Chapter 13
Chemical and Mechanical Site Preparation

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Abstract

Site-preparation operations before reforestation can (1) reduce woody competition in the following stand, (2) improve surficial drainage or adverse soil conditions, (3) clear harvest debris to facilitate planting, and (4) reduce future fire hazard. Planning is critical to meet financial and biological objectives of site preparation, particularly for preharvest treatments. Mechanical site preparation, often done in conjunction with burning, may employ a variety of equipment to reduce or rearrange the volume of standing live or downed debris to improve planting accessibility. Soil-manipulation treatments can have major impacts on soil physical and chemical properties that influence long-term site productivity; they also can correct problems created by earlier operations or improve drainage of naturally wet soils. Mechanical methods should be applied carefully on steep, highly erodible, or nutrient-poor soils. Chemical site preparation, on the increase with the recent availability of new herbicides, has little adverse impact on soils when used alone or with fire and effectively controls woody competition in the new plantation. As with mechanical techniques, considerable expertise is required for success. Site-preparation practices may differ by physiographic region and will vary according to management philosophy and expected product value.

13.1 Introduction

Successful artificial regeneration of pines in the southeastern U.S. almost always requires some level of site preparation to ensure adequate survival and enhance pine productivity. Site-preparation procedures are designed to accomplish one or more of the following: (1) reduce competition; (2) improve drainage or other adverse soil conditions; (3) clear the site of debris to facilitate planting; and (4) reduce future fire hazard. Site preparation is but the first of various silvicultural practices (i.e., quality planting, herbaceous weed control, fertilization, and thinning) that can lead to improved yields, reduced rotations, and increased economic returns [6, 13, 14, 22]. The gains in yield are largely promoted through site preparation by (1) reducing direct competition of crop trees and other plants for site resources, (2) increasing availability of site resources through more subtle means, e.g., incorporating organic matter into the soil, changing soil temperature and moisture regimes that affect nutrient turnover and movement, and reducing rainfall interception by litter or foliage [20], or (3) facilitating resource uptake through the development of larger tree root and foliage systems.

Because the financial investment in site preparation is the major cost in developing a timber stand and that cost must be carried for the entire rotation, it is important to select a cost-effective method that meets the needs of both site and landowner. The potential investment in site preparation will vary widely depending on site quality, location, and accessibility, and on expected product value. Foresters must clearly define their objectives when considering site-preparation alternatives and match those objectives to site and cost constraints. In this chapter, we describe the mechanical and chemical site-preparation systems available and in use to regenerate the major pine species in the southeastern U.S. so that managers and landowners can make informed decisions.

13.2 Site-Preparation Alternatives

13.2.1 Reducing Competition

In recent years, considerable research and operational observations have demonstrated that pine survival and growth can be greatly enhanced through site-preparation treatments which reduce competition for site resources. Shade-intolerant species such as the southern pines have high light requirements for photosynthesis. When overtopped by competing plants, they are likely to experience both survival and growth losses because of water and light limitations [8].

In practice, competing plants are virtually never eliminated, but rather temporarily reduced in size, number, or both. Indeed, the total elimination of vegetation other than the planted pine is not desirable because these other plants may help retain nutrients on the site, provide wildlife food and shelter, and promote erosion control. They also

M.L. Duryea & P.M. Dougherty (eds), Forest Regeneration Manual, pp. 251–261.

enhance the plant diversity normally associated with forests. It may be possible to site prepare only a portion of the total area to be planted in either spots or strips to help foster species diversity. Although less costly than treating the entire area and likely to successfully increase crop-tree survival, site preparation in spots or strips is often not as effective as complete treatment in promoting long-term pine growth. Ultimately, site-preparation effectiveness must be judged on the basis of its impact on economics and on the long-term productivity of the site (see chapter 2, this volume).

13.2.2 Improving Drainage or Other Soil Conditions

On poorly and very poorly drained soils, the post-harvest water table may be too high to permit successful pine regeneration. Pine survival and growth are often limited by anaerobic conditions on these sites. Drainage has been employed on some wet sites of the Lower Coastal Plain to improve soil aeration [6, 26]. Bedding also may be necessary to provide additional water-table control in the immediate vicinity of the seedling. Moreover, many such sites on the Lower Coastal Plain are phosphorus deficient, and growth benefits to pine plantations can be spectacular from preplant phosphorus applications in conjunction with drainage and bedding (see chapter 14). Once the plantation is established and has developed adequate leaf area, the water table is largely controlled by transpirational water loss. Drainage-ditch outflow may be restricted to provide additional water for mature plantations during the growing season.

The amelioration of adverse soil conditions on upland sites can improve pine survival and growth by (1) breaking soil layers that hinder planting and restrict root development, (2) concentrating organic matter near the seedlings, and (3) increasing soil macropore volume, which improves aeration and may increase moisture holding capacity. Disking, bedding, and ripping or subsoiling are used to accomplish these objectives but should be applied judiciously to avoid adverse treatment impacts such as increased erosion or unnecessarily high costs. Moreover, these treatments must precede planting by enough time that rainfall can re-wet and settle the soil.

13.2.3 Clearing Site Debris

In the past, intensive mechanical site-preparation treatments such as shearing, raking, piling, and disking were applied mainly to enhance the planting operation [9, 2I]. This practice likely is an extension of intensive mechanical treatments used in agriculture. However, as with the development of minimum tillage in agriculture, foresters too are finding that completely removing debris is neither necessary nor desirable in preparing a site for planting. Although planting difficulty may increase if more debris is allowed to remain, these areas often exhibit greater pine growth because of the lack of soil loss and compaction from more intensive mechanical operations.

13.2.4 Reducing Fire Hazard

Large amounts of woody debris remaining after logging can be not only a major impediment to subsequent planting operations, but also a fire hazard during the first few years of plantation establishment. This hazard can be reduced by broadcast burning the debris directly following logging or piling it and later burning the piles. Chopping or crushing before burning may permit more complete combustion and more rapid microbial decomposition. Chemical site preparation often increases the fire hazard because of the large amount of dry fuel created. For this reason, herbicide treatments are almost always followed by controlled burning to reduce fire hazard and facilitate planting. The use of fire is discussed fully in chapter 12, this volume.

13.3 Planning and Timing

13.3.1 Planning the Site-Preparation Operation

Site-preparation planning should begin before harvesting, which itself should be an integral part of the site-preparation process. Such planning and integration will facilitate selection of the most biologically appropriate and cost-effective site-preparation method, which will maximize survival and growth of the following forest [5].

Before harvesting, sites should be surveyed for information on vegetation, topography, and soils. The plantation management plan, along with knowledge of species composition, size classes, and frequency, will permit foresters to estimate the likelihood of future competition problems. Soil drainage, pH, texture, organic matter content, and depth to pans also can be important considerations in selecting the proper site-preparation method, as can geographic information about slope, the location of ponds, lakes, and streams, and the nature of adjacent public-use areas and residences (see also chapters 9 and 10).

13.3.2 Timing Site-Preparation Treatments

Site-preparation treatments may be applied before or after harvest. Traditionally, postharvest treatments are more common because preharvest ones require advanced planning and expenditures relatively early in the life of the new plantation.

13.3.2.1 Before harvest

Preharvest site preparation has been used sparingly in the Southeast. Nevertheless, its advantages include (1) improved accuracy and speed of forest surveys and reduced harvesting costs; (2) reduced postharvest site-preparation costs; (3) the possibility of applying expenses to the stand about to be harvested; and (4) increased growth of high-value wood from existing crop trees if held for a few more years [5].

The most commonly used preharvest site-preparation treatments are herbicide applications, harvesting of unmerchantable woody biomass for fuelwood, and prescribed burning. Herbicides are the most effective but may cost more than other treatment types. However, injecting unwanted stems or broadcast application of selective herbicides can control or eliminate the prolific sprouting that can hamper survival and growth of crop trees in a regenerating stand. Prescribed burning can be used at the appropriate time following herbicide application to reduce fire hazard and improve stand access for cruising and harvest. However, although prescribed fire can greatly reduce the biomass of small competing woody vegetation, it does little to reduce the number of sprouting rootstocks unless carried out annually during summer over a 3- to 5-year period. Frequently, on regularly burned upland sites, little additional site preparation is necessary.

13.3.2.2 After harvest

Planning for postharvest site-preparation treatments before logging also is important. Anything that can be done to reduce the amount of downed or standing harvest debris or minimize the amount of soil damage will reduce site-preparation cost and may enhance growth of the succeeding stand. Numerous post-harvest site preparation systems — mechanical, chemical, and fire — have proven successful when used alone or in various combinations; however, timing is crucial. If reducing competition is the objective, the treatment(s) chosen must be applied when the probability of greatest effect is expected. If removing logging debris is the objective, it must be treated before substantial regrowth occurs and in periods favorable for burning. If ameliorating soil physical properties is the objective, soil moisture conditions must be heeded as these will dictate treatment timing to maximize treatment effect. As is the case with most silvicultural operations, the ultimate success of any given treatment is usually related to the forest manager's experience, adequacy of personnel training, the quality-control system used, and Mother Nature.

Long-range planning is necessary if site-preparation treatments are to be effective, especially if the program is large, because contractors must be identified, contracts negotiated, and contractors "educated" as to management expectations before work can begin. Then equipment must be moved among sites in an orderly manner to minimize both costs and site damage.

13.4 Site-Preparation Methods

13.4.1 Mechanical Site Preparation

Mechanical site preparation includes those activities, exclusive of the use of herbicides and fire, intended to improve conditions for the establishment and growth of the crop species. The objectives of mechanical site preparation are to (1) manage or dispose of debris remaining after harvesting; (2) control existing or anticipated vegetation likely to compete with the crop trees; and (3) alter soil physical properties to facilitate subsequent silvicultural operations, enhance forest establishment and growth, or both.

Mechanical site-preparation operations may expose large areas of mineral soil; therefore, they must be planned and executed with care in areas with erodible soils on sloping terrain. Though the amount of erosion varies considerably by soil type [1, 23], possible water channels should always be oriented parallel to topographic contours to minimize soil erosion. This will act to conserve soil moisture but in some cases may be at odds with harvesting considerations. Conflicts of this type should force careful reconsideration of the site-preparation prescription, particularly in terms of overall objectives.

13.4.1.1 Manipulating residual woody biomass

Forest harvesting frequently leaves both standing and downed debris that must be physically rearranged to facilitate other site-preparation activities such as burning, disking, or bedding and planting. Standing residual stems are often severed or chopped/crushed before other operations can proceed.

Some mechanical site-preparation operations can have a major impact on access and equipment operability in the subsequent forest, and therefore on economics. For example, debris-pile size and orientation determine bed orientation and thus tree-row orientation relative both to one another and to access roads. These factors often determine the profitability of subsequent operations performed with ground-operated equipment. Mechanical site-preparation treatments that impact subsequent tree-row orientation should always be planned with future silvicultural and harvest operations in mind.

Slashing. — Slashing is the cutting or felling of standing live or dead nonmerchantable trees and other vegetation. Slashing frequently is carried out by hand with chain saws, brush saws, axes, and brush hooks, although heavy duty flail-type or rotary cutter heads, mounted on articulated, rubber-tired, skidding tractors, have been used. The hand techniques tend to be very labor intensive because individual stem sizes are often small and access to and within the treatment area is often difficult.

Slashing is done principally to reposition live fuel so that it dries before burning, improve access for regeneration activities, and temporarily reduce competition for the succeeding stand. However, severed hardwoods and shortleaf pine (*Finns echinata* Mill.) will sprout from their stumps unless treated with herbicide when cut. If herbicide is not used, sprout vigor will be lowest if the slashing is done in early summer and greatest if done from late fall until spring leaf-out.

Slashing is employed sparingly as a substitute for conventional mechanical site preparation on tracts where the cost of moving large mechanized equipment to the site is not justified or in areas inaccessible to or inoperable by equipment normally used for site preparation. It also is employed for aesthetic reasons in areas with high public visibility.

Shearing. — Shearing is the cutting of standing vegetation and stumps with a swept-back, sharpened blade, normally horizontally mounted on the front of a crawler tractor. The height of the cutting edge is maintained at or near the soil surface, severing most woody plants and depositing them in the cleared swath of the preceding pass. "V" shearing blades have two cutting edges swept back from their juncture in front of the tractor center. A forward-pointing "stinger", usually attached at this juncture, is used to split large stumps. However, the additional length of "V" shearing blades equipped with a "stinger" relative to straight blades may limit tractor maneuverability in broken terrain.

Shearing often is the first in a series of mechanical operations done to clear sites of large amounts of standing vegetation or stumps that will hinder subsequent operations (e.g., piling, bedding, and machine planting). In addition, proper shearing orients most stems parallel to the intended debris pile, thereby facilitating piling (see section directly following).

Shearing nearly always precedes piling; however, burning may immediately follow shearing where pile burning is prohibited or where debris accumulations do not warrant piling. Shearing usually enhances burning and if most material is consumed, follow-up piling may not be required. Piling can be omitted in such cases, particularly if the site will not be bedded, or if the site will be hand-planted. Piling also can be eliminated if little debris remains or if acceptable beds can be made using a "V" blade on the bedding tractor. A burn following shearing enhances piling because less material remains to be piled, reducing the chance of inadvertently moving topsoil into the piles.

Piling or raking. — Piling or raking is the movement of organic debris into orderly piles. The purpose of piling is to clear loose debris, roots, and stumps remaining after harvesting and shearing. The purpose of raking is to facilitate bedding and planting operations. Raking followed shearing on approximately 60% of the southern Coastal Plain plantations established in 1980 [15]. In some cases, root-raking is done to reduce the amount of large roots near the soil surface that will interfere with mechanical planting and to minimize sprouting from those roots.

Piling operations are most frequently done with crawler tractors equipped with rakelike front-mounted blades. Piling blades also are available for use on articulated, rubber-tired, skidding tractors. The lower edge of piling blades is usually equipped with teeth spaced at various intervals to allow soil to pass through but retain large pieces of debris. Some blades may be formed entirely of such teeth. Earth-moving straight blades have also been used, but predictably considerable amounts of soil may be pushed into the piles.

The piling of large amounts of organic matter also can adversely affect soil nutrient levels and subsequent plantation growth [2, 23, 25, 33], particularly if much of the site nutrient capital is in this debris (e.g., on well-drained sandy forest soils). Displacement of nutrients into piles is estimated to exceed that from harvest by 200% [29].

Shearing and piling operations require multiple passes over the entire tract of land with heavy equipment, which can significantly compact fine-textured soils if done when soils are wet. Compaction can have long-term detrimental effects on plantation performance [7, 28]. However, Gent and Morris [11] report no increase in bulk density of a wet sandy loam soil due to shearing and piling or chopping. They note, however, that the site may have been compacted by an earlier thinning operation. Compacted areas associated with harvesting tend to be localized at skid trails and landings.

Debris piles are generally burned to diminish their size, but are rarely reduced to the point that they do not dictate bed and, hence, tree row orientation, particularly if the area was burned before piling. Consequently, the profitability of subsequent mechanized ground operations (e.g., thinning, ground fertilization, and harvesting) may depend on careful pile layout, planning, and execution. To facilitate such activities, piles should be oriented to maximize the number of long rows with easy access to roads. In addition, piles should be spaced at even multiples of bed spacing and parallel to one another to fully utilize the site and eliminate short rows that terminate in piles on the sides. Piling tractor operators are generally not attuned to the importance of these factors unless they have done mechanical ground operations in plantations with poor row orientation.

Chopping or crushing. — Chopping or crushing refers to the rolling of a heavy steel drum studded with radially oriented cutting blades across a site. The purpose of chopping or crushing is to enhance burning by consolidating fuels and by severing live vegetation which promotes its drying and subsequent burning. Chopping also reduces the average length of small stems and shallow roots, thereby facilitating tillage. Drum chopping may loosen surface soils to the depth of blade penetration when the drum is pulled at relatively high speed; such drums are usually pulled by either an articulated rubber-tired skidder or a crawler tractor. Large self-propelled tree crushers with chopping drums for wheels also are used for this purpose.

Chopping normally progresses in a circular manner from the tract edge toward the center, except where steep terrain dictates "downhill"-only passes or where equipment operation is prohibited by wet areas or drains. Incomplete burns on roll-chopped areas often leave many downed stems that are a major impediment to both hand and machine planting. In such instances, hindsight strongly suggests that the large residual stems should have been left standing and controlled by other means. Crawler tractors pulling drum choppers may be equipped with a shearing blade to sever stems too large for the tractor to flatten with a pushing blade.

Chopping or crushing alone does little to inhibit the subsequent development of woody competition. However, it may facilitate later ground treatments since the sprouts will be smaller in diameter and the foliage closer to the ground than before.

13.4.1.2 Manipulating the soil

Mechanical site-preparation operations that till the soil (i.e., disking, bedding, and ripping) are frequently used to ameliorate adverse conditions such as soil compaction created by earlier activities such as wet-weather harvesting. They may also be used to improve surficial drainage on poorly drained soils. These techniques are somewhat unique relative to debris manipulation and herbicide application, in that they can dramatically alter soil physical and chemical properties by rearranging the upper soil horizons, rocks, and organic matter. Disking, bedding, and ripping, if properly applied, can positively affect plantation establishment and subsequent productivity. However, if misapplied, they can adversely affect long-term site productivity, particularly if some of the more heavy-handed techniques are used with little regard for their potential site-specific impacts.

Disking. — Forestland disking utilizes a stronger, more robust version of the agricultural disk. It consists of a series of large-diameter, saucer-shaped steel blades joined at the center of an axle that allows them to roll when the implement is pulled. The concave blade surfaces face the leading end of the axle. The blade edges are sharpened, and usually serrated, to permit deeper penetration into the soil, cutting or breaking of small stems and roots, and rolling over larger obstructions. Occasionally, two axles of blades are set at a fixed angle to one another and pulled as a unit. Blade diameter and curvature, disk weight, and forward speed are the principal machine determinants of disk performance. Soil tilling and depth of cut are enhanced by setting the disk axle at an angle to the direction of travel and adding weight to the disk. Disks are most frequently pulled by crawler tractors, though large, articulated, rubber-tired skidding tractors also may be used.

Forestland disking is frequently done to ameliorate surface soil compaction (generally confined to the upper 30 cm; [17]) that usually results from harvesting, chopping, or shearing and piling. Disking was able to restore soil bulk densities to preharvest levels only in the upper 8 to 13 cm in Piedmont soils [10]. Tilled surface soils allow for increased rooting by young trees because of improved aeration and moisture movement, and decreased resistance to penetration [20]. Disking also is used to incorporate organic surface layers into the underlying mineral soil and, where appropriate, to prepare soils for bedding.

Hardwood sprouting can be greatly reduced by disking in summer when soils are dry. The disk can sever all but the largest roots, uprooting small stems and vines not controlled by earlier treatments such as shearing or chopping. The disking operation is more effective if preceded by a burn that removes as much organic debris as possible. Disking also will break up small- to medium-diameter pieces of weathered slash, which facilitates their passage through the bedding plow or around mechanical planter coulters.

Bedding. — Bedding is the formation of a more or less continuous mound of soil with a narrow two-axled disk or bedding plow; the two axles operate in opposition to each other and are angled backward from the plow center. The concave surfaces of the individual blades on each axle face the plow center. When pulled forward, the rolling blades move soil toward the center, thereby creating the bed. The outermost blade on each axle is often larger in diameter than the others; consequently, it moves additional soil onto the bed and produces well-defined bed shoulders. Packing rollers are sometimes attached to the rear of the bedding plow to flatten large soil chunks on the bed surface and unify soil in the bed. Bedding plows are most often pulled by crawler tractors, although the faster articulated rubber-tired skidders can be used with "stump-jumping" type bedding plows. On the Lower Coastal Plain, preplant phosphorus fertilizer is often applied just ahead of bed formation and from the bedding plow prime mover.

Bedding is usually done on sheared and piled sites with poor surface drainage but also is common on such sites with excellent surface drainage. Soils near the top of the bed are drier and warm sooner in spring than are adjacent areas; this promotes early root growth, which enhances the chances of successful establishment and accelerates seedling growth. Contour bedding is essential to minimizing soil erosion on upland sites. The perceived benefits of bedding on well-drained sites probably arise from the similarity of its effects to those of disking (i.e., woody competition control and soil tillage). The woody competition control resulting from the combination of shearing, piling or raking, and bedding can be dramatic [7, 26] because sites requiring bedding are often dominated by perennial woody competitors. However, on well-drained upland sites, first-season seedling growth and survival may be limited more by late-season soil moisture deficits on bedded than on comparable nonbedded sites with similar levels of competing vegetation.

Ripping. — Ripping or subsoiling is done with one or two vertically mounted rock-ripping shanks on a crawler tractor. The shanks are tipped with a replaceable wear shoe and drawn or pushed through the soil at a depth of 40 to 60 cm. Horizontal "wings" near the tooth tip may be used to increase fracturing of soils with high clay content. Tractor power requirements are directly related to soil strength, ripping depth, and number and size of residual trees on the site.

Burning should precede ripping to minimize the amount of small- and medium-diameter organic debris which can become trapped in front of the ripping shank, particularly when two shanks are being used. Large-diameter material should be left standing as it too will be trapped by the shanks and hinder tractor operation if not oriented parallel to or leaning in the direction of travel. Ripping is done parallel to topographic contours to avoid creating erosion channels and to trap overland water flow from intense rainfall. This latter effect was noted by Miller [18], who found a reduction in storm-flow water yield relative to that in an uncut watershed the first year after contour ripping in southeastern Oklahoma.

Ripping is used for site preparation on both rocky upland soils that have developed from consolidated bedrock and on other soils with high-strength clay horizons that may inhibit root development. The latter soils must be ripped when dry to maximize fracturing of these layers. When these soils are wet, the ripping shank creates only a narrow vertical slit through the layers. Soil displaced by passage of the ripping shank begins to immediately slough into the slit, and this displacement is greatly accelerated by rainfall. A shallow depression flanked by small berms of displaced soil remains after natural fill-in is completed. Seedlings are then planted in this depression. Ripping has the potential for encouraging more deep root development than any of the other tillage operations [20], a decided advantage in areas with a pronounced summer drought.

13.4.2 Chemical Site Preparation

From 1950 to 1979, 2,4,5-T was the primary herbicide used for forest vegetation control [12, 21, 31]. The chemical could be applied inexpensively ($37 to 74/ha) with air or ground equipment. Nevertheless, 77% of sites were prepared for planting by mechanical methods — with herbicides used largely on marginally productive sites and on sites too steep for machine operation.

Table 13.1. Herbicides registered for forest site preparation (February 1990).

Common name	Trade name	Manufacturer
Dicamba	Banvel® Herbicide	Sandoz
Dicamba + 2,4-D (amine)	Banvel® 720	Sandoz
Dichlorprop	Weedone® 2,4-DP[1]	Rhone Poulenc
Dichlorprop + 2,4-D (ester)	Weedone® 170	Rhone Poulenc
Dichlorprop + 2,4-D (ester) + Dicamba	Acme® Super Brush Killer	PBI/Gordon
Glyphosate	Accord®	Monsanto
	Roundup®	Monsanto
Hexazinone	Pronone® 5G	Pro-Serve
	Pronone® 10G	Pro-Serve
	Velpar® L	DuPont
	Velpar® ULW	DuPont
Imazapyr	Arsenal®	American Cyanamid
MSMA	Trans-Vert®[2]	Rhone-Poulenc
	Riverside 912[3]	Riverside Chemicals
Picloram	Tordon® K	Dow
Picloram + 2,4-D (amine)	Tordon® 101 Mixture	Dow
Triclopyr (amine)	Garlon® 3A	Dow
Triclopyr (ester)	Garlon® 4	Dow

[1] Registered under FIFRA Section 24-C in Alabama, Arkansas, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia.
[2] Registered for use only as a tank mix with Weedone® 170.
[3] Registered under FIFRA Section 24-C in Alabama and Mississippi.•Table 2.

The 1979 suspension of forestry uses of 2,4,5-T by the U.S. Environmental Protection Agency resulted in a sharp decline in chemical site preparation because the alternative herbicides available were several times more expensive than 2,4,5-T and were therefore not widely accepted by foresters [21]. However, this same suspension produced a surge of interest by chemical companies, forest-products

Table 13.2. Herbicides registered for forest site preparation in the southern United States (February 1990) [5].

Herbicide trade name	Site preparation	Tree inject	Cut surface	Frill girdle	Basal bark	Individual stem soil-application
Accord®	X					
Acme® Super Brush Killer	X	X	X	X	X	
Arsenal®	X					
Banvel® 720	X					
Banvel® Herbicide	X	X	X	X		
Garlon® 4	X				X	
Garlon® 3A		X	X	X		
Pronone® 5G	X					X
Pronone® 10G	X					X
Riverside 912	X					
Roundup®	X	X		X		
Tordon® K	X					
Tordon® 101 Mixture	X	X	X	X		
Trans-Vert®	X					
Velpar® L	X	X				X
Velpar® ULW	X					
Weedone® 170	X		X	X	X	
Weedone® 2,4-DP	X					

companies, and research organizations in silvicultural herbicide research. To minimize the possibility that other herbicides would meet the same fate as 2,4,5-T, numerous long-term studies have been installed assessing impacts on the environment, growth and yield, and economics arising from herbicide use [2, 6, 13, 18, 20, 22, 24, 26, 27, 29, 30].

The use of herbicides for forest site preparation has increased in recent years because (1) several effective compounds are now available; (2) herbicide use has minimal impact on soils; (3) increased machinery and fuel costs have made mechanical methods less attractive economically; (4) foresters are generally observing increased plantation growth rates on herbicide-treated, relative to mechanically treated, areas; and (5) herbicide treatments usually kill the root systems of treated trees, greatly reducing the potential for sprouting of undesired species (Tables 13.1 and 13.2) [5, 21].

The primary objective of chemical site preparation is to reduce sprouting of competing hardwoods that usually develop in the succeeding plantation. Site preparation is an ideal time to use herbicides to control competing vegetation because no crop trees are present and therefore subject to herbicide damage. Most site-preparation herbicides require no waiting period between their use and the planting of southern pines. The two exceptions are Garion® products (a 1-to 3-month wait depending on rate and formulation), and Tordon® 101 Mixture (a minimum wait of 6 months). Since both products are normally applied in spring, the waiting periods do not interfere with planting the following winter. Because chemical site preparation cannot remove woody debris, planting may be more difficult than when mechanical site-preparation methods are used. However, with chemical site preparation, since heavy equipment is not needed on the site, redistribution of nutrients into debris piles, increased erosion, and severe compaction are not likely to result. The selection and use of an effective chemical site-preparation treatment depend on sound knowledge of herbicide effects on the species to be controlled and the environment, plus a sensitivity to public concerns about the particular tract to be treated.

Fire is almost always used in combination with chemical site preparation (also see chapter 12, this volume) because it can enhance herbicide effects by heightening the stress on targeted species. Burning also reduces the amount of harvest debris and thereby facilitates planting. However, managers should carefully consider the potential for nutrient loss and increased soil erosion before deciding to burn a given area.

Two recent publications [5, 19] discuss the various herbicide-application techniques and equipment. Chapter 19, this volume, also provides detailed information on chemical methods for vegetation management (in plantations), which are similar to those used in chemical site preparation.

13.4.2.1 Herbicide formulation and selection

Herbicides may be soil or foliar active. Chemically, however, they may be polar or nonpolar compounds. Polar molecules are normally soluble in polar solvents such as water. Nonpolar molecules are oil soluble but are often applied to soil surfaces or plant parts as aqueous suspensions or emulsions. Esters, which are derivatives formed from the covalent union of acids and alcohols, are oil soluble and must be emulsified with adjuvants in order to be applied in aqueous tank mixes. Some herbicide molecules contain carboxyl groups which form water-soluble salts with organic amines. Esters best penetrate the cutin and suberin layers of leaves and bark, whereas amines best translocate through the xylem. Surfactants are commonly added to amine formulations to enhance foliar uptake of the herbicide. Most forest herbicides can be directly mixed with water and formulated as amine salts, water-soluble liquids, water-dispersible liquids, or dispersible granules to be mixed in water.

Herbicide selection depends on the species to be controlled, soil characteristics, proximity of the tract to sensitive areas, potential worker exposure, environmental safety considerations, and treatment costs. A thorough understanding of the label provides the user with information on species susceptibility, recommended rates, and application timing. Careful attention to label precautions is essential to safe and environmentally responsible use of the herbicide. Soil texture, rock content, organic matter content, and pH are important considerations for soil-active herbicides. Indeed, soil texture is a key determinant in selecting an appropriate herbicide. Soil erosion on some Upper Coastal Plain sites has eliminated much of the coarse-textured upper horizons, exposing the fine-textured subsoil. Since application rates of soil-active herbicides must be substantially increased on fine-textured soils, foliar-active herbicides will likely be the most cost-effective treatment.

13.4.2.2 Application method and timing

Application methods for chemical site preparation include (1) hand applied soil-active pellets, (2) spot application of soil-active herbicides, (3) cut-surface treatments, (4) basal spray on individual stems, (5) backpack foliar sprays, (6) tractor-mounted mist blowers, (7) tractor-mounted clustered nozzles, (8) tractor-mounted boom sprayers, and (9) aerial systems. When selecting an application method, foresters should carefully consider the proximity of the proposed treatment site to sensitive areas — for instance, croplands or gardens, neighboring home sites, public use areas such as major roads or outdoor recreation areas, rivers and other open water, and soils with high water tables. Selection of a method also depends on season of the year, size of the area to be treated, human and financial resources available, and policy of the particular organization.

Application timing will vary according to herbicide type and application method selected. Cut-surface treatments can be applied throughout the year. However, foliar- and soil-active treatments depend on stage of leaf development and environmental conditions. Foliar treatments are most effective in spring immediately following full leaf expansion but before the development of a thick cuticle. Exceptions include glyphosate, which is most effective in late summer and early fall, and imazapyr, which can be applied throughout the growing season. Foliar-active compounds should not be applied under droughty conditions because herbicide uptake and translocation are inhibited under those circumstances. Soil-active compounds are most effective if applied between the time of budbreak until full leaf expansion so that transpiration can move the herbicide from the roots through the plant to the site of activity.

Herbicides for site preparation commonly are applied too soon after harvesting. Hardwoods should first be allowed to sprout if these herbicide treatments are to be effective. If harvesting occurs in fall or winter, the tract should not be chemically site prepared until the following fall to permit sprouts to develop the leaf and stem area necessary for absorbing enough herbicide to kill the entire plant.

In addition to woody shrubs, fortis, and grasses, unmerchantable live pine also are often present and difficult to control with some herbicides (i.e., glyphosate, hexazinone, and imazapyr). These chemicals must be used in combination with other compounds (i.e., picloram, 2,4-DP, or 2,4-D) to adequately control the residual pine. Tank mixtures should be carefully considered before treatment, though, since certain combinations may be antagonistic because of mode of action or rate of translocation.

13.5 Site-Preparation Practices Within Physiographic Regions

13.5.1 Lower Coastal Plain

Much of the vast expanse of nearly level terrain that characterizes the Lower Coastal Plain is often plagued by poor surface drainage during winter and spring. Consequently, bedding there is critical to good seedling survival and early growth, although areas with good surface drainage may not require bedding if the particular soil has good internal drainage. These wet soil conditions may dictate use of low-ground-pressure tires or tracks on harvesting and site-preparation equipment in order to maximize the number of days that equipment may be operated on such sites. Soil phosphorus levels also are often too low for acceptable tree growth on many of these soils, and phosphorus is frequently added during the bedding operation. Despite the fact that opportunities for chemical site preparation are limited on the poorly drained sites of the Lower Coastal Plain, triclopyr has been shown to be effective on the waxy-leaved, nonarborescent species common here.

Chemical treatments will have much less impact on soils than mechanical treatments on the fragile sandhill sites of the Lower Coastal Plain, which are quite susceptible to degradation when organic matter is displaced or removed during harvesting or mechanical site-preparation treatments. Indeed, growth response is often significant on bedded, nonscalped sites, presumably because the plow concentrates organic matter in the bed. Consequently, care must be taken to minimize the movement of topsoil to windrows, and every effort should be made to dispose of logging debris in place. Because the soils tend to be coarse textured and the species composition is predominantly oaks (*Quercus* spp.), hexazinone can be used at low, cost-effective rates.

13.5.2 Upper Coastal Plain

Mechanical site-preparation practices in the Upper Coast Plain vary widely, and few site-specific limitations exist. However, there are large areas of very erodible soils on steep topography which should not be denuded during site preparation, nor should potential cross-contour water channels be created without some provision for erosion control. Those that shear, pile, disk, or bed such areas do so on the contour, or use less intensive methods, or use herbicides for site preparation.

Chemical treatments also vary widely in the Upper Coastal Plain. Commonly used and effective broadcast treatments include glyphosate, hexazinone, imazapyr, picloram, and triclopyr. Fall application of glyphosate or imazapyr allows managers to site prepare areas harvested late the previous year. Glyphosate has an environmental advantage in that it breaks down almost immediately on contact with the soil, thus causing no residual or water-quality problems. Since imazapyr controls a broad spectrum of woody and herbaceous plants and has proven to be effective throughout the growing season, this product is now widely used. Hexazinone, primarily used on well-drained, coarse-textured soils, is particularly effective on oaks and sweetgum (*Liquidambar styraciflua* L.). It is not effective on wet soils and is effective only at high rates on soils high in organic matter. Picloram and triclopyr are often used in combination to control woody plants. Picloram should not be used on wet areas with perched water tables because it does not readily decompose in water.

13.5.3 Piedmont

Because of their fine textures, Piedmont soils generally are more compactable over a greater range of moisture contents than Coastal Plain soils. Soils with shallow A horizon and deep, well-developed clay horizons, or soils with appreciable amounts of 2:1 type clays, should not be subjected to machine operations when wet. To quote Burger and Kluender [2], "Except where shearing and raking are absolutely necessary, mechanical methods that remove and incorporate organic matter should be avoided." Consequently, soil tillage is more likely to be needed in the Piedmont to ameliorate compaction due to harvesting than is the case on the Coastal Plain. In addition, the previous comments (see 13.5.2) regarding site-preparation practices on steep, erodible Upper Coastal Plain soils also apply to similar soils in the Piedmont.

Chemical site preparation will minimize soil impacts in the Piedmont and elsewhere. Recommendations and considerations are the same as those mentioned for Upper Coastal Plain sites (see 13.5.2).

13.5.4 Interior Highlands

Sites in the Interior Highlands tend to be steep and, hence, susceptible to erosion unless the soil has a high rock content. Such steep terrain also may limit the operation of certain types of site-preparation equipment. Chopping tends to be used more in the eastern portion of this area. Some organizations shear and pile parallel to topographic contours before disking, bedding, or both. Contour ripping is used most extensively in the western portion of the

Table 13.3. Advantages and disadvantages of mechanical site preparation techniques (adapted from [5]).

Technique	Advantages	Disadvantages
Mechanical		
Bulldozing (windrow, rootrake)	– Complete vegetation removal – Easy to administer – Machine plant	– Short-term vegetation control – High cost – Loss in soil productivity – Erosion – Loss of area in windrows – Water quality and sedimentation – Possible soil compaction and/or puddling – Large capital investment – Very low production
Shearing and piling	– Less soil and site disturbance, therefore less potential for erosion and site degradation – Easy to administer – Machine plant	– Short-term vegetation control – High cost – Low production – Sedimentation/erosion – Soil compaction
Disking	– Easy to administer – Effective for natural regeneration – Machine plant	– High cost – Severe erosion on steep slopes – Short-term vegetation control
Bedding	– Better survival on wet sites – Machine plant – Easy to administer	– Expensive; usually requires multiple mechanical treatments – Short-term vegetation control
Drum chopping	– Fewer water-quality and erosion problems – Machine plant (if good burn) – Usually provides for a good fire – Easy to administer	– Hardwood resprouting – Low productivity – Adverse site impacts under some conditions – Must be used in combination with fire to clear debris – Short-term vegetation control
Burning	– Low cost – Reduces logging debris – Controls many small hardwoods	– Temporary air pollution – Short-term vegetation control – Possibility of escape – Normally used in combination with other methods – Often considerable hardwood resprouting
Total utilization	– If done correctly, little needed for site preparation – Machine plant	– Rarely accomplished – Short-term vegetation control – Hardwood resprouting
Chemical	– Lower capital expenditures – Higher productivity (more area per day) – Less resprouting – Can be used on more rugged terrain – Less soil disturbance – Growth response of crop trees – Relatively lower costs – Machine plant (if good burn)	– Narrow window of application (day/season) – Must train personnel – Need follow-up burn to facilitate planting – Highly controversial – Crew morale problems due to short spray sessions and season – Litigation – Difficult to administer

Highlands, particularly in the Ouachita Mountains of Arkansas and Oklahoma where conserving soil moisture during the growing season is important. It is probably a matter of time until ripping becomes widely used on upland sites with fine-textured soils across the Southeast.

Herbicides are a viable site-preparation option in the Interior Highlands; however, because site quality is generally low, treatment costs are an important managerial consideration. Herbicide recommendations are similar to those for the Upper Coastal Plain (see 13.5.2).

13.6 Decisionmaking: Considering All the Variables

The many site-preparation methods available in the Southeast can be applied to a wide variety of sites with varying results. The keys to success are (1) a clear immediate and long-term objective for the specific site, (2) an understanding of the biological and economic impact of the alternatives (Table 13.3), and (3) the ability to integrate this understanding with the available options and resources to meet short- and long-term treatment objectives.

Site-preparation practices are driven by a large number of variables other than those unique to physiographic regions (see 13.5), including past practices, soil characteristics, species complex, proximity of sensitive areas, tract size, and site quality. For instance, the amount, distribution, and moisture content of woody biomass remaining after harvest are a primary consideration; shearing is generally the only practical mechanical treatment for dealing with a large amount of large-diameter, live, standing material if it is not going to be treated with herbicides. Sites with high water tables during the early part of the growing season almost always must be bedded for successful establishment and good early growth.

Management philosophy and objectives also strongly influence choice of treatment. The economic downturn of the 1980s forced many organizations to reevaluate forest practices with a strong emphasis on reducing costs; and it was this process that was probably responsible for considerable change towards least-cost site preparation alternatives that had any chance of succeeding biologically. Management-driven determinants that dictate practices are, for example, commitments to using machine planting wherever possible, disking for hardwood control, and restrictive slash-burning regulations or policies.

Ultimately, growth response of crop trees after site preparation should shape management approach. As the hardwood component in pine stands decreases, pine yields have been found to increase [3, 4, 13, 14, 16, 22, 32]. Glover and Dickens [13] documented the long-term effect of hardwoods on pine growth in a South-wide evaluation of research installations and operational comparisons. Burkhart and Sprinz [3], using data from Glover et al. [14], noted that hardwood basal area remained constant in pine stands over time. They concluded that although pines tend to grow faster than hardwoods, pine mortality and hardwood ingrowth combine to maintain a constant proportion of hardwood basal area through time. Contrary to common belief, this implies that hardwoods adversely affect pine yield throughout the rotation. Glover et al. [14] estimated that in a given stand, the pine volume to hardwood volume ratio was 1:1 and reducing hardwood volume by a given unit resulted in a like increase in pine volume. However, little research has been conducted in this area, and little is known about the impact of the relative competitiveness of various hardwood species on pine yields.

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