposed activities that could have an effect on soil productivity.

Table 1. Comparison of alternatives by activity and acreage for the Commercial Harvest in Beaver Creek Watershed, Cumberland Ranger District, Daniel Boone National Forest. Highlighted areas indicate activities that have the potential to affect soil productivity.

Activity	Proposed Action	Alternative A: Proposed Action Modified	Alternative B: Minimal road development	Alternative C: No Action
Two-aged shelterwood (acres)	170	170	170	0
Commercial thinning (acres)	133	133	133	0
Site preparation with herbicide (acres)	170	0	0	0
Post-harvest crop tree thinning (acres)	0	170	170	0
Planting of soft mast shrubs in landings (acres)	0	12	7	0
Manual/mechanical NNIPS control along roads (acres)	30	25	25	0
System road construction (miles)	0.9	0.9	0	0
Temporary road construction (miles)	1.0	1.0	0	0
Road maintenance (miles)	6.3	6.3	6.3	0

Soil productivity is defined here as the capacity of the soil to meet the management objective, found in the Forest Plan (USDA, 2004), for a particular project area. The physical, chemical, and biological properties of the soil, such as texture, organic matter, nutrients, porosity, soil organisms, pH and base saturation, all affect the productivity of the soil in different ways. In addition to water and air, soil is the most fundamental of resources for a forest.

Affected Environment

Across the dissected landscape of the DBNF soils can be tremendously different in a very short distance. Therefore, it is prudent to consider the great variance of soil conditions that surround the "average" conditions described herein. Elliott and others (1999) recognized that the relationship between disturbance and soil productivity is complex because it involves interactions among disturbance type and intensity, site-specific soil properties, and climate variation.

Most of the soils within the project area are silt loams, sandy loams, or loams. These soils are on average strongly leached, highly weathered, old, acid, and have definite horizon development and low native fertility (ultisols). Alfisols are another group of soils in the project area that are less acid than ultisols, have clay subsoils, and higher native fertility. A smaller portion of the project area soils, particularly those on steep, exposed upper and side slopes, are very mildly weathered with some horizon development and high sand content (inceptisols).

Erosion Potential. Erosion is defined as a process where soil and rock-particles detach from the land and transport over an area by wind, water, gravity, ice, and chemical action (Keller et al., 2011). Forested soil erosion is affected by rainfall erosivity (amount and intensity), soil erodibility (infiltration capacity and structural stability), topography (slope percent and length), and vegetative cover (Brady and Weil, 2002). Rock fragment content also influences soil erosion.

Erosion on a forested soil is often the result of improperly maintained forest roads and the use of heavy equipment for logging. Road construction and road use are the primary sources of non-point source pollution on forested lands, contributing up to 90 percent of the total sediment from forestry operations (EPA, 2016). Best management practices (BMPs) were specifically developed to control erosion and sedimentation that can result from forest management activities.

All but two of mapping units in the project area are rated by the Natural Resource Conservation Service (NRCS) as having severe erosion potential on more than 50% of the mapping unit (Soil Survey, 2016). The amount of extensive cliffline within the analysis area influences this interpretation.

Compaction. Compaction is an increase in soil strength and a decrease in macropore space. It inhibits soil aeration and water infiltration, and decreases soil productivity by reducing water availability for plant uptake. Compaction directly affects tree growth by reducing root growth, height, and timber volume (Greacen and Sands, 1980; Froehlich and McNabb, 1984). However, compacted soils may have lower erodibility because of increased soil strength (Liew, 1974). Amaranthus and others (1996) reported a decrease in soil microbial populations from compaction; however, a more recent review of forest management effects on soil productivity included several studies that reported "few substantial changes in microbial structure due to compaction" through the first 5 years after harvest (Scott and Page-Dumroese, 2016).

Soil compaction may result from the use of heavy equipment to harvest timber and prepare a site for planting. Depending on the initial porosity of the soil, compaction may occur after a single pass of equipment (Wronski, 1984). Existing compaction levels in undisturbed areas of the project do not negatively affect soil productivity.

O Horizon. A defining characteristic of forest soil is the presence of a litter layer, or O horizon. Across the hardwood-dominated forests of the project area, the O horizon may range from less than 1 to 3 inches in depth. The retention of the O horizon is essential for the maintenance of soil productivity. This layer serves several critical functions:

- It protects the soil from exposure to erosive forces.
- It serves as a nutrient source for soil organisms which in turn drive most of the transformations and nutrient cycling in the soil.
- It alleviates compaction.
- It increases infiltration in heavy soils and decreases infiltration in sandy soils
- It insulates the mineral soil from extremes of temperature and moisture.

Soil Organisms. An area of soil should be thought of as an entire environment that includes a community of microbes and other soil organisms that serve to break down and transform the soil into available nutrients for plant growth. Nutrient availability is highly influenced by microbial activity and other chemical parameters, particularly pH. Many nutrients taken up by plant roots are first cycled through a soil organism before becoming available to the plant. In fact, natural biological processes in the soil are responsible for about 60% of the available nitrogen and 50% of the available phosphorus in the soil (Follett, 1995).

Soil Mapping Units and Properties. There are 24 soil mapping units within the spatial bounds of the soil analysis area (Figure 1) (Table 3) (Soil Survey Staff, 2016). Most of these soils are well-drained silt loams, sandy loams, or loams in texture. Maximum depths may reach up to almost 90 inches to bedrock (Table 4). Many of the mapping units are complexes, which contain two or more components.

The most common soil mapping unit is Steinsburg-Ramsey rocky sandy loams, 20-40% slopes. Sub-xeric black oak/white oak communities that include hickories, sourwood, vaccinium, blackgum, and mountain laurel, are often found on these soils. Other commonly occurring soil mapping units in the project area, such as the Rigley-Donahue complex, 30-60 % slopes, and Latham silt loam, 6-12% slopes, often sustain sub-mesic communities due to the clay-enriched subsurface soils. These communities have higher water and nutrient availability, and may support dogwood, white ash, American Beech, sugar maple, yellow-poplar and a diverse herbaceous understory.

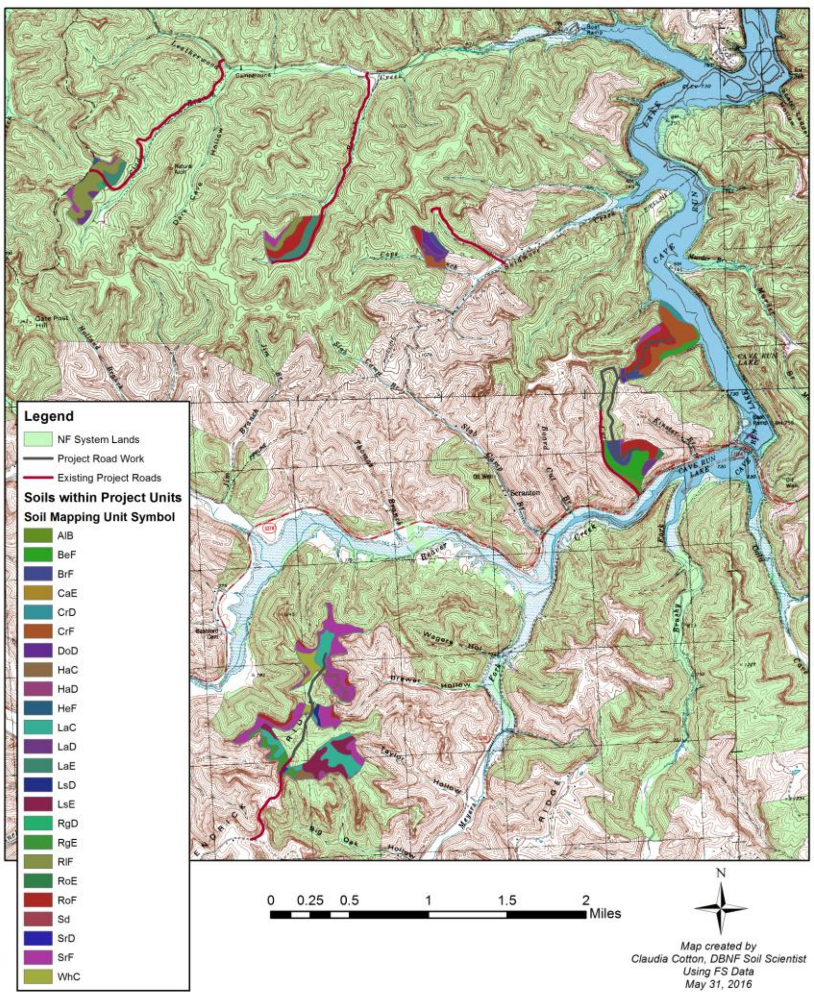


Figure 1. Stands, soil analysis area, roads, and soil mapping units for the Commercial Harvest in Beaver Creek Watershed, Cumberland Ranger District, Daniel Boone National Forest.

Table 2. Soil mapping units and the number of acres they cover as well as the percent of the project area for the Commercial Harvest in Beaver Creek Watershed, Cumberland Ranger District, Daniel Boone National Forest.

Soil Mapping Unit	Soil Mapping Unit Symbol	Acres in Project	Percent of Project Area
Steinsburg-Ramsey rocky sandy loams, 20-40% slopes	SrF	72	19
Rigley-Donahue complex, 30-60 % slopes	RoF	58	16
Cranston gravelly silt loam, 30-60% slopes	CrF	39	11
Rigley stony fine sandy loam, 30-60% slopes	RlF	37	10
Latham silt loam, 6-12% slopes	LaC	37	10
Latham-Shelocta silt loams, 20-30% slopes	LsE	25	7
Latham silt loam, 20-30% slopes	LaE	19	5
Berks channery loam, 40-70% slopes	BeF	14	4
Whitley silt loam, 6-12% slopes	WhC	12	3
Latham silt loam, 12-20% slopes	LaD	12	3
Rigley gravelly fine sandy loam, 20-30% slopes	RgE	11	3
Donahue rocky sandy loam, 6-20% slopes	DoD	8	2
Hartsells fine sandy loam, 12-20% slopes	HaD	7	2
Brookside silty clay loam, 30-60% slopes	BrF	6	2
Cranston gravelly silt loam, 12-20% slopes	CrD	4	1
Hartsells fine sandy loam, 6-12% slopes	HaC	3	1
Latham-Shelocta silt loams, 12-20% slopes	LsD	2	1
Steinsburg-Ramsey rocky sandy loams, 6-20% slopes	SrD	1	<1
Rigley gravelly fine sandy loam, 12-20% slopes	RgD	1	<1
Rigley-Donahue complex, 20-30% slopes	RoE	1	<1
Helechawa-Alticrest-rock outcrop complex, 30-50% slopes	HeF	1	<1
Allegheny loam, 2-6% slopes	AlB	1	<1
Skidmore gravelly fine sandy loam	Sd	<1	<1
Caneyville-Bledsoe-rock outcrop complex, 12-35% slopes	CaE	<1	<1

Table 3. Series, typical pedons, and associated characteristics for soils within the Commercial Harvest in Beaver Creek Watershed, Cumberland Ranger District, Daniel Boone National Forest.

Series	Typical Pedon	Depth (ft)	Drainage	Permeability
Allegheny	loam, 2-6% slopes, rarely flooded in cultivation	7.4	well	moderate
Berks	channery loam, s-facing slope of 3-8% in a cultivated field	2.8	well	moderate to mod rapid
Brookside	silty clay loam, on a 16% irregular s-facing slope	6.7	moderately well	moderate slow

	in a pasture			
Cranston	gravelly silt loam, forest	6.3	well	moderate rapid
Donahue	sandy loam, wooded	2.8	well	moderate slow
Hartsells	fine sandy loam, pasture	3.3	well	moderate
Helechawa	loamy sand, 18% south facing slope in sub-xeric forest	5.0	excessively	moderate rapid
Latham	silt loam, on 20% slope N-facing convex in woods	3.3	mod well	slow
Ramsey	loam, forested	1.7	somewhat excessive	rapidly
Rigley	fine sandy loam, on an E-facing steep side slope in second growth woods	4.6	well	moderate rapid
Shelocta	silt loam, on a 25% concave slope in pasture	5.0	well	moderately
Skidmore	gravelly fine sandy loam, on a 1% slope in a cultivated area	5.8	well to somewhat excessive	moderately rapid
Steinsburg	gravelly loam, cultivated on 3-8% S-facing slopes	2.5	well	moderate
Whitley	silt loam, on a smooth slightly concave 3% ridge top slope in woods	6.7	well	moderate

As noted previously, all but two of the mapping units are rated by the NRCS as having severe erosion potential on more than 50% of the mapping unit. That being said, there is a caveat to using Soil Survey information for forestry purposes.

While GIS and soil survey information is valuable, it has distinct limitations recognized by forest soil scientists and forest land managers (Binkley and Fisher, 2000). The soil survey was created to map productive soils for agricultural use. Since forested soils are often too rocky and steep for this purpose, they were mapped at a coarser scale and the series were often grouped together into complexes that include multiple soil series and characteristics.

Soil map units in NRCS soil surveys are typically delineated at a mapping scale of 1:20,000 (3.18 inches/mile) or 1:24,000 (2.64 inches/mile). This scale of mapping is larger than the area typically covered by stands, the common unit of management on the DBNF. For this reason, soil mapping unit slopes can have a wider range than stands (e.g., Table 2). Thus, it is necessary to judge risks to soil stability and productivity based on site-specific topography rather than on inclusion in a broad slope class, soil map unit, or interpretation. These interpretations are used as a first approximation to identify areas that need to be field verified for soil and landscape conditions.

Multiple field visits to the analysis area for this project have yielded additional on-the-ground information that modifies the severe erosion potential interpretation. Rather than solely depend on the interpretation of the soil mapping units listed above, our field observations indicate that the soils in the analysis area vary in their erosion potential.

Observations made during field visits to the project stands revealed the soils in the analysis area to be on ridge tops with slope gradients often less than 15%, and on side slopes with slope gradients often less than 30%. Soil survey data may be useful but it needs to be modified and augmented by site-specific sampling.

Environmental Consequences

Method of Analysis

Forest management activities have been shown to impact soil productivity by affecting soil erosion, compaction, the O horizon, and the soil microbial and decomposer community (Powers et al., 2005; Schoenholtz et al., 2000; Elliott et al., 1999). Following this logic, four resource indicators were analyzed to determine potential effects to soil productivity (Table 2).

Table 4. Resource element, indicators, and measures for soil effects analyses within the Commercial Harvest in Beaver Creek Watershed, Cumberland Ranger District, Daniel Boone National Forest.

Resource Element	Resource Indicator	Resource Measure
Soil Productivity	Change in erosion potential	Acres of mineral soil exposure from various activities
Soil Productivity	Change in soil compaction	Acres of mineral soil exposure from various activities
Soil Productivity	Change in the O horizon	Acres of mineral soil exposure from various activities;
Soil Productivity	Change in the soil microbial and decomposer community	Discussion of herbicide mobility and persistence; discussion of herbicide use on the soil microbial and decomposer community; Acres of application

The following project activities may affect soil productivity in the following ways:

1. Changes in mineral soil exposure (affects erosion potential, compaction, and the O horizon): the construction and use of skid trails, roads, and landings; mechanical/manual NNIPS removal; the use of herbicide.

2. Changes in the soil microbial and decomposer community: herbicide use.

Effects caused by erosion, compaction, and decreases in the O horizon were determined by quantifying the number of acres of exposed mineral soil.

Effects caused by herbicide use were discussed using the best available science, as well as quantifying the number of acres to be treated.

Spatial and Temporal Bounds of Analysis

The spatial bounds for this effects analysis are the boundaries of the stands to be managed and the soils beneath the road work to be done for this project (Figure 1). The temporal bounds for the effects analysis is three years, or the maximum amount of time it takes for mineral soil to become re-vegetated after disturbance on most sites on the DBNF.

Effects Analysis

The Proposed Action

Change in mineral soil exposure

Activities that could cause mineral soil exposure include the construction and use of roads, landings and skid trails, mechanical NNIPS control along roads, and the use of herbicide.

Road Construction - Under the Proposed Action, 1 mile of temporary road and 0.9 mile of permanent system road would be constructed in the analysis area. These activities would expose mineral soil and could affect the soil productivity through a change in erosion potential, compaction, and O horizon removal.

The temporary and permanent road construction would expose soil until the installation of the gravel cover. Once the project work is completed, the temporary road would be seeded, gated, and closed. Kentucky BMPs would be followed (Stringer and Perkins, 1997). Given that this alternative calls for less than two miles of road construction, it would be unlikely that this activity would cause effects to soil productivity. When converted to acres and compared to the total amount of acres in the project, less than 1% of the land would have exposed mineral soil from this activity (Table 5). Activities of this magnitude usually do not result in long-term detrimental effects to soils on the DBNF.

Design criteria and BMPs related to the installation of gravel cover, installation of water control structures, and ground conditions during allowable use should minimize the direct and indirect effects to soils related to road construction while staying within the standards of the Forest Plan and other guidance. Surface erosion associated with road construction decreases rapidly following construction, especially if BMPs are followed and/or roads are closed (Grigal, 2000).

Cumulatively, there will be additional horse and mountain bike trail construction related to the Cave Run Trails Non-Motorized trail project within the project area. The design criteria related to construction in that project should not result in effects that would increase the direct/indirect soil effects to a level beyond that defined in the Forest Plan.

Landing Construction and Skid Trails - Landings and skid trails would increase the amount of mineral soil exposure. This could affect soil productivity by increasing the erosion potential, decreasing the O horizon through vegetation removal, and increasing compaction though heavy equipment operation during construction and use.

The Forest Plan contains a vegetation standard requiring no more than 10% of a harvest area to be in landings, skid roads, or exposed soil (USDA FS, 2004). When compared to the total amount of acres in the project, less than 1% of the land would have exposed mineral soil from landings (Table 5). This falls within the 10% Forest Plan standard. Furthermore, commercial material would be limbed and bucked on the landings, and the addition of brush on the perimeter would serve to reduce erosion run-off.

Although the existing skid trails in the harvested units could be used, and even with the uncertainty of the location of new skid trails, these activities could still be accomplished within acceptable limits of soil disturbance outlined in the Forest Plan if design criteria are followed. These include the 10% rule listed above, post-project seeding and mulching, location approval, proper spacing and use of water control structures, and ground conditions for use.

Cumulatively, there are no other projects that are building landings within the project area.

Manual/Mechanical NNIPS Control along Roads – Manual and mechanical treatment methods to control NNIPS could potentially affect soil productivity by increasing the amount of exposed mineral soil, which would increase erosion potential. Mineral soil exposure would be caused by removal of the vegetation by uprooting, disking, and plowing.

This treatment would be used along roads, which are relatively open areas that commonly have a history of prior soil disturbance. If NNIPS are manually or mechanically controlled along roads and expose mineral soil, then soil effects would be minimized by mulching and/or re-seeding with native grasses and forbs. If design criteria are followed properly, then this activity could be accomplished within acceptable limits of mineral soil exposure.

Cumulatively, the Kentucky Department of Transportation controls roadside vegetation with the use of mowing and mulching. This activity does not expose mineral soil to an extent that would increase the direct/indirect effects listed above.

Use of Herbicide – If herbicide is used for site prep, then an increase in exposed mineral soil could occur, which could affect erosion potential. An increase in erosion potential should not occur with the use of herbicides because in most cases, herbicides would be directly applied to the target plants using spot treatment. If spot treatment of herbicide is employed, then large patches of total vegetation removal that would result in exposed mineral soil would be unlikely. If mineral soil is not exposed, then erosion potential should remain unchanged.

Cumulatively, the Kentucky Department of Transportation uses herbicides to control roadside vegetation. However, the dead vegetation that results from this application covers the mineral soil and does not increase erosion potential. The effects from this activity should not increase the direct/indirect effects discussed above from the use of herbicide in the project area.

Table 5. Summary Table for all alternatives: Acres of mineral soil exposure resulting from activities within the Commercial Harvest in Beaver Creek Watershed, Cumberland Ranger District, Daniel Boone National Forest.

Activity	Amount	Acres of Exposed Mineral Soil[1]	Acres of Disturbed Soil /Total Acres of Project
Proposed Action			
Road Construction	1.9 mile	2.76	0.9%
Landings	11 maximum	2.20	0.7%
Manual/Mechanical NNIPS control	30 acres	0.0	0.0%
Herbicide Site Prep	170 acres	0.0	0.0%
Alternative A – Modified Proposed Action			
Road Construction	1.9 mile	2.76	0.9%
Landings	11 maximum	2.20	0.7%
Manual/Mechanical NNIPS control	25 acres	0.0	0.0%
Herbicide Site Prep	0 acres	0.0	0.0%
Alternative B – Minimal Road Development			
Road Construction	0 miles	0.0	0.0%
Landings	11 maximum	1.1*	0.36%
Manual/Mechanical NNIPS control	25 acres	0.0	0.0%
Herbicide Site Prep	0 acres	0.0	0.0%
Alternative C – No action			
Road Construction	0.0	0.0	0.0%
Landings	0.0	0.0	0.0%
Manual/Mechanical NNIPS control	0.0	0.0	0.0%
Herbicide Site Prep	0.0	0.0	0.0%

[1] Assuming road width of 12 feet; 1 landing = 0.2 ac; and design criteria applied.
* Swing-landings are half the size of regular landings.

Herbicide Use: Mobility and Persistence, Changes in the Soil Microbial and Decomposer Community, Acres of application

Two herbicides are proposed for the purpose of site preparation: triclopyr and imazapyr.

Triclopyr. Studies have addressed the environmental fate of triclopyr in soil and water (USFS, 1996; Ganapathy, 1997). Both showed that triclopyr binds to organic matter in the soil and is held near the surface where it degrades more easily than in the lower horizons of the soil. Adsorption of triclopyr is generally characterized as “not strong." Microorganisms degrade triclopyr readily. It degrades more rapidly under warm, moist conditions which favor microbial activity. Persistence varies widely, depending on soil type and climate. Under most conditions triclopyr breaks down relatively quickly and has a half-life in soil of 1.1 to 90 days (NPIC, 2002). Triclopyr did not affect the growth of soil microorganisms up to 500 parts per million (USFS, 1984). Given the application methods it is unlikely that the 500 ppm level would be reached under normal circumstances.

Long-term forest and pasture studies found very little indication that triclopyr will leach substantially either horizontally or vertically in loamy soils (Durkin, 2011b). This reduces the likelihood that the herbicide would leach into streams, lakes, or groundwater. If it does reach water, triclopyr breaks down relatively quickly and has a half-life 1 to 10 days in water (NPIC, 2002). Ganapathy (1997) concluded that “with the use of buffer zones around streams and ephemeral drainage routes, forestry applications of triclopyr could be made without harm to nearby streams.” The USFS (1996) stated that “triclopyr contamination of groundwater has not been reported.”

Imazapyr. Imazapyr should be applied directly to plants and not soil. If imazapyr gets into the soil, the existing soil pH would affect the mobility or persistence of the chemical. A soil with a pH less than 5 would cause the chemical to bind with the soil, whereas a pH greater than 5 would not bind the chemical to the soil, allowing it to be mobile in the soil solution (Durkin, 2011a). If imazapyr is mobile in the soil solution, then it could be taken up by plants, degraded by microbes, or leached off-site in heavy rain events (Tu et al., 2001). If imazapyr remains bound to the soil, then it could have a negative effect on plant re-establishment.

Soil-mobile imazapyr is degraded primarily by microbial metabolism (Tu et al., 2001). Sunlight does not degrade imazapyr but it does degrade in water. Estimates for the soil half-life of imazapyr vary widely (from 25 to 2,972 days) in the published literature (Durkin, 2011a). Because of this uncertainty, it would be important to adhere to conditions that maximize this chemical’s degradation. If a soil is waterlogged and anaerobic, degradation of imazapyr is decreased. As the pH of a soil increases, microbial degradation of imazapyr will decrease (Tu et al., 2001). In general, microbial metabolism increases with increasing temperature and increasing soil moisture (to a point).

There is little information available about the effects of imazapyr on the soil microbial and decomposer community. Forlani et al. (1995) reported that imazapyr inhibited growth for some types of soil bacteria in laboratory assays; however, the effects appeared to be species specific. No field studies have been reported.

In water, imazapyr can be rapidly degraded by sunlight with a half-life averaging two days. Runoff is a concern because soil particles that bind imazapyr can be transported offsite. If a site to be treated with imazapyr has steep slopes, bare soils, minimal vegetation coverage, soils with high clay content, and heavy or prolonged precipitation, then runoff may be an issue. Non-target plants could be affected by runoff that contains imazapyr.

Herbicide would not be used in every stand, nor is it proposed in every alternative; only the Proposed Action includes herbicide use. Table 6 displays the estimated area of each stand where herbicides would be applied. For context, the treatment area in each stand would be less than a tenth of an acre and the total area of treatment for the entire project would be 0.052 acre (Table 6). This would be less than 0.02% of the total project acreage. The numbers reported in Table 6 are worst-case, as the application would be targeted onto cut stumps and soil exposure would only occur from spray reaching spots where leaf litter is not present around a stump. Cut surface application to selected species would minimize the soil exposure to herbicide.

Table 6. For the Proposed Action only, estimated area that will be affected by herbicide use within the Commercial Harvest in Beaver Creek Watershed, Cumberland Ranger District, Daniel Boone National Forest.

Stand	Total Acres in Stand	Area to be treated per Acre (ft^2)	Total area treated in stand (ft^2, ac)*	Stand Acres treated/Stand acres**
29	17	4	68, 0.002	0.012%
7	45	2	90, 0.002	0.004%
26	22	12	264, 0.006	0.027%
40	73	16	1168, 0.027	0.037%
46	54	12	648, 0.015	0.028%

*Stand 29 example: 17 total acres x 4 ft^2/acre = 68 ft^2/in stand to be treated; 68 ft^2 = 0.002 acres.

**Stand 29 example: 0.002 acres to be treated/17 acres in stand x 100 = 0.012%

Considering the limited spatial scope of application and design criteria, the herbicide activities in the Proposed Action may still be accomplished within acceptable limits of the effects.

Cumulatively, the Kentucky Department of Transportation uses herbicides to control roadside vegetation. The effects from this activity should not increase the direct/indirect effects discussed above from the use of herbicide in the project area.

Alternative A – Modified Proposed Action

Alternative A is identical to the Proposed Action with the following modifications:

1. Use annual cereal grains for revegetating areas that have exposed mineral soil
2. Plant soft mast shrubs in landings
3. Post-harvest site prep to be done manually without any herbicide use
4. NNIPS manual/mechanical treatment prior to any ground disturbance

Effects would be consistent with those outlined in the Proposed Action with the following exceptions:

No effects from the use of annual cereal grains. Planting soft mast shrubs in landings would have a positive effect on soil productivity primarily by alleviating compaction and introducing a source of litter to build up the O horizon. There would be no herbicide effects.

With the elimination of herbicide use, this Alternative would cause soil disturbance over a longer time frame and a larger spatial scale. Manual and mechanical post-harvest site prep at 10 years would create soil disturbance through the use of mechanical equipment as described in the Proposed Action, but would occur later with this alternative. The effects of NNIPS manual/mechanical treatment prior to any ground disturbance would be consistent to those described in the Proposed Action, but would occur sooner with this alternative. This could cause a change in soil productivity. If number of stand entries increases and soil disturbance is spread over a longer time frame, then vegetation would take longer to recover, compaction could increase, and overall effects to soil productivity could increase in intensity due to less recovery time between stand entries.

All effects from implementing Alternative A would be within the limits of soil disturbance as outlined in the Forest Plan and other guidance, but the soil disturbance would be spatially larger and temporally longer than what would occur in the Proposed Action.

Alternative B – Minimal Road Work

Alternative B is similar to Alternative A with the following modification:

1. Eliminate the construction of all system and temporary roads and use the swing-landing method to remove the commercial material from the site. Landings will be half the size of those in the previous alternatives. Trees will be limbed and bucked where they are felled in the unit.

Effects would be consistent with those outlined in Alternative A with the following exceptions:

If there is no new road construction, then there would be no negative effects to soil productivity that would occur from this activity, such as exposed mineral soil, compaction, and litter layer removal. If landings are smaller, then less mineral soil would be exposed, less compaction would occur, and more O horizon would remain intact versus the two previous alternatives. In context, the total area that would be covered in swing landings would be 1.1 acres, or less than 0.5% of the total project area (Table 5).

Since commercial material would be limbed and bucked in the unit, there would be less brush on the landing and more passes on skid trails, which would decrease the litter layer on the landing and increase soil compaction on the skid trails. If there is a decrease in landing area with this alternative, then effects to soil productivity from compaction on skid trails should still fall within the limits of soil disturbance as outlined in the Forest Plan and other guidance.

For example, Alternative B would produce a total of 1.1 acre of soil disturbance through landing construction and use. The Forest Plan Standard calls for a maximum 10% of an area (or 30 acres in this project) that can be disturbed in landings, skid trails, and exposed soil. Subtracting 1.1 acres from 30 would leave 29 acres remaining in the project area that could be disturbed and still meet the standard. Assuming a skid trail is 12 feet wide, 29 acres is equivalent to 20 miles of 12-foot wide skid trails throughout the project.

If the skid trails fall within this mileage, then effects to soil productivity from implementing Alternative B would be within the limits by which we manage soils on the DBNF.

Alternative C – No Action

Under Alternative C no activities from the project would be implemented. There would be no direct, indirect, or cumulative effects to soil productivity with this Alternative.

Consistency with Forest Plan

Based on the analysis, the Commercial Harvest in Beaver Creek Watershed would be consistent with the Forest Plan direction for the soil resource.

Summary for the Soil Resource

Based on field work, analyses within this report, and best available science there would be no adverse effects to the soil resource as a result of this undertaking if the provided recommendations are followed. Alternatives clearly have different amounts of soil disturbance among them, but the activities proposed could be implemented within the range of effects outlined in the Forest Plan and other guidance.

References

Amaranthus, M.P., D.S. Page-Dumroese, A. Harvey, E., Cazares, and L.F. Bednar. 1996. Soil compaction and organic matter affect conifer seedling nonmycorrhizal and ectomycorrhizal root tip abundance and diversity. Research Paper PNW-RP-494. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 12 pp.

Binkley, D. and R.F. Fisher, 2000. Ecology and management of forest soils, 3rd ed. John Wiley & Sons, New York, NY. 490 pp. Book (4th ed.) available for purchase online at: http://www.wiley.com/WileyCDA/WileyTitle/productCd-0470979461.html.

Brady, N.C. and R.R. Weil. 2002. The nature and properties of soil, 13th ed. Prentice Hall, Upper Saddle River, NJ. 960 pp. Book available for purchase online at: http://www.amazon.com/Nature-Properties-Soils-14th-Edition/dp/013227938X.

Durkin, P. 2011a. Imazapyr, human health and ecological risk assessment, final report for USDA FS, Southern Region. Syracuse Environmental Research Associates, Inc. Manlius, NY.

Durkin, P., 2011b. Triclophyr, human health and ecological risk assessment, final report for USDA FS, Southern Region. Syracuse Environmental Research Associates, Inc. Manlius, NY.

Elliot, W.J.; Page-Dumroese, D.; Robichaud, P.R. 1999. *The effects of forest management on erosion and soil productivity*. **Proceedings of the Symposium on Soil Quality and Erosion Interaction,** Keystone, CO, July 7, 1996. Ankeney, IA: Soil and Water Conservation Society. 16 p.

EPA. 2016. https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-forestry, Accessed 3/10/16.

Follett, R.F., 1995. Fate and transport of nutrients: nitrogen. Working Paper 7. USDA ARS, Fort Collins, CO. Available online at: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/crops/?cid=nrcs143_014202.

Forlani, G., M. Mantelli, M. Branzoni, E. Nielsen, F. Favilli. 1995. Differential sensitivity of plant-associated bacteria to sulfonylurea and imidazolinone herbicides. Plant and Soil 176 (2):243-253.

Froehlich, H.A. and D.H. McNabb. 1984. Minimizing soil compaction on Pacific Northwest forests. In E.L. Stone (ed.). Forest Soils and Treatment Impacts. Proc. 6th American Forest Soils Conference, Knoxville, TN, pp. 159-192.

Ganapathy, C., 1997. Environmental fate of triclopyr. Environmental Monitoring & Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA 95814-5624. http://www.cdpr.ca.gov/docs/emon/pubs/fatememo/triclopyr.pdf . 18 p.

Greacen, E.L. and R. Sands. 1980. Compaction of forest soils – a review. Aust. J. Soil Res. 18:163-189.

Grigal, D.F. 2000. Effects of extensive forest management on soil productivity. Forest Ecol. Mgt. 138:167-185.

Keller, G., S. Wilson-Musser, P. Bolander, and V. Barandino, Jr. 2011. Stabilization and rehabilitation measures for low-volume forest roads. USDA Forest Service. Publication 7700 Transportation Management. 333 pp. Publication available online at: http://www.fs.fed.us/t-d/php/library_card.php?p_num=1177%201801P.

Liew, T.C. 1974. A note of soil erosion study at Tawau Hills Forest Reserve, Malay. Nat J. 27:20-26.

National Pesticide Information Center (NPIC), 2002. Triclophyr; General fact sheet. Oregon State University. http://npic.orst.edu/factsheets/triclogen.pdf . 4 p.NuFarm. 2012a. Imazapic 2SL herbicide specimen label. Burr Ridge, IL.

Powers, R.F., D.A. Scott, F.G. Sanchez, R.A. Voldseth, D. Page-Dumroese, J.D. Elioff, D.M. Stone. 2005. The North American long-term soil productivity experiment: findings from the first decade of research. Forest Ecol. Mgt. 220:31-50.

Schoenholtz, S.H., H. Van Miegroet, J.A. Burger. A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities. Forest Ecol. Mgt. 138:335-356.

Scott, D.A. and D.S. Page-Dumroese. 2016. Wood bioenergy and soil productivity research. Bioenergy Research, 11 p. 10.1007/s12155-016-9730-6.

Soil Survey Staff, Natural Resources Conservation Service (NRCS), United States Department of Agriculture (USDA). 2016. Soil Survey Geographic (SSURGO) Database for the Daniel Boone National Forest, Kentucky. Available online at http://soildatamart.nrcs.usda.gov. Accessed December 23, 2015.

Tu, M., C. Hurd, and J.M. Randall. 2001. Weed control methods handbook: tools and techniques for use in natural areas. The Nature Conservancy. 219 p.

USDA Forest Service, U.S. Department of Agriculture, 1984. Pesticide Background Statements. Volume 1. Herbicides. Agriculture Handbook No. 663.

USDA Forest Service, Pacific Northwest Region, 1996. Triclopyr: herbicide information profile. http://www.fs.fed.us/r6/nr/fid/pubsweb/tri.pdf .14 p.

USDA Forest Service. 2004. Land and resource management plan for the Daniel Boone National Forest. U.S. Department of Agriculture, Forest Service, Daniel Boone National Forest, Winchester, KY.

Wronski, E.B. 1984. Impact of tractor thinning operations on soils and tree roots in a Karri forest, Western Australia. Aust. For. Res. 14:319-332.