STUDY GUIDE FOR THE

MISSISSIPPI BOARD OF REGISTRATION FOR FORESTERS

EXAMINATION

BOARD OF REGISTRATION FOR FORESTERS
STATE OF MISSISSIPPI

Forest and Wildlife Research Center
Mississippi State University
Research Bulletin

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Multiple authors contributed to this publication. This publication was edited by James E. Henderson, associate extension professor and the late Robert C. Parker, professor emeritus, Department of Forestry, Mississippi State University.

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Mississippi State University

MISSISSIPPI STATE UNIVERSITY®

STUDY GUIDE FOR THE MISSISSIPPI BOARD OF REGISTRATION FOR FORESTERS EXAMINATION

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FORWARD

The Mississippi Board of Registration for Foresters commissioned this study guide to help applicants preparing for the Mississippi Registered Forester's examination. Thanks to the authors who generously donated their time to prepare their subject review in the study guide and the examination questions in the test data bank. Special thanks to Dr. James Henderson, Forestry associate extension professor, and Dr. Robert Parker, Forestry professor emeritus, for their persistence in making this publication possible. We hope you find this study guide helpful in your endeavor to become a Mississippi Registered Forester.

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INTRODUCTION

Those desiring to become registered by the State of Mississippi to practice forestry must complete a written examination administered by the Mississippi Board of Registration for Foresters (BORF). The examination consists of 100 multiple choice or true/false questions based on 9 topic categories that include silviculture, management, measurements, economics, timber harvesting, professional ethics, fire, insects and diseases. To pass the examination applicants must correctly answer 70 questions drawn from these 9 topic categories.

The study guide is divided into 9 chapters corresponding to the 9 major topic areas covered in the BORF examination. Each chapter was written by experts in their field. Within each chapter the content is presented in an outline format. Some topics are more quantitative (e.g., forest measurements) and other are more qualitative (e.g., silviculture); thus, some chapters utilize a more concise outline form while other chapters follow a more expanded outline format. The purpose of this publication is to serve as a “refresher” of basic concepts that would be learned while completing requirements for a bachelor’s degree in forestry. This publication should not be an applicant’s only source of information when preparing for the BORF examination.

CHAPTER 1

SILVICULTURE

Andrew W. Ezell[1] and Scott D. Roberts[2]

This review consists of three major sections related to site preparation, regeneration of a new stand, and mid-rotation management of that stand. Readers are also directed to two tables at the end of this review which contain a list of silvicultural terms and definitions that may help on the Registered Foresters examination, and a list of chemical herbicides commonly used in the Southeast. This review does not contain the answers to every silviculture question that might occur on the examination, so readers are encouraged to consult other materials as well while studying for the examination.

1) **Site preparation** is one of the most important phases of a silvicultural system due to the cost involved, the length of time that investment has to be carried before it can be "repaid", and the influence that it has on the new stand. The vast majority of all site preparation activities conducted in the South is related to the establishment of pine plantations.

   a) The three primary concerns of site preparation include:

      i) <u>Harvest debris</u> is less of a problem today compared to 30-40 years ago as utilization standards have changed allowing the use of more of each harvested stem, as well as utilization of many trees previously considered unmerchantable. This has greatly decreased the need for consolidating or clearing of harvest debris from forest sites to be replanted.

      ii) <u>Competing vegetation</u> is generally the greatest concern for site preparation in the South. The climate and soils of the region are very conducive to the growth of vegetation, and not all of the vegetation on any particular site consists of desired crop species. It is not uncommon to have 3000-5000 hardwood stems per acre on sites which are to be planted to pine. While herbaceous species can also be a deterrent to survival and early growth of desired crop tree species, woody species control is generally the primary objective of site preparation activities on cutover sites. Effective control of competing vegetation is the single most important factor in the establishment of a new stand of trees.

      iii) <u>Mineral soil conditions</u> can also be a concern on some sites. The two principal problems encountered are insufficient drainage and restrictive layers due to fragipans, plow pans, or compacted soils. Exposure of mineral soil for seedbed preparation can also be a concern where natural regeneration is an objective.

   b) Site preparation practices are generally classified as either mechanical site preparation or chemical site preparation. Each of these approaches consists of a number of methods or options, and care should always be taken to match the method to the conditions on site. Prescribed burning is also a tool which can be used in site preparation.

[1]Professor and Head, and [2]Professor, Department of Forestry, Mississippi State University

i) Mechanical site preparation methods include shearing, chopping, windrowing, subsoiling, bedding, and ditching.

(1) Shearing is accomplished with larger bulldozers using a V-blade or KG blade. The purpose of shearing is to cut (shear) standing stems close to the ground surface to facilitate clearing them from the site.

(a) In past decades, shearing was often associated with windrowing whereby bulldozers were used to pile the sheared debris into long piles across the site.

(b) Currently, improved utilization standards allow for economic removal of most trees, including many stems that may have been sheared many years ago. This has resulted in a reduction in the amount of residual debris remaining on the site. Shearing is still commonly used, typically with a V-blade, to cut residual standing stems. A beneficial secondary effect of using a V-blade is that debris can be displaced to either side of the bulldozer and this is often used to clear lanes for planting trees.

(c) Unfortunately, shearing promotes sprouting in hardwoods and woody shrub species. It should also be noted that many small diameter stems will bend over and not be severed as the blade passes over them.

(2) Chopping (also known as roller drum chopping) involves a bulldozer pulling a large steel cylinder with blades attached across the site.

(a) The purpose of chopping is to break up (or chop) any debris on the ground and to knock down and break up small residual standing stems (up to approximately 6 inches) on the site.

(b) Historically, chopping was used extensively with burning as it places the debris near the ground surface which facilitates prescribed burning.

(c) Because the practice increases the amount of debris on the ground, it can sometimes be a deterrent to planting if the site is not burned. Like shearing, chopping also promotes sprouting of hardwoods.

(3) Windrowing (also termed piling) is accomplished using bulldozers, typically with root rake blades attached.

(a) Debris is cleared from the site and pushed into long linear piles known as windrows. These windrows were historically burned, although burning is not required.

(b) The primary benefit of windrowing was clearing of the site for other operations, but the practice typically has negative side effects. As the debris is pushed into windrows, nutrient-rich topsoil is also moved into these piles. The nutrients in the biomass being piled are also consolidated in the windrows, and repeated passes over the site by the heavy equipment can result in soil compaction. Thus windrowing often results in nutrient displacement and compaction thereby having a negative impact on the growth of the next stand of trees.

(c) Given this recognition of the negative effects, and the reduced levels of residual biomass following harvest these days, the practice of windrowing has been greatly reduced throughout the Southeast.

(4) Subsoiling, sometimes referred to as ripping, can be completed with either a bulldozer or farm tractor depending on site conditions.

(a) The practice involves pulling a metal tine approximately 14-18 inches below the surface for the purpose of fracturing heavy or compacted layers in the soil, thus creating a more favorable rooting environment for the new trees. While the primary use of this method has historically been on retired agricultural areas to be planted in trees, many cutover forested sites are new being subsoiled to break up restrictive soil layers.

(b) Most retired agricultural fields should be subsoiled, particularly if they were in agricultural use for 20 years or longer, as most will have soil compaction resulting from livestock grazing or repeated trafficking by farm machinery.

(5) Bedding is the practice of raising mounds of soil with a plow on which seedlings are planted.

(a) Historically, bedding has been used in low lying areas to promote surface drainage and provide a planting site which raises the seedling out of saturated soil conditions.

(b) Bedding of some upland sites is now undertaken in order to consolidate topsoil, facilitate planting, provide a better rooting environment, and provide short term competition control.

(c) Bedding on upland sites is often combined with subsoiling when a combination plow is used to prepare the site.

(6) Drainage ditches were once commonly used on excessively wet sites. In many cases, this was the only way to make these sites suitable for commercial forestry activities.

(a) Drainage ditches are rarely used today due to cost of constructing the ditches and the legal ramifications associated with draining jurisdictional wetlands.

ii. Chemical site preparation is typically accomplished through the use of broad spectrum herbicides.

(1) Key factors involved in chemical site preparation include mode of application, equipment, herbicide selection, and time of application.

(a) Chemical site preparation generally involves broadcast applications using either helicopters or skidders.

(i) Helicopters are used in the majority of the work due to cost and speed with which they can cover acreage.

(2) While there are more than 25 herbicides registered for site preparation activities, the vast majority of acres in the South are currently (as of 2011) treated with tank mixtures of imazapyr (ex. Chopper or Chopper GEN2) and glyphosate (ex. Accord XRTII or Razor Pro).

(3) If waxy-leaf species are a concern on the site, triclopyr (ex. Garlon 4) is either added to the tank mix or substituted for the glyphosate.

(4) The imazapyr/glyphosate/triclopyr tank combinations are typically applied late in the growing season.

(5) Due to the importance of controlling competing vegetation when establishing new stands in the South, chemical site preparation is used more extensively than mechanical site preparation.

(6) Some land managers choose to use both chemical and mechanical practices on some acreage, but cost becomes a factor in such decisions.

(7) Mechanical site preparation is rarely used alone, the primary exception being the subsoiling of old agricultural fields which do not require chemical treatments.

(iii) Prescribed Burning is one of the oldest techniques of site preparation. In many cases, burning can reduce the amount of residual debris on the site, thus improving access for future management practices.

(1) Burning also recycles nutrients contained in the forest biomass back into the soil. Where natural regeneration techniques are being used, prescribed burning can improve seedbed conditions by reducing the litter layer and exposing mineral soil.

(2) Burning alone, however, promotes sprouting of hardwood species, and therefore is not effective for competition control.

(3) In addition, burning does nothing to address soil issues related to insufficient drainage or restrictive layers.

(4) Overall, the use of burning in site preparation has been greatly reduced over the past 20 years.

2) **Regeneration.** When it comes time to regenerate a stand, landowners/managers have two basic options –natural versus artificial regeneration.

a) Pine regeneration on intensively managed lands is primarily accomplished with artificial regeneration, although some non-industrial private landowners still rely on natural regeneration.

b) In actively managed stands in the South, the overwhelming majority of harvest activity is directed toward the creation of even-aged stands due to the increased efficiency, simplicity, and cost-effectiveness associated with even-aged management of shade intolerant species.

c) Natural regeneration is generally favored in stands of existing hardwoods; however artificial regeneration techniques are sometimes used for establishing hardwoods on old field sites.

d) In addition, certain hardwood species, such as cottonwood, are sometimes managed on relatively short rotations in intensively managed plantations.

e) Another choice a landowner must make during the regeneration phase is what species to establish in the new stand.

   i) Pines in general, and loblolly pine specifically, have very wide ecological amplitudes and can establish and grow well on a wide range of sites, the one major exception being that pines do not do well on high pH soils.

      (1) Pines can do well on bottomland sites, but establishing regeneration on frequently flooded sites can be problematic.

   ii) Selection of the appropriate species in hardwood management differs from pines in a couple of respects.

      (1) In the management of bottomland or upland hardwood forests, there is typically more than one crop species.

      (2) Also, hardwood species tend to be much more site specific than pines. It is therefore imperative that the manager match the species to be regenerated with the appropriate site.

f) Artificial regeneration of pines can be accomplished by either planting of seedlings/cuttings or through direct seeding. Prior to the ready availability of genetically improved loblolly and slash pine seedlings, direct seeding of pines was relatively common. However, it is rarely used in pine management anymore. Direct seeding of oaks was used for many years, but the lack of consistently acceptable results has decreased use of this method.

   (i) Planting is the most often used method for artificial regeneration in the South. Both hardwoods and pines are typically planted using 1-0, bareroot seedlings. Second-generation open-pollinated (2nd-Gen OP) seedlings are widely available for loblolly pine, and genetically improved seedlings are also available for slash, longleaf, and shortleaf pines. The most common approach for using genetically improved loblolly pine planting stock in managed plantations is through the use of reasonably sized block plantings (40 to 50 acres) of a single family. In recent years there has been an increase in the availability of mass-controlled pollination (MCP) seedlings, although these seedlings typically cost about twice what 2nd-Gen OP stock costs, which generally limits their use to industrially managed lands. Even further genetic gains can be attained through the use of varietal (clonal) loblolly pine planting seedlings, but high cost is currently limiting the wide-scale use of this planting stock option.

   (ii) With few exceptions, genetically improved planting stock for hardwood species is not commercially available in the South. The most notable exception is cottonwood which has a long history of clonal selection and breeding efforts in the South. Other hardwood species where genetically improved planting stock is available, on an extremely limited basis, include cherrybark oak, sweetgum, and sycamore.

   (iii) The density of planted seedlings in plantations varies greatly depending on site characteristics, objectives of management, and the anticipated silvicultural regime. Loblolly pine plantations are typically established at between 435 and 700 seedlings per acre. Hardwood plantations are usually established at between 300 to 435 seedlings per acre.

g) Natural Regeneration

i) Clearcutting in pine management in the South is used most extensively with artificial regeneration.

(1) The primary reasons for this are the efficiency and profitability of harvest operations combined with the opportunity to use chemical site preparation and genetically improved seedlings.

(2) Clearcutting can be a suitable natural regeneration harvest option for southern pine management; however, cutting unit size and configuration must be adjusted to provide for adequate seed dispersal from adjacent upwind seed sources.

(a) For example, seed from loblolly pines can typically be expected to adequately disseminate up to two-times the height of the tree; therefore, clearcut units would generally be restricted to 150-200 feet in width downwind from the seed source.

(3) Clearcutting is generally not the harvest method of choice for natural regeneration of southern pines.

(4) Clearcutting can be used to regenerate both bottomland and upland hardwood stands in the South; however, the approach provides little control over species composition of the new stand, and often results in stands lacking in higher value hardwood species.

(a) For this reason, removal of the hardwood overstory is generally not recommended until adequate advanced regeneration of suitable species has been attained, which by definition means that this is not a clearcutting operation (see discussion below).

ii) Seed tree harvesting is a suitable approach for naturally regenerating even-aged stands of southern pines, and may become even more attractive as stands established with 2nd generation genetically improved planting stock are ready for final harvest.

1) However, even with 2nd-Gen improved trees, the approach will typically result in lower yields as the seed trees may be mating with non-improved sources. This could be especially detrimental if increased resistance levels are needed for diseases such as fusiform rust.

2) The use of the seed tree method will usually be more attractive to some nonindustrial private landowners or on some public lands (e.g., National Forests or Wildlife Refuges).

3) If natural regeneration is desired, a seed tree harvest provides the greatest opportunity for control over species composition in the next stand and selection of favorable phenotypes for the seed trees that are retained.

4) This seed tree method is only applicable for use with species whose seeds are wind disseminated since relatively few trees per acre are retained.

(a) For example, retention of 6-8 loblolly pine seed trees per acre is commonly suitable for most conditions.

(5) The seed tree method can be used with most southern pines (although not longleaf pine) and some light-seeded hardwood species such as cottonwood, yellow poplar, sycamore, or green ash.

(6) The seed tree approach will not likely be successful if used with heavy-seeded species such as oaks.

iii) The shelterwood method is the most flexible of the even-aged regeneration methods.

(1) Typically two or more harvests in the overstory are used to reduce overstory density, build the crowns of future seed-bearing trees, and create an understory environment conducive to seedling establishment and growth.

(2) While the approach can be adjusted to facilitate the establishment of a new stand of virtually any species, the number of entries in the stand, complexity of operations, and decreased profitability often override the biological advantages and the method is rarely used in southern pine or hardwood management in its purest form.

(3) A natural regeneration approach often referred to as a 'pseudo seed tree' or 'pseudo shelterwood' is often used for the regeneration of hardwoods and was commonly used for regenerating pines in the 1970s and 1980s.

(a) This approach consists of controlling undesirable species in the midstory and understory, reducing the overstory to a residual stocking of approximately 40-60 square feet of basal area/acre and allowing regeneration to establish.

(b) When used in pines, burning was used to control undesirable stems and the residual overstory was removed quickly once the regeneration was established – usually within a few years following the initial harvest.

(c) In hardwoods, especially oak stands, the undesirable midstory/understory stems are typically injected with herbicide and overstory basal area is reduced only if needed to achieve 40-50% sunlight on the forest floor.

(d) The oak regeneration commonly takes 2-5 years to reach acceptable size (2-3 feet tall). At that time, the overstory can be removed producing an even-aged stand, or it may be retained resulting in a two-aged stand.

iv) Selection harvests produce uneven-aged stands.

(1) The single-tree selection approach is well adapted for use with shade tolerant species but its use with shade-intolerant species will eventually result in stand conversion to more shade-tolerant species.

(2) Group selection can be used with intolerant species such as pine or oaks if enough sunlight can be made available for regeneration.

(3) However, while biologically possible, selection systems are often unattractive economically due to the number of operations, complexity, and cost associated with the management.

(4) Selection management is rarely used in active management of southern pines, and "true" selection management is rarely used in hardwoods.

(5) Selection management should not be confused with "selective" cutting which is often practiced in hardwoods, and is nothing more than high-grading.

(6) In bottomland areas, repeated application of such harvests will result in stands of shade-tolerant lower-valued hardwood species.

(7) On upland sites of lower site quality, desirable hardwood species such as oaks can regenerate following selective harvests, primarily because of a lack of understory/midstory stems on these relatively poor sites.

(8) It should be noted, however, that it usually requires over 100 years to produce oak sawtimber on these upland sites, and the sites are better suited for pine management if timber production is the goal of ownership.

(9) True selection harvests consider age, size, species, and tree condition in making selections for removal. Having a diversity of tree age classes is desirable biologically and sustained yield is desirable economically, but these attributes are easier achieved and maintained on a forest-level basis – not from each individual stand.

v) Coppice is a natural regeneration approach in which the majority of the stems in the new stand come from stump sprouts or root suckers.

(1) Given the general inability of most conifers to sprout, coppice regeneration is typically only applicable with hardwood species.

(2) Only a few hardwood species in the South, such as cottonwood, are ever managed using coppice systems.

(3) When naturally regenerating mixed hardwood stands, it's common that some of the new stand will come from spouting.

(4) In most cases, this is from stump sprouting as root sprouting is rarely an important source of regeneration for the most desirable hardwood species, particularly in bottomland hardwood forests.

(5) Most hardwood species have some ability to regenerate by sprouting; however, some species are more prolific sprouters than others.

(6) In addition, the ability of any tree to sprout will be influenced by the condition of the tree prior to harvest, and in some cases the age or size of the tree.

(a) For example, the sprouting ability of many bottomland oak species, including cherrybark oak, is reduced as they get into the larger size classes; while the sprouting ability of other species, such as sweetgum, is less affected by tree size.

(7) When relying on coppice for the regeneration of all or some of the subsequent stand, the forest manager must understand the sprouting abilities of the various species involved and how this ability changes among different species and with different tree sizes.

3) Mid-rotation Management

a) Release operations include either herbaceous weed control (HWC) or woody release. By definition, all release operations (cleaning, liberation, weeding) are completed before trees get beyond the sapling stage, and are ideally performed before the trees reach the sapling stage.

i) Herbaceous weed control is best accomplished by applications of herbicide in the first year either before or immediately following planting but prior to the actual growing season. In southern pine plantations, HWC can be achieved by adding 3 oz. of sulfometuron methyl (Oust XP) or 4 oz. sulfometuron + metsulfuron (Oust Extra) to the site preparation tank mixture if chemical site prep is accomplished in August – November prior to planting.

(1) In established pine plantings, the herbicides most frequently used for HWC include Arsenal AC, Oust XP, Oust Extra, and Oustar.

(a) Tank mixes of Arsenal AC/Oust XP or Arsenal AC/Oust Extra are commonly used in loblolly pine or slash pine plantings, but are not typically recommended for longleaf plantings due to the sensitivity of longleaf pine to imazapyr (Arsenal AC) and metsulfuron methyl (Escort XP).

(b) Oustar (a premix of sulfometuron methyl and hexazinone) can be used for any of these three species, and is often preferred for longleaf.

(2) Herbaceous weed control is more challenging in hardwoods, in large part because fewer herbicides are labeled for such use.

(a) Sulfometuron methyl is used with many species of hardwoods, but applications should be avoided in areas which are expected to flood following application of the herbicide.

(b) In such areas, and in all cottonwood plantings, oxyfluorfen (Goal 2XL) is used for control of broadleaf forbs.

(c) Grass herbicides such as clethodim or fluzaifop-butyl can be used safely over pines or hardwoods and offer the best option for difficult to control grass species such as bermudagrass or Johnsongrass.

(d) Since chemical site preparation is rarely conducted for hardwood plantings, almost all herbaceous weed control in these areas is conducted as a post-plant, pre-budbreak application.

ii) Woody release operations are rarely needed on sites which have received adequate chemical site preparation.

(1) Herbicide selection for woody release is limited in pine stands. Imazapyr in the form of Arsenal AC can be used with or without metsulfuron methyl (Escort XP) to control overtopping hardwoods in loblolly and slash pine stands, but use of metsulfuron methyl is not recommended for use in longleaf stands.

(2) Woody release operations generally involve a single broadcast application within the first two to three years following stand initiation.

(a) Applications are usually made with a helicopter, although in some cases the herbicides are applied from the ground.

(3) The use of herbicides in young hardwood stands for woody release is not a viable option.

b) Improvement treatments involve the removal of undesirable stems of any species from a stand beyond the sapling stage to improve the composition and quality of the residual stand.

i) In most cases the improvement treatment simply represents a delayed release treatment (i.e., a cleaning or liberation treatment should have been done early in the life of the stand).

ii) Improvement treatments can be accomplished by cutting and removing the undesirable stems if there is adequate commercial value to carry the cost of the operation.

iii) If not, the improvement can be accomplished by chemical injection of the undesirable stems.

c) Thinning involves reducing the density of a stand for the purpose of improving the growth of residual stems or enhancing the overall health of the stand.

(i) Thinning methods include a choice of low, crown, selection, mechanical, or "free".

(ii) Where multiple thinning operations are applied over the life of a stand, the method or combination of methods usually change in subsequent entries.

(iii) In southern pine plantations, the first entry frequently involves a combination of row (mechanical) and selective thinning.

(1) This provides the manager an opportunity to both create access into the stand and make qualitative selections for the removal of trees from the majority of the stand. In such applications, 4th row or 5th row removals are normally used with selective removals in the residual stand.

(2) Selective thinning simply refers to any thinning in which the decision on whether to harvest or retain a given tree is based on tree size, stem quality, crown condition, or spacing criteria, and is basically a form of free thinning.

a) Note that "selective" thinning is not the same as selection thinning. Selection thinning is a primary thinning method in which trees from the upper crown classes are removed to favor the development of more desirable trees in the lower crown classes.

b) Given that in the South we are typically managing shade intolerant species, true selection thinnings are not used with these species.

(3) After the first thinning in pines, most subsequent thinnings will be repeated applications of selective removals.

(iv) Decisions on when to thin, and how intensively to thin, can be based on a range of different criteria.

(1) The most common criterion used in the Southeast is basal area, with a typical thinning in pine stands reducing residual basal area to between 60 and 80 square feet per acre.

(2) Another approach involves the use of relative density measures, the most common of which is Reineke's Stand Density Index (SDI), an index of stocking based on the number of trees per acre and the quadratic mean diameter of the stand.

(a) SDI is used to set upper limits (when to thin) and lower limits (how intensively to thin) to stand stocking.

(b) These limits are based on stand-level management objectives such as avoiding density-related mortality (self-thinning), optimizing stand-level production, or optimizing individual tree growth rates.

(3) Other criteria for when to thin can include when the trees reach a certain operational height or diameter, or when stand vigor shows signs of decline (e.g., live crown ratios below 35-40%).

(4) These approaches have to be combined with some criteria for how intensively to thin.

v) The majority of intensive forest management in the South involves southern pines, and therefore the majority of thinning occurs in pine.

vi) Hardwoods can also benefit from thinning, but comparatively few stands are actively managed, thus thinning in hardwoods is not as common as in pines.

(1) When used, thinning in hardwoods focuses primarily on two items – species composition and stem quality making thinning in hardwoods very much like an improvement cut.

(2) When making thinning decisions in hardwoods, crown characteristics are primarily used to predict the future performance of a tree, although if stem quality is lacking or if species is undesirable, crown characteristics are less important.

(3) Hardwoods are usually thinned using either the crop tree approach to crown thinning or a selective approach very similar to pine thinning with the addition of species consideration.

(4) While basal area is used in targeting stocking guides in hardwoods, it is not used exclusively for establishing residual stand conditions in hardwoods due to the overriding importance of stem quality.

(a) Rather, each stand is considered separately and residual basal area may vary widely depending on species composition, stem quality, and the distribution of desirable trees.

(b) Additionally, extra care is required in hardwoods to avoid damage to the residual stems as this can cause unacceptable reductions in future stem quality and thus value of the stand.

d) Mid-rotation Brush Control

i) Both thinning and improvement operations are considered excellent opportunities to enhance stand quality and value in both pine and hardwood stands.

ii) This has largely been due to the emergence of hardwood pulpwood markets which facilitate the removal of undesirable species and low quality stems in either type of management.

iii) Consequently, the use of non-commercial operations to remove or kill (e.g., injection) larger, merchantable-sized stems during the time considered to be the “middle” of the rotation has been greatly reduced.

iv) The most common stand improvement operation currently used in the South is midrotation brush control (MRBC).

v) The most typical MRBC operation in loblolly pine stands involves an aerially broadcast application of imazapyr (Arsenal AC) soon after a first thinning.

(1) If a skidder is used for the application, Chopper or Chopper GEN2 may be used in southern pine stands. Escort XP (metsulfuron methyl) may be added to the application if needed for control of Rubus or winged elm in either aerial or ground applications, but Escort should not be sprayed over longleaf pine.

(2) In pine management, the hardwood stems being sprayed in MRBC treatments are typically sub merchantable.

e) Salvage

i) Salvage operations are never planned in a silvicultural regime, but are utilized if sufficient damage occurs during a rotation.

ii) If damage is too extensive, the entire stand may have to be harvested and regenerated.

iii) Otherwise, damaged trees are removed to recover any value they might retain and to protect the overall health of the residual stand.

iv) The primary causes of damage in southern forests leading to the need for salvage operations include ice storms, wind (straight line, tornadoes, hurricanes), and bark beetles (Southern pine beetle, Ips beetles).

v) In addition to the conventional salvage operations, bark beetles may require a sanitation operation which involves removing the trees from a designated area around the active infestation to create a buffer zone in order to stop the spread of the beetles.

vi) Ice storms and wind can cause significant damage to both pine and hardwood stands, but bark beetles attack only pines.

f) Fertilization

i) Most forest stands, particularly those on upland sites, do not have optimal levels of nutrients to support forest growth throughout the entire rotation.

ii) Years of research across the Southeast have shown that southern pine stands generally respond positively to the application of fertilizer. While biological responses can be expected, fertilization is not a cost-effective practice for most management situations.

iii) Most of the fertilization that has taken place in the South has occurred on industrially managed plantations of loblolly and slash pines.

iv) Fertilization is not operationally practiced in mixed bottomland or upland hardwood stands.

v) Two general approaches to fertilization are available for use in southern pine stands.

(1) These include fertilization at the time of stand establishment, and fertilization during the middle of the rotation.

vi) Strong responses to the addition of phosphorus (P) at or near the time of plantation establishment have been observed on some P-deficient sites, primarily poorly-drained soils on the lower coastal plain.

(1) Volume gains commonly average 40-50 cf/ac/yr on sites with severe P deficiencies and a single application of 50 lb P per acre generally last for 20 years or more.

(2) Growth gains over course of rotation can exceed 100% on severely deficient sites.

(3) Fertilizer P can be added as diammonium phosphate (DAP), triple super phosphate (TSP), or rock phosphate.

(4) Currently DAP is most commonly used as it also provides nitrogen.

vii) With the exception of phosphorus on P-deficient sites, nitrogen (N) is generally the most growth limiting nutrient in forest systems and N is the chemical nutrient used in the greatest amounts by trees.

(1) Near the time of canopy closure in most managed pine plantations, a stand's potential use of N and P begins to exceed the ability of the site to supply those nutrients.

(2) Studies across the region have shown that over 85% of midrotation pine stands will respond positively to additions of N and P, with average growth gains of 50 cf/ac/yr over an 8-year period following application of 200 lb N/acre and lb P/acre. (Lower doses of N are recommended for longleaf pine stands.)

(a) In order to sustain these growth increases through the end of a rotation, fertilization is required to be repeated on 5-6 year intervals.

viii) In the late 1990s and early 2000s, nearly 1.5 million acres of pine plantations were being fertilized annually, almost all of it occurring on industrially managed plantations.

1) Since that time, the amount of fertilization has decreased dramatically as the cost of fertilizers has increased substantially.

2) Fertilization can provide strong growth responses in pine plantations, but managers must be more selective in which acres are fertilized to ensure that growth gains are economically efficient.

g) Pruning is a practice in which the lower branches of the crown, both live and dead, are removed in order to produce clear, or knot-free wood on the pruned portion of the stem.

i) The practice typically has little, if any, impact on the growth of the pruned tree as long as sufficient live crown is retained.

ii) Some forest companies have been practicing pruning for years, and are clearly benefiting economically from the practice. However, these companies not only own the forestland, but also process the pruned trees at their own sawmills, and thus realize the value added from the clear lumber that is produced.

iii) Non-industrial private landowners would be unlikely to realize a large enough increase in the stumpage value of their stand to make the practice of pruning an attractive economic investment.

iv) Very little pruning is done in forested stands of the South.

4) Silvicultural Terms

Term	**Definition**
Stand	A contiguous group of trees sufficiently uniform in species composition, age class distribution, and overall condition to be a distinguishable unit. The basic unit of silviculture.
Forest	An area of land typically consisting of a collection of stands of varying characteristics including non-forest vegetation. Commonly the administrative unit in the practice of forestry.
Stand age	The mean age of the dominant and codominant trees in an even-aged stand.
Rotation	The period between regeneration and final cutting in an even-aged stand.
Age class	A period of time less than or equal to 20% of the rotation length.
Even-aged	A stand of trees composed of a single age class (i.e., the range of tree ages is less than 20% of the rotation length).
Two-aged	A stand consisting of trees in two distinct age classes separated in age by more than 20% of the rotation length.
Uneven-aged	A stand with trees of three or more distinct age classes, either intimately mixed or in small groups.
Pure Stand	A stand composed principally one species (or a few closely related species); conventionally at least 80% based on numbers, basal area, or volume.
Mixed Stand	A stand composed of two or more prominent and unrelated species (i.e., no species comprises more than 80% of the stocking).

Term	Definition
Artificial regeneration	A stand created by direct seeding or by planting seedlings or cuttings – includes a choice by the manager of species and planting stock.
Natural regeneration	The establishment trees in a stand, or age class within a stand, from natural seeding, sprouting, suckering, or layering.
Site productivity	The inherent ability of a site to supply the resources needed for growth (synonymous with site quality).
Production	The physical product resulting from tree growth (biomass, cords, tons, board feet, etc.).
Yield	The amount of wood that may be harvested from a particular stand at various ages.
Site quality	The productive capacity of a site (synonymous with site productivity).
Site index	A species-specific measure of actual or potential forest productivity expressed in terms of the average height of dominant/codominant trees at a specified index or base age.
Stand Density	A quantitative measure of stocking expressed either absolutely (TPA, basal area, volume/ac) or relative to some standard condition.
Stocking	An indication of the growing-space occupancy in a stand relative to a pre-established standard.
Relative stand density	The ratio, proportion, or percent of absolute stand density to a reference level defined by some standard level of competition.
Basal area	The cross sectional area of all stems of a species, or all stems in a stand, measured at breast height and expressed per unit land area. Commonly used as a measure of stocking.
Shade tolerance	The capacity of trees to grow satisfactorily in the shade of, and in competition with, other trees.
Succession	The graduate supplanting of one community of plants by another.
MCP (or SMP)	Acronyms representing mass control-pollination or supplemental mass-pollination where full-sib seedlings are derived using operational procedures that mimic control-pollination techniques.
Varietal Seedlings	Clonal pine seedlings developed from either somatic embryogenesis or cuttings.

5) Major Herbicides used in Forestry

Chemical	Product Name	Uses
Imazapyr	Arsenal AC	HWC, woody release, MRBC
	Chopper	Site prep & MRBC – used in areas with significant amounts of waxy leaf species
	Chopper GEN2	Site preparation with few waxy leaf species
	Generics	Site preparation and release
Glyphosphate	Accord XRTII	Site preparation
	Razor or Razor Pro	Site preparation
	Generics	Site preparation

5) Major Herbicides used in Forestry

Chemical	Product Name	Uses
Triclopyr	Garlon 4	Site preparation in areas with significant amounts of waxy leaf species.
	Garlon XRT	Basal bark applications
Hexazinone	Velpar L, Velpar DF	HWC
Sulfometuron Methyl	Oust XP	HWC
Metsulfuron Methyl	Escort XP	Woody release, MRBC
Sulfometuron Methyl/Hexazinone	Oustar	Premix for HWC
Sulfometuron Methyl/Metsulfuron Methyl	Oust Extra	Premix for HWC

HWC = herbaceous weed control; MRBC = mid-rotation brush control

CHAPTER 2

FOREST MANAGEMENT

John D. Kushla[1] and Donald L. Grebner[2]

Forest Management entails the integration of forest and wildlife ecology, soils, hydrology, recreation, aesthetics, and silvicultural principals with the economic and management sciences. Consequently, this section will cover a broad range of information from these many disciplines. The focus in this section will be on the structural components of natural resources, environmental policy, silvicultural systems, financial analysis, forest regulation, and technical terms. Indeed, you may find questions repeated here that you have seen in other portions of the BORF examination study guide.

1) Evaluating Structural Components in Natural Resources

a) Timber Volumes
Merchantable timber volumes can be measured by weight, board foot, cords, or cubic foot values.

i) Merchantable timber volumes can be measured by weight, board foot, cords, or cubic foot values. With regard to sawtimber, volumes are often estimated by the board foot. There are 3 standard log scales used to measure merchantable sawtimber volume:

(1) Doyle Log Rule: This rule was developed by Edward Doyle in 1850 as follows:
$V = [(D - 4)^2 L/16]$, where
V = volume in board feet, and
D = diameter measured in inches at the small end, inside bark,
L = length of log in feet.
For a standard 16' log, this equation is reduced to $V = (D - 4)^2$.

(2) Scribner Log Rule: Developed by J.M. Scribner is 1846. It is based on a series of cutting solutions for a log 16' long, for 1" thick boards and allowing ¼" for saw kerf. The diagrams are approximated by the equation:
$V = [(0.79D^2 - 2D - 4)(L/16)]$, with
V = volume in board feet,
D = diameter measured in inches at the small end, inside bark, and
L = length of log in feet.

(3) International ¼ -inch Log Rule: Judson C. Clark developed this rule in 1917, and it is still used today. Clark derived this rule empirically from observations of the losses in the cutting of logs into lumber. This is one of the few log rules that incorporated log taper into the cutting solutions. Log taper is assumed to be ½ -inch to 4 feet of log length. There are a series of formulae for different log lengths. For a 16-foot log:
$V = (0.796D^2 - 0.375D - 1.23)$, with
V = volume in board feet, and
D = diameter measured in inches at the small end, inside bark.

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ii) Selecting a log rule: Doyle is the standard log rule in Mississippi for sawtimber, but it is the least accurate. The Doyle Rule is most accurate at logs of 30 inches diameter, underestimating sawtimber volumes for logs less than 30 inches diameter and overestimating volume when diameter is greater than 30 inches. The Scribner Rule underestimates all log volumes, but is more consistent than the Doyle Rule for logs greater than 20 inches. Neither the Doyle nor the Scribner rules allow for log taper. Consequently, the International ¼ -inch Log Rule is the most accurate, being empirically derived for different log lengths and accounting for log taper.

2) Overview of Forest Policy

Forest legislation has as its primary purpose to protect the environment and safeguard public health. Specific legislation is titled with regard to a certain aspect that an environmental law protects. Taken together, all forest legislation has a major impact on forestry practices in Mississippi and the nation.

a) The Endangered Species Act of 1973 mandated the protection of threatened and endangered species, and the ecosystems in which they live. Both plant and animal species are protected under this act. This act is administered by two agencies: the National Oceanic and Atmospheric Administration and the United States Fish and Wildlife Service. The former has responsibility over marine species, whereas the later has jurisdiction over freshwater fish and all other species. This bill is designed to prevent species extinction.

i) Listing Process: A species must be listed with either agency to afford special protection under this law. Once petitioned, the agency must substantiate whether protection under the law is warranted, not warranted, or warranted but precluded.

ii) Section 4 under the law requires protection of critical habitat, since habitat loss is the primary means of extinction for most species. Consequently, the agency must define critical habitat zones for the protection of a species.

iii) Habitat Conservation Plans allow for the incidental taking of a protected species, as permitted under an amendment to the law in 1982.

iv) The “Safe Harbor” policy was developed in 1999 as a voluntary agreement between a private landowner and the US Fish and Wildlife Service. Under this agreement, the landowner agrees to alter management to attract a protected species for assurances of future “taking” above a pre-determined level.

v) In Mississippi, there are 42 species of animals and plants listed as protected under this law. They include the Louisiana black bear, the Mississippi sandhill crane, the red-cockaded woodpecker, and the American chaffseed. The endangered species having the greatest impact on forest management in Mississippi is the red-cockaded woodpecker.

vi) The most serious form of taking an endangered species is that done knowingly. Criminal charges for taking endangered species can result in monetary fines, prison sentences, or both.

b) The Clean Water Act of 1977

This legislation mandated control of toxic pollutants to navigable waters of the United States from industrial point-source pollution.

i) Section 404 exempted normal silvicultural operations from permitting for dredge and fill operations in wetlands.

ii) In 1987, Congress amended the Clean Water Act to include the control of non-point source pollution to the navigable waters of the United States. This federal mandate required states to develop Best Management Practices (BMPs) to comply with the new requirements. These are voluntary guidelines designed to minimize the impact of forest operations on water quality, particularly sedimentation. Ultimately, the forest landowner is responsible for implementing state BMPs.

iii) In Mississippi, the Mississippi Forestry Commission developed voluntary Best Management Practices for forest operations to minimize the impacts of road construction, which has the greatest impact on stream sedimentation, and silvicultural operations on water quality. Meanwhile, the Mississippi Department of Environmental Quality is charged with enforcing federal and state environmental laws, and monitoring with their compliance.

c) Occupational Safety and Health Act

i) Under this legislation, the Department of Labor sets safety standards and procedures to assure safe work environments for employees. The Occupational Safety and Health Administration (OSHA) enforces these standards and provides training.

ii) Employers are required to follow all applicable OSHA standards. It is very important that forest landowners do not directly supervise vendors on their property, or the Department of Labor shall consider them as employers. In that case, forest landowners would have to meet all applicable payroll and safety standards.

3) Overview of Silviculture and Silvicultural Systems

a) Overview of Silviculture

i) Non-industrial private landowners control about 67% of the commercial forest in Mississippi. At present, forest land in Mississippi only produces at 55% of its overall potential. Adequate forest regeneration would produce the greatest gains in productivity of forested land within the state.

ii) Herbicide use is common in forest operations. Herbicide use is regulated by its label, which is a legal document. The herbicide label details instructions on target vegetation, safe use with regard to environmental conditions, rates of application, and proper mixing, handling, disposal, and storage. Herbicides can be used in site preparation, release from competition, and control of invasive plant species. In hardwood stands, herbicides may be used for timber stand improvement by stem injection.

(1) Herbicides can be used to their greatest advantage and effect in site preparation since the crop species has not been established. In site preparation, herbicides can be used at their highest labeled rates.

(2) In release from competition, herbicides are used at a lower rate depending on the species and age of the crop trees. Release treatments target woody as well as herbaceous

competition. Indeed, grasses are the most aggressive competitors to pine seedlings under five years of age.

(3) Invasive plant species are very aggressive, and so displace other plants from the ecosystem. Often these plants are non-native, having become established here without their native control vectors (diseases and insects). Controlling invasive plant species involves eradiation from the immediate site. Herbicides are often the most effective means to achieving this objective. Nevertheless, there is no herbicide available that will control an invasive plant with a single application. Eradicating invasive plants on a site takes repeated herbicide application over several consecutive years.

(4) Timber stand improvement may be necessary to do in mixed hardwood stands. Timber markets primarily favor oak species. Where markets do not favor other hardwood species, such hardwoods may be considered unwanted. These hardwoods should be removed from the stand as a first step in preparation for natural regeneration. Most herbicides used in forestry kill hardwoods. Therefore, timber stand improvement is effected using stem injection of larger trees, or basal application on small trees.

iii) The government recognizes the capital intensive nature of forestry, and offers incentives to practice forest management. These incentives include direct payments through cost share programs, and indirect assistance through the tax code.

(1) Cost sharing programs reimburse qualifying forest landowners for specific forest management practices (such as site preparation, tree planting, release, or prescribed burning). Often, the government has certain objectives to achieve through its cost share programs. Federal programs are administered through the US Department of Agriculture, and are funded through the Farm Bill. These include Conservation Reserve Program (CRP), Conservation Stewardship Program (CSP), Environmental Quality Incentives Program (EQIP), Wildlife Habitat Quality Incentives Program (WHIP), and Wetlands Reserve Program (WRP). The state program is administered through the Mississippi Forestry Commission and called the Forest Resources Development Program (FRDP). Funding for this program is through severance taxes on harvested timber. The MFC Service Forester primarily monitors compliance for the FRDP cost share program.

(2) There are numerous tax incentives in the federal and state tax codes. Tax incentives are allowed as tax credits or deductions. The federal Internal Revenue Service allows timber income to be taxed as a capital gain, which may be a lower rate than for personal income. The IRS also has ownership categories which allow for different tax incentives based on ownership objectives as hobby, investment, business, or farm. Both federal and state tax codes permit taxpayers to recoup expenses for reforestation. For example, the Mississippi Reforestation Tax Credit permits forest landowners in Mississippi up to $75,000 in tax credits when paying for forest regeneration.

b) Overview of Silvicultural Systems: Silvicultural systems involve the harvest operations for the regeneration and maintenance of a desired species in a suitable stand structure. Essentially, there are systems for even-aged stand management and uneven-aged stands. Which silvicultural system is used is determined by an analysis of landowner objectives as well as financial analyses of expected costs and returns.

i) Even-aged Silvicultural Systems: These employ three methods: clearcutting, seed tree, and shelterwood. Even-aged stands are cut at a definite rotation length, as determined by the objectives of the landowner.

(1) Clearcutting: Involves the harvesting of all merchantable trees on the site. It may be a patch, stand, or strip. Regeneration is obtained by sprouting, seedfall from adjacent trees, direct seeding, or planting. Residual trees may be removed in site preparation to facilitate regeneration, especially in planting. This method is best for shade intolerant species, especially southern pine stands.

(2) Seed Tree: Harvesting is done in stages for this method. Often, timber stand improvement is done first to release crop trees for better seed production. After several years, cutting is done again, leaving the seed trees to regenerate the next stand. Generally, 4-10 trees per acre are left. After advance regeneration is established, the crop trees are removed. This method works well with light-seeded, shade intolerant species, such as loblolly or shortleaf pines.

(3) Shelterwood: As with seed tree, the shelterwood system involves several harvests for timber stand improvement, leaving the crop trees, and finally the removal of crop trees after advanced regeneration is established. This method is useful in regenerating heavy seeded species, those having greater shade tolerance, or those species with irregular seed crops. Examples include longleaf pine and most oak species.

ii) Uneven-aged Silvicultural Systems: These rely completely on selection harvests. There are two methods of selection: individual and group. Since the stand comprises all ages, regeneration is done continuously. Size classes proxy for age, and the diameter distribution approximates a "reverse J" shape. Harvesting is planned on periodic cutting cycles, and merchantable trees are removed from different size classes.

(1) Individual Selection: In this method, harvests are made of individual trees only. This system is best suited for shade tolerant species. In mixed stands, use of individual selection will increase the proportion of shade tolerant species

(2) Group Selection: With this method, small groups of trees are removed at a time. Openings may vary from a fraction of an acre up to about 2 acres. This method favors the maintenance of less shade tolerant species in mixed stands. Ultimately, this method creates a mosaic of small, even-aged stands with an uneven-aged forest structure. Group selection harvests and patch clear cuts of similar size will produce similar stand structures and species composition.

4) Overview of Financial Analysis Models

Financial analysis is critical to sound forest management. Money has a time value based on compound interest formulae. The keystone to financial analysis is the model of Net Present Value, and its special derivations.

a) Net Present Value: This model represents the difference between the present value of all revenues less the present values of all costs over a specified period of time, at a given discount rate. The discount rate can be used to calculate the opportunity cost of time. Also called Net Present Worth or Present Net Worth.

NPV = (Present value of all revenues – Present value of all costs)

NPV is used to sort or rank alternative investments. If positive, the investment is considered acceptable, whereas a negative net present value is disregarded as an alternative. If NPV is zero, the investment is neutral. NPV can also be used to calculate the optimal rotation length for a given discount rate. Moreover, as the discount rate increases, the optimal rotation length decreases, other parameters remaining the same.

b) Internal Rate of Return: Discount rate at which the net present value is zero, when all discounted revenues and costs are equilibrated. Generally, this is the expected interest that a particular investment will generate. Also called the Rate of Return, Return on Investment, or Hurdle Rate.

c) Benefit/Cost Ratio: Another form of the net present value calculation. In this case, the values are expressed as a ratio of all discounted revenues divided by all discounted costs. If the benefit/cost ratio is greater than or equal to 1, the investment would be positive. If the ratio is zero, then net present value is zero, and the internal rate of return equals the discount rate. If the ratio is less than 1, the investment is not acceptable. B/C = (present value of all revenues / present values of all costs).

d) Equivalent Annual Income: This is a special form of the net present value calculation, in that it expresses the NPV for a given investment as an equalized payment of annual revenues (or costs, if negative) for the given time horizon of the investment. This model allows the comparison of investments with different time horizons. Also called the Equal Annual Equivalent or Annual Income Equivalent.

$EAI = NPV \{ [i(1 + i)^n] / [(1 + I)^n – 1] \}$, where

i = discount rate,

n = number of time periods

e) Land Expectation Value: This is a special form of the net present value calculation for an infinite series of investment horizons or rotations. It is calculated as the net revenue at the end of the first rotation, discounted by an infinite series of those rotations. In forestry, this calculation represents the amount to purchase bare land to conduct the given investment scenario. Also known as Soil Expectation Value or Bare Land Value.

$LEV = \{ [NR] / [(1 + i)^R – 1] \}$, where

NR = Net Revenue at the end of the first rotation,

i = discount rate, and

R = rotation length

5) Overview of Stand Management Principles in Natural Resources

a) Estimating Stand and Forest Conditions

Individual tree growth in a stand depends on the site and the spatial arrangement of other trees. Using these spatial arrangements to project stand growth will influence ingrowth, increment, and mortality within the stand.

i) -3/2 Power Rule: Defines the upper limit for stand density of trees for a given size at which self-thinning occurs (within even-aged stands, competition among individual trees eventually results in mortality). This concept is also known as the stand density index.

$V = kN^{-3/2}$, where
V = average tree volume,
N = number of living trees per unit area, and
k = a tree species-specific constant

ii) Even-aged Stand Growth: Follows a sigmoid curve, depending on intermediate stand management activities. Such differences over time will affect wildlife habitat for nesting, roosting, or foraging as the structural characteristics of the stand varies.

iii) Uneven-aged Stand Growth: The target forest structure is one that provides a steady volume growth over time. Volume increment is maintained by a relatively constant diameter distribution. This system can be maintained indefinitely so long as adequate regeneration is provided. Harvesting is designed to periodically remove trees of appropriate size and species to maintain the diameter distribution.

iv) Even-aged versus Uneven-aged Characteristics*

Growth/Structure Characteristic	Even-Aged Stands	Uneven-Aged Stands
Trees/unit area	Decreases with age	Varies through time
Mortality rate of stems	Decreases with age	Remains +/- constant over time
Mortality of volume	Increases with age	Remains +/- constant over time
Height of canopy	Increases with age, then plateaus	Remains +/- constant over time
Canopy cover	Ranges from none to full	Ranges from full to one w/gaps
Average tree diameter	Increases with age	Fluctuates with harvests & mortality
Diameter distribution	Bell-shaped curve	Reverse J-shaped curve
Basal area	Increases with age, then plateaus	Fluctuates with harvests & mortality
Timber growth rate	Rises, peaks, then declines	Remains +/- constant over time
Timber yield	Increases with age, then plateaus	Fluctuates with harvests & mortality

* From Bettinger, P., K. Boston, J. P. Siry, and D. L. Grebner. 2009. Forest Management and Planning. Elsevier – Academic Press, Boston, MA. p.79.

v) Stand Growth over Time: Multiple measurements of a forest stand condition over time permits evaluation of current stand conditions, as well as observing changes during the time period. Given stand measurements at 2 points in time, Index 1 represents the initial stand measurements, and Index 2 those at the end of the period. Then the following can describe the stand conditions:

V_1 = volume of the stand at the initial time
V_2 = volume of the stand at the end of the period
$M_{1\text{->}2}$ = volume of mortality between the measurement times
$C_{1\text{->}2}$ = volume of harvested trees between measurement times
I_2 = ingrowth of volume at the end period, having grown into the smallest diameter class recognized between measurement times

The following can be said about the observed changes in stand characteristics over time: V_2 inherently includes net ingrowth. The net change in volume is estimated as:

Net Change	$= (V_2 - V_1)$
Gross growth, including ingrowth	$= (V_2 + M_{1\text{->}2} + C_{1\text{->}2}) – V_1$
Gross growth, excluding ingrowth	$= (V_2 + M_{1\text{->}2} + C_{1\text{->}2} - I_2) – V_1$
Net growth, including ingrowth	$= (V_2 + C_{1\text{->}2}) – V_1$
Net growth, excluding ingrowth	$= (V_2 + C_{1\text{->}2} - I_2) – V_1$

These equations can also be used to describe wildlife habitat and its changes over time as well, by substituting suitable habitat for volume measurements.

b) Projecting Stand Conditions

i) Growth and Yield Tables: Originally these were developed to allow resource managers to understand how stands and forests will change over time.

ii) Volume Table: Shows the volume contained in trees of various heights and diameters. The measurements are based on merchantable volumes for individual trees, in board feet, cubic feet, cords, or tons. Volumes are estimated from measurements in experimental plots.

Volume Table for Longleaf in BF (Int'l 1/8-in Rule to 5" merchantable top)*

	Number of 16-ft. Logs						
DBH (in)	1	2	3	4	5	6	**Basis (# trees)**
7	19	29	44	-	-	-	77
8	21	37	59	82	-	-	89
9	23	45	75	106	137	-	45
10	26	53	91	129	168	210	35
11	29	61	107	154	201	248	27
12	32	69	124	180	235	291	11
13	-	78	140	207	270	336	9
14	-	86	158	234	306	382	5
15	-	94	177	263	345	432	15
16	-	103	197	293	387	484	9
17	-	112	218	324	431	539	11
18	-	121	239	356	475	595	1
Basis (#trees)	46	134	86	60	8	-	334

* From Bettinger, P., K. Boston, J. P. Siry, and D. L. Grebner. 2009. Forest Management and Planning. Elsevier – Academic Press, Boston, MA. p.92.

Volumes within the blocked area indicate estimates based on measured trees, and volumes outside this block are estimates not based on measurements from experimental plots. The column and row at the ends indicate the basis, or number of trees measured in each diameter or height class.

iii) Yield Table: Shows the estimated volume of wood from a stand on a per unit area basis. Measurements are based on stand characteristics, such as age, stand density, and site quality. Volumes are estimated over a wide geographic range from samples in well-stocked stands.

iv) Growth and Yield Simulators: Computer programs have supplanted the use of growth and yield tables, incorporating stand development such as accretion, ingrowth, and mortality into their programming. Estimates are not confined to the categories of a yield table. All models are based on a number of assumptions:

(1) Individual Tree, Distance-Independent Model: Based on modeling individual tree growth. Actual distance to other trees is not a variable. Competition is modeled through other stand density characteristics, such as basal area. Example: OAKSIM for modeling even-aged upland oak stands of northern North America, or the Forest Vegetation Simulator (FVS) from the USDA Forest Service.

(2) Individual Tree, Distance-Dependent Model: Again, simulates individual tree growth, but includes detailed spatial information to model competition among trees. Example: PTAEDA3 modeling loblolly pine plantations.

(3) Whole-Stand Model: A yield table is an example of a whole-stand model. However, estimates do not account for stands with less than full stocking. Empirical yield tables use measurements from average stands, thereby reflecting expected average conditions. Whole stand simulators use whole stand data, such as stand age, site index, stand density, quadratic mean diameter, but do not include the detail of individual tree simulators. Example: DFSIM for modeling even-aged Douglas-fir stands in the Pacific Northwest.

(4) Diameter Class Models: Include more detail than whole-stand models, by projecting each diameter class within a stand separately. These models are somewhat a blend of the individual tree and whole-stand approaches. Example: Simulator for Intensively Managed Stands (SiMS) models planted pine, natural pine, and hardwood stands in the southern United States.

(5) Gap Simulators: Model the gap a tree may create when it dies, allowing light for ingrowth. Therefore, they are similar to individual tree models. However, these models are often developed by biologists to simulate ecological process, so timber volumes may not be recorded. Example: Zelig simulator.

(6) Snag and Coarse Woody Debris Simulators: Project the amount of standing and fallen dead wood over time to estimate wildlife habitat suitability.

c) Optimization for Stand Level Objectives

Decision making to plan a course of action can be difficult in life. This is due to the fact that the multitude of choices increases exponentially with complexity. Optimization techniques allow us to sort through this complexity in making a plan of action. Stand level decisions require developing the best management plan to meet landowner objectives, while satisfying numerous constraints, such as maintenance of cash flow, timing of operations, or protection of habitat. Ultimately, the multitude of uses for a single unit of land become competitive. Two challenges that have arisen include the determining the optimum rotation age for even-aged stands, and the timing of intermediate treatments, i.e. thinning of stands.

i) Rotation Ages for Even-aged Stands:

(1) Physical rotation age is defined by the lifespan of a tree species.

(2) Technical rotation age is the length of time necessary to grow a stand of trees to meet the size required for commercial markets.

(3) Silvicultural rotation age is determined by the age for maximum seed production for natural regeneration.

(4) Biological rotation age occurs when the stand has reached its maximum volume production, such as given by the culmination of mean annual increment.

(5) Income generation rotation age produces the highest level of average income or forest rent. This can be calculated by potential harvest revenue in each period by the stand age.

(6) Economic rotation age gives the highest discounted net revenue. If only the discounted net present value is recognized, the age would be somewhat longer than if the discounted value of future rotations were considered (i.e., land expectation value).

(7) Value growth percent rotation age is determined when the marginal cost of keeping a stand equals the marginal revenue of cutting it. In other words, the stand would be harvested when the value growth rate equals the discount rate. In this scenario, the rotation age would increase as the discount rate decreases.

ii) Timing of Thinning

(1) There are many factors to consider when deciding to make partial cuts in a stand. These include the species mix, varying growth rates of individual trees, varying growth rates as the stand ages, type of thinning (from below, from above, diameter limit, by row in a plantation), intensity of thinning, and the possibility of performing the thinning during any time period or cutting cycle. Remember, row thinning will not change average stand diameter; this is only achieved by some form of selection in thinning. In selection thinning, trees are marked to keep or remove. If marked to cut, the tree is painted twice, at DBH and the stump, to provide a post-harvest check. Selection thinning will change the average diameter of the residual stand.

(2) Besides these considerations, there are numerous interactions that can occur. Species differ in their tolerance of competition. Of the southern pines, slash pine is most susceptible to stagnation from overstocking. Thinning intensity will affect the timing of later thinning and the final harvest volumes. The type of thinning can have similar effects. Site quality can also affect timing of thinning. Since the stand growth rate is directly proportional to site index, thinning will be more frequent as site index increases. In uneven-aged management, entries are theoretically meant to continue forever, which generally means more thinning than with even-aged stands.

(3) Optimal solutions involve determining the optimal sustainable diameter distribution, optimal species mix, and optimal entry cycle length. For converting an even-aged stand to an uneven-aged stand, one must consider the optimal strategy and length of time to do this.

iii) Optimal Stand Density or Stocking may be a management objective in itself, as opposed to maximizing economic or commodity value. In this case, the objective becomes determining which trees to thin in each time period.

6) **Forest Regulation**

a) Forest regulation involves the technical aspects of controlling stocking, growth, yields, and harvests to meet management objectives across an entire forest. Often, the management objective has been sustained yield, which provides stability to markets. On the whole, forest regulation represents a significant shift in thinking from stand level management with silvicultural systems.

Forest regulation is the process to achieve that sustained yield by providing an equal distribution of age and size classes across different site classes. There are several, more simplistic methods for regulating forest conditions, as follows:

i) Area regulation: An indirect method of determining and controlling the amount of timber cut annually or periodically on the basis of stocked area. This approach sets the harvested amount by area first. Subsequent harvests on equal amounts of forested area annually or periodically will then regulate a forest. Oldest stands are cut first. This method will regulate a forest within one rotation, but harvest volumes may vary greatly.

ii) Volume regulation: Direct method of determining and controlling the amount of timber cut annually or periodically based on growing stock volume and growth increment. This approach sets the harvest volume first, then harvests the required volume annually or periodically to regulate a forest. This method is independent of area. Oldest stands are cut first. This method will produce greater stability on harvest volumes during forest regulation, but it will take longer to regulate the forest than when using area control. In some cases, regulation cannot be achieved.

iii) Basal Area regulation: This method of determining and controlling the amount of timber cut annually or periodically is based on basal area of the growing stock and its increment.

iv) Area/Volume regulation: A mixed approach of determining and controlling the amount of timber cut annually or periodically based on both growing stock volume and stocked area.

b) In a regulated forest, the rotation age that maximizes CMAI will maximize the volume harvested annually. However, this is not the optimal economic rotation because the cost of maintaining the inventory of growing stock is not considered. The best economic rotation age for a regulated forest will be where the LEV is maximized. Since LEV accounts for the time value of money, the best economic rotation will be shorter than the best biological rotation.

c) Mathematical Modeling for Optimization
Given the complexity of the real world, management science uses modeling to achieve forest regulation. There are several mathematical approaches to finding an optimal solution to forest regulation.

i) Linear programming involves solving an equation set, whereby objectives and constraints are described by linear equations. Non-linear programming is similar, but uses non-linear functions in these equations. This often better matches natural conditions, since stand development follows a non-linear growth curve. However, non-linear programming on a large scale is not commonly done due to lack of appropriate information.

ii) Heuristic approaches use a sequential analysis of alternatives based on logic, and explore a larger range of the solution space. This approach provides a reasonable solution faster, but may sacrifice optimality in the solution set.

iii) Dynamic programming is widely used today. This approach facilitates the exploration of a large number of alternatives by exploring a more limited range of options. One can work iteratively through a sequence of dynamic equations in a forward-flowing manner to a final solution, or backwards flowing from a solution to arrive at a set of initial conditions.

d) Approach to Solving Decision Models

i) Understand the management problem: It is very important to be able to read or listen to a description of the management scenario and be able to identify the landowner goals, the important objectives to achieve, and important issues. This permits focus on the pertinent details and immediately can eliminate potential solutions that are of little concern.

ii) Translate the management problem into a series of mathematical equations: This step is particularly crucial. Proper identification of variables (objectives or constraints) and their coefficients (mathematical relationships to the variables) defines the solution space to the problem at hand.

iii) Solve the problem mathematically or graphically: A set of linear or dynamic equations can be solved to arrive at an optimal solution. Relatively simple, 2-dimensional problems can be solved graphically to visualize the solution space.

iv) Check the solution: Verification of the answer is essential before embarking on the course of action. For instance, substitution of the values back into the initial set of equations should produce answers within the parameters given. If not, the management problem may need to be clarified and redefined, and a new set of equations developed.

v) Feasible solutions for the decision variables satisfy all the constraints: Optimal solutions provide a set of values that maximizes (minimizes) the objective function. Occasionally, no feasible solution is possible that satisfies all constraints, such as budget constraints. A set of solutions is considered efficient, when no other solutions can produce more of one output while maintaining the same values of other outputs.

7) Additional Terms

Term	Definition
Accretion	The incremental growth of trees in a stand during a measurement cycle.
Basal Area	Sum of the cross-sectional area of each tree at the Diameter of Breast Height. It is reported on a per-unit area basis. For a single tree, $BA = \pi r^2$, or $BA = \pi [(DBH)^2/4]$. When expressed in feet, the equation becomes $BA = 0.005454 (DBH)^2$.
Board Foot	A unit of measure for sawtimber containing 144 cubic inches of wood in a square board that is 12 inches on a side and 1 inch thick.
Culmination of Mean Annual Increment	For a given stand, the point at which the CAI curve crosses the MAI curve. This point is considered to represent the biological rotation age for an even-aged stand which maximizes volume production of the stand.

Term	Definition
Current Annual Increment	The growth rate of a tree, stand, or forest expressed on an annual basis.
Diameter at Breast Height	A measure of the girth of a standing tree at breast height, which is 4.5 feet or 1.37 meters above the ground on the uphill side.
Even-Aged	A stand of trees regenerated at the same time. The ages of individual trees are within 20% of the average stand age.
Feasible Region	The range of potential solutions that satisfy all constraints in decision modeling.
Ingrowth	The growth of trees in a stand attributed to small trees growing into merchantable size during a measurement cycle.
Log Scales	These models or rules were developed to estimate the volume of logs on a board foot, cubic foot, linear foot, or cord basis. With regard to sawtimber, log scales estimate the volume of wood products that can be sawn from a log.
Long Term Sustained Yield	A level of harvested forest products that can be maintained in perpetuity on a regulated forest.
Mean Annual Increment	The volume growth of a stand or forest on a per acre basis, divided by its age. Generally considered the biological maturity for harvest decisions. For a stand, MAI = (volume or weight per acre/stand age).
Mortality	The death of trees in a stand during a measurement cycle.
Optimization	A mathematical technique that determines the maximum (or minimum) value of variables, such as landowner objectives, within a given set of constraints.
Periodic Annual Increment	The volume growth rate of a tree, stand, or forest over some length of time.
Quadratic Mean Diameter	The diameter of the tree of average basal area: QMD (inches)=$\sqrt{(BA / (0.005454 * n))}$, where BA is stand basal area per acre, and n is the number of trees per acre.
Rotation Age	The number of years between stand establishment and final harvest.
Site Index	The height of the dominant and co-dominant trees at a standard base age, such as at 25 or 50 years of age. Height of dominant/co-dominant trees is relatively independent of stand density.
Stand Density	A count of the number of trees on a given per-unit area basis. This parameter has the greatest influence on diameter growth, stem quality, stand volume growth, and regeneration success.
Stand Density Index	An empirically derived value relating the maximum stand density for a given basal area of a particular species that can be supported before experiencing mortality. This parameter defines the upper stand density for thinning decisions.
Stand Table	A description of number of trees per unit area by diameter size classes.
Stocking	A relative concept relating the conditions of a site regarding the stand density that it could support.
Uneven-Aged	A forest having at least 3 distinct age classes, ranging from regeneration through mature trees.

CHAPTER 3

FOREST MEASUREMENTS

Robert C. Parker[1]

This review covers the major principles students would lean in a forest measurements course. This review does not cover every possible forest measurements question that might occur on the examination, so readers are encouraged to consult other materials as well while studying for the examination.

1) Acreage Determination

a) Within G.L.O. Survey System

i) Dimensions/Sizes: Townships, sections, forties
(1) township = 36 sq. miles (6 x 6 sections)
(2) township = 36 sections of 640 acres each
(3) section = 80 chains x 80 chains = 640 acres
(4) forty = 20 chains by 20 chains

ii) Section numbering/orientation within Townships

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

iii) Acres contained in legal description
1) W1/2 of NW 1/4 of SE 1/4 of Section 15
2) Contains 20 acres

b) From survey measurements

i) 10 square chains = 1 acre

ii) within geometric shapes of known dimensions

(1) triangle = 0.5 x Base x Height

(a) tract of 20 x 60 chains = 60 acres

(2) rectangle = length x width

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(a) tract of 20 x 60 chains = 120 acres

(3) $C^2 = A^2 + B^2$

(a) if you walk N90°E for 60 chains then S00°W for 80 chains, then distance back to the beginning point is 100 chains and the bearing is tan(angle) = 60/80 thus angle = N36.87°W

2) Determination/Use of Map/Photo Scale

a) Conversion of representative fraction (RF) to equivalent scale representations
Feet per inch, chains per inch, etc.
RF = 1/S; 1 unit = S equivalent units
if unit is inches then S/12 gives 1 inch = xx feet
xx feet/66 gives 1 inch = yy chains

b) Photo scale from known ground measurements
RF = 1/S = d/D
where d= image distance, D= ground distance
if a section measures 240/60 inches in width; then
1/s = 4 inches/5280 ft.= 4/63360 inches = 1/15840

c) Obtaining desired aerial photo scale
RF = 1/S = f/(H - h) where f = camera focal length,
H is aircraft altitude above mean sea level (MSL) and h is average terrain elevation/height.

if f=0.5 ft., H=12,350 ft., h=350 ft. then 1/s=1/24,000

to achieve 1:12,000 at average ground level;
1/12,000 = .5 ft./(H-350 ft.), H must be 6,350 ft.

3) Distance Measurement

a) On geometric shapes
if tract is right triangle with 30 chains on base and 40 chains in height, the hypotenuse is 50 chains from $c^2 = 30^2 + 40^2$ and $c = (2500)^{0.5}$ = 50 chains

b) Using scaled lengths on known map scale
if RF= 1:24,000 then a map distance of 1.5 inches is equal to 24,000 x 1.5 inches or 3,000 ft. or 45.45 chains

4) Tree Form, Size, and Volume

a) Mesavage and Girard Form Class

i) Definition – diameter inside bark (dib) at top of first 16 ft. log expressed as percentage of diameter at breast height (dbh) outside bark (ob)

ii) computation from tree measurements if dbh=18 and dib at 17.0 ft. is 14.4 inches, then form class = 14.4/18 x 100 = 80

iii) computation of log volume within tree if form class is 76 and dbh is 14 inches, the dib at 17.6 ft. or 1st-16 ft. log is 10.64 inches. The Doyle volume = $((10.64-4.0)/4)^2$x16 or 44.1 board feet; or use table for Scribner.

b) Characteristics of Log Rules

i) International ¼ inch

(1) originally derived as Int'l 1/8 inch rule

(2) allows for 1/4 inch saw kerf

(3) approximates lumber yield from logs

(4) uses mathematically correct equation

ii) Scribner (and/or Scribner Decimal C)

(1) diagram log rule

(2) allows for saw kerf

(3) developed by store keeper for barter

(4) official log rule of U.S. Forest Service

(5) equal to Doyle at approximately 25 inches

(6) never overscales Int'l ¼

iii) Doyle

(1) originally derived from equation

(2) underscales small logs; overscales large

(3) developed by a preacher

(4) equal to Scribner at approximately 25 inches and overscales Scribner after 26 inches

(5) overscales Int'l 1/4 after 29 inches

c) Legal Log Rule in Mississippi: The one agreed to by the buyer and seller.

d) Computation/determination of log volume by Log Rule (16 ft. logs; D = dib at small end of log)

i) Doyle = $((D - 4)^2 \times L)/16$

ii) Scribner = $0.79D^2 - 2D - 4.0$

iii) Int'l 1/4 = $0.796D^2 - 1.375D - 1.230$

e) Overrun/Underrun = (Mill Tally - Scale)/Scale x 100

i) overrun = positive number

ii) underrun = negative number

f) Cross sectional area = $0.005454 \times D^2$ sq.ft.

i) if D = tree DBH in inches; area= basal area

ii) if D = log diameter; area = cross sectional area

g) Single tree volumes

i) From regression equations

(1) Bd.ft. volume = $-32.32 + 0.002D^2H$
where D= tree dbh, H= merchantable height in feet

(2) Bd.ft. volume = $-32.32 + 0.002(16.0)D^2$ merchantable height
= $-32.32 + 0.032D^2$ merchantable height

ii) Using Form Class computations

h) Average tree height from Site Index Equation

$SI = H \exp[-12(1/50 - 1/A)]$

if SI50 = 80 and Age =30 then H=68 ft.

Using natural log:

$\ln SI = \ln H - 12(1/50 - 1/A)$

$\ln H = \ln SI + 12(1/50 - 1/A)$

$= 4.3820266 + 12(0.02 - 0.03333)$

$= 4.3820266 + 12(-0.01333)$

$= 4.3820266 - 0.16$

$\ln H = 4.2220266$ (take INV of lnX function)

H = 68.2 feet

Using exp function:

$80 = H \exp(0.1596)$

$80 = H (1.1735)$

H = 68.2

i) Tree height measurement with clinometer

H = (distance/index distance) x (reading from top – reading from bottom)

1. Percent scale
   for reading of 120 at 50 ft. then
   H = 50/100 x 120 = .5 x 120 = 60 ft.

2. Topographic scale
   for reading of 60 at 1.5 chains then
   H = (1.5/1.0) x 60 = 90 ft.

5) Stand Dimensions and Expressions

a) Quadratic mean diameter

QMD = diameter of tree of average basal area (BA)

If stand BA=80 sq. ft./acre and trees/acre =100 then

QMD = diameter of tree of BA =(80/100) sq.ft.

since BA = $0.005454D^2$ then D = (BA/0.005454)0.5

or D= (0.80/0.005454)0.5 = 12.11 inches

b) Basal area per acre in relation to number of stems and average dbh.

If average dbh= 10 inches and stems/acre = 200 then

BA/acre = (0.005454×10^2) x 200 = 109.08 sq.ft.

c) Stand/Stock tables - definitions and uses

Stand table = number of trees/acre by dbh class

Stock table = volume/acre by dbh class

Stand & Stock table = number and volume of trees per acre by dbh class

6) Site Index

a) Definition and interpretation

The average height of dominant and codominant trees at the index age.

b) Determination/calculation from tree measurements

SI = H exp[-12(1/50 - 1/A)]

if Age =30 and H=75 ft. then SI = 88 ft.

7) Cruise Computations (Strip, Fixed Radius Plot, Variable Plot)

a) Sample size computation

infinite population: $n=\dfrac{t^2 * cv\%^2}{ae\%^2}$

finite population: $n=\dfrac{1}{\frac{1}{n}+\left(\frac{ae\%}{t \times cv\%}\right)^2}$

where t = student's t value at the confidence level

cv = coefficient of variation as percent
ae = allowable error as percent of mean volume
n= acres/(plot size)=population size

if t = 1.96 at the 95% level of confidence
cv = 60% variation
ae = +/- 10% of mean volume
then n = $(1.96^2 \times 60^2)/10^2$ = 138.29 = 139 samples

b) Plot/Line Spacing/Orientation

i) to attain desired percent cruise
To achieve a 10% cruise with 0.1 acre plots spaced at 2 chain intervals on a cruise line, what is the cruise line spacing?

cruise = plot acres/[(plot dist x line dist)/10]
.10 = 0.1/[(2 x L)/10]
L = 5 chains

ii) in relation to topography

c) Cruise computations

i) Percent cruise; theoretical and actual
%cruise =(#plots x plot size)/tract acres x 100%
%cruise = cruise acres/tract acres x 100%
%cruise = plot size / area represented x 100%

Strip %cruise = (length x width/10)/tract acres
Plot %cruise = (#plots x plot size)/tract acres
Prism %cruise = [#plots x (plot size of tree of mean dbh)]/tract acres

ii) Per Acre Conversion Factor
PACF = 1/plot size

Strip: Plot size = (L x W)/10 acres
PACF = 1/(L x W/10)
Plot: Plot Size = $\pi r^2/43560$ acres
PACF = 1/plot size in acres
Prism: Plot Size = ba/BAF for given dbh
PACF = BAF/(BA of tree)
= BAF/(0.005454D2)

iii) Mean volume per acre
Volume/acre = (volume tallied)/(acres in tally)

vi) Mean basal area per acre
Prism = (#trees x BAF)/#points
Plot = [sum(#trees in dbh)(BA of dbh)]/[#plots x plot size]
Strip = [sum(#trees in dbh)(BA of dbh)]/[length x width/10]

v) Stratified – weighted mean and total volumes
volume/acre = [sum(stratum volume/acre x stratum acres)]/[sum of stratum acres]
total volume = [sum(stratum volume/acre x stratum acres)]

d) Stand/Stock Table Computations

i) Per Acre Conversion Factor by dbh class
Strip/Plot PACF = 1/plot size
Prism PACF = BAF/BA of dbh class

ii) Mean volume per acre by dbh class
dbh volume/acre = (dbh tally volume)/acres in tally

Prism=(PACF x trees tallied x tree volume)/#points
Plot =(PACF x trees tallied x tree volume)/#plots

iii) Mean basal area per acre by dbh class
Prism= (BAF x #trees in dbh class)/#points
Plot = (PACF x trees tallied x tree ba)/#plots

e) Statistical Computations and Interpretations

i) Confidence Interval for specified confidence level:
$CI: \bar{x} \pm ts_{\bar{x}}$

Interpretation: I am 95% confident (i.e. 95 times out of 100) that the true population mean is within the confidence interval of CI_{lower} and CI_{upper}; i.e. give the mathematical and/or the equivalent dollar values.

ii) Sampling error for specified confidence level
$$SE\% = \left[\frac{ts_{\bar{x}}}{\bar{x}}\right] 100\%$$

Interpretation: The sampling error merely expresses (i.e. translates) half of the confidence interval as a percentage of the mean so that samples of different means and variances can be compared. The interpretation is the same as for the confidence interval. I am 95% confident that the true population mean lies between the mean minus (SE% of the mean) and the mean plus (SE% of the mean); i.e. give the mathematical values and/or dollar values. Allowable error is desired sampling error prior to the cruise; sampling error is a computed cruise statistic; i.e. after-the-fact.

Example: SE%=10%

mean volume = 4,500 bd.ft. per acre

value = $400 per mbf

4.500 x ($400) ± 0.10 x (4.500) x $400

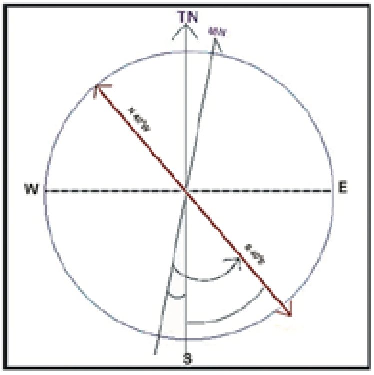
$1,800 ± $180 per acre

iii) Coefficient of variation

$$SE\% = \left[\frac{s_{\bar{x}}}{\bar{x}}\right]100\%$$

Interpretation: The CV is a unitless value that expresses the standard deviation as a percentage of the sample mean; thus allowing us to compare samples of different means and variances. The CV is a measure of sample variation, contains no unit of measure, and can be used to compare inventories of different means and standard deviations.

8) Bearings and Azimuths



a) Magnetic Declination

b) Conversion of magnetic to true and true to magnetic
(draw picture of TN, declination angle, etc.)

Example: If declination is N05°E, what is the true bearing of the magnetic bearing S40°E?
Answer: S35°E true

9) Topographic Maps

a) Scale determination and expression

b) Contour line interpretation: contour line connects points of equal elevation.

c) Direction determination

d) Distance measurement: use converted RF

10) Tree Growth

a) Radial growth (vs. diameter growth)

b) Bark thickness - usually expressed as single bark

c) Computation of periodic DBH growth using current dbh and bark thickness, and past radial growth

current dib = current dbh – 2 x single bark

past dib = current dib – 2 x radial growth

past dbh = past dib + double bark thickness

If Current dbh = 16.2 inches, radial growth =1.5 in 10 years, single bark thickness is 1.6

inches, and you assume double bark thickness is equal to 10 percent of past dib; what is the dbh growth of this tree over the past 10 years?

Answer: past dib = 16.2 - 2(1.6) -2(1.5) = 10.0
past dbh = 10.0 + .10(10.0) = 11.0 inches
dbh growth = 16.2 - 11.0 = 5.2 inches

11) Example Cruise Computations

a) Strip Cruise:
You completed a strip cruise of a 40.0 acre tract using strips that were 1.0 chains in width (at 10 chain intervals) and 38 chains in cumulative length. You tallied sawtimber on the entire strip width and pulpwood on the right half of each strip. The tally volume was 22.8 cords of pulpwood and 9,500 board feet, Doyle, of sawtimber.

The actual cruise intensity and average volume per acre for SAWTIMBER was:

a. 10 percent and 2,375 bd.ft. per acre
b. 10 percent and 2,500 bd.ft. per acre
c. 9.5 percent and 2,375 bd.ft. per acre
d. 9.5 percent and 2,500 bd.ft. per acre

Correct Answer is d

The actual cruise intensity and average volume per acre for PULPWOOD was:

a. 4.75 percent and 11.4 cords per acre
b. 4.75 percent and 12.0 cords per acre
c. 5 Percent and 11.4 cords per acre
d. 5 percent and 12.0 cords per acre

Correct Answer is b

b) Plot Cruise:
Using 0.1-acre, fixed-radius plots, you tallied the following volume on 20 plots within a 40 acre tract: (PACF is per acre conversion factor or number of trees factor, NTF; BA is basal area of single tree). Partial computations completed.

DBH	Number	Volume/Tree	BA	PACF	Trees	Volume
10	100	16	0.5454	10	1,000	16,000
12	60	36	0.7854	10	600	21,600
14	80	75				
Totals	240					

The mean volume per acre and average volume per tree is computed to be:

a. 3,160 bd.ft. per acre and 35 bd.ft. per tree
b. 4,267 bd.ft. per acre and 25 bd.ft. per tree
c. 4,880 bd.ft. per acre and 41 bd.ft. per tree
d. 4,880 bd.ft. per acre and 45 bd.ft. per tree

Correct Answer is c

The mean basal area per acre and basal area in the 12 inch class is:

a. mean is 93.6 sq.ft. and 23.6 sq.ft. in 12 inch class
b. mean is 95.0 sq.ft. and 25.0 sq.ft. in 12 inch class
c. mean is 90.0 sq.ft. and 20.0 sq.ft. in 12 inch class
d. mean is 80.0 sq.ft. and 20.0 sq.ft. in 12 inch class

Correct Answer is a

c) Prism Cruise:

The Per Acre Conversion Factor (PACF) or Number of Trees Factor (NTF) for a prism is BAF/ BA, where BA is the basal area of a given tree size. Using a BAF 15 prism, you tallied the following trees on 10 points within a 40 acre tract: (partial computations completed).

DBH	Number Tallied	Volume/Tree	PACF	Trees	Volume
10	25	16	27.50	687.5	11,000
12	15	36	19.10	286.5	10,314
14	20	75			
Totals	60				

The mean basal area and quadratic mean DBH is:

a. 80 sq.ft. and 12.0 inches
b. 90 sq.ft. and 11.5 inches
c. 90 sq.ft. and 12.0 inches
d. 70 sq.ft. and 11.5 inches

Correct Answer is b

The mean volume per acre and total tract volume is:

a. 4,236 bd.ft. per acre and 169,440 bd.ft. total
b. 4,500 bd.ft. per acre and 180,000 bd.ft. total
c. 4,236 bd.ft. per acre and 180,000 bd.ft. total
d. 4,500 bd.ft. per acre and 169,440 bd.ft. total

Correct answer is a

d) Strip Cruise:

You completed a strip cruise of a 40.0 acre tract using strips that were 1.0 chains in width (at 10 chain intervals) and 38 chains in cumulative length. You tallied sawtimber on the entire strip width and pulpwood on the right half of each strip. The tally volume was 22.8 cords of pulpwood and 9,500 board feet, Doyle, of sawtimber.

The actual cruise intensity and average volume per acre for SAWTIMBER was:

a. 10 percent and 2,375 bd.ft. per acre
b. 10 percent and 2,500 bd.ft. per acre
c. 9.5 percent and 2,375 bd.ft. per acre

d. 9.5 percent and 2,500 bd.ft. per acre

Correct answer is d

%Cruise = [(1 x 38)/10]/40 =3.8 acres/40 = 9.5%

Volume/acre = 9,500 bd.ft. /3.8 acres = 2,500 bd.ft./acre

The actual cruise intensity and average volume per acre for PULPWOOD was:

a. 4.75 percent and 11.4 cords per acre

b. 4.75 percent and 12.0 cords per acre

c. 5 Percent and 11.4 cords per acre

d. 5 percent and 12.0 cords per acre

Correct answer is b

%Cruise = [(0.5 x 38)/10]/40 =1.9 acres/40 = 4.75%

Volume/acre = 22.8 cords /1.9 acres = 12.0 cords/acre

e) Plot Cruise:

Using 0.1-acre, fixed-radius plots, you tallied the following volume on 20 plots within a 40 acre tract: (PACF is per acre conversion factor or number of trees factor, NTF; BA is basal area of single tree.) Partial computations completed.

					TOTAL		
DBH	Number	Volume/ Tree	BA/Tree	PACF	Tree	Volume	BA
10	100	16	0.5454	10	1,000	16,000	545.40
12	60	36	0.7854	10	600	21,6000	471.24
14	80	75	1.0690	10	800	60,000	855.20
Totals	240				2,400	97,600	1,871.84

The mean volume per acre and average volume per tree is computed to be:

a. 3,160 bd.ft. per acre and 35 bd.ft. per tree

b. 4,267 bd.ft. per acre and 25 bd.ft. per tree

c. 4,880 bd.ft. per acre and 41 bd.ft. per tree

d. 4,880 bd.ft. per acre and 45 bd.ft. per tree

Correct answer is c

BA per tree = 0.005454 $(DBH)^2$ = 0.005454 $(14)^2$ = 1.0690

PACF = 1/(plot size in acres) = 1/.1 = 10

Volume/acre = 97,600 bd.ft./ 20 plots= 4,880 bd.ft. per acre

Volume/tree = 97,600/2,400 trees = 41 bd.ft. per tree

The mean basal area per acre and basal area in the 12 inch class is:

a. mean is 93.6 sq.ft. and 23.6 sq.ft. in 12 inch class

b. mean is 95.0 sq.ft. and 25.0 sq.ft. in 12 inch class

c. mean is 90.0 sq.ft. and 20.0 sq.ft. in 12 inch class

d. mean is 80.0 sq.ft. and 20.0 sq.ft. in 12 inch class

Correct answer is a

BA per tree = 0.005454 $(DBH)^2$

BA per acre = 1,871.84 sq.ft. / 20 plots = 93.6 sq.ft. per acre

BA12" class = 471.24 sq.ft. / 20 plots = 23.6 sq.ft. per tree

f) Prism Cruise:
The Per Acre Conversion Factor (PACF) or Number of Trees Factor (NTF) for a prism is BAF/BA, where BA is the basal area of a given tree size. Using a BAF 15 prism, you tallied the following trees on 10 points within a 40 acre tract: (partial computations completed)

			TOTAL		
DBH	#Tallied	Volume/Tree	PACF	Trees	Volume
10	25	16	27.50	687.5	11,000
12	15	36	19.10	286.5	10,314
14	20	75	14.03	280.6	21,045
Totals	60			1,254.6	42,359

The mean basal area and quadratic mean DBH is:

a. 80 sq.ft. and 12.0 inches
b. 90 sq.ft. and 11.5 inches
c. 90 sq.ft. and 12.0 inches
d. 70 sq.ft. and 11.5 inches

Correct answer is b

PACF = BAF / tree BA = 15/[.005454 (14)2]= 14.03
BA/acre = (60 trees x 15 BAF)/ 10 points = 90 sq. ft. per acre
DBHqm: Trees/acre = 1254.6/10 = 125.46 trees/acre
BA/tree = 90/125.46 = 0.7174 sq. ft. per tree

$$\text{DBH}= \sqrt{\frac{.07174}{0.005454}} = 11.47 = 11.5 \text{ inches}$$

since: ba = 0.005454(DBH)^2

The mean volume per acre and total tract volume is:

a. 4,236 bd.ft. per acre and 169,440 bd.ft. total
b. 4,500 bd.ft. per acre and 180,000 bd.ft. total
c. 4,236 bd.ft. per acre and 180,000 bd.ft. total
d. 4,500 bd.ft. per acre and 169,440 bd.ft. total

Correct answer is a

Volume/acre = 42,359/10 points = 4,235.9 or 4,236 bd.ft. per acre
Total volume = 40 acres x 4,236 bd.ft/acre = 169,440 bd.ft.

CHAPTER 4

FOREST ECONOMICS

Robert K. Grala[1]

Cash flows from forest activities occur at different stages during the investment's duration and often occur many years apart. Therefore, they have a different time value (i.e., opportunity cost) and need to be expressed in terms of the same point in time to make them comparable. The following sections describe techniques used to express forest investment cash flows in terms of point in time equivalency.

1) Compounding is a process of calculating a future value of a cash flow. Cash flows can include both costs and revenues that occur only once during an investment's duration, but also costs and revenues occurring annually or periodically (Klemperer 2003). When a cash flow is compounded to the future, its future value will growth exponentially because interest accumulates both on the principal (original value of the cash flow) and interest already accumulated in previous time periods (Bullard and Straka 1998, Gunter and Haney 1984).

a) Calculating a future value of a single item cash flow

i) A future value of a single item cash flow can be calculated by using a formula for calculating a future value of a single sum (Klemperer 2003, Bullard and Straka 1998, Gunter and Haney 1984):

$V_n = V_0 \times (1 + i)^n$

Where: V_n stands for the future value of the cash flow, V_0 stands for the present value of the cash flow, *i* is the interest rate, and *n* is the number of years, over which future value is being carried.

Example:

A pine sawtimber price is expected to increase at the rate of 0.50% per year over the next five years. What will the pine sawtimber price be five years from now, if the current pine sawtimber price is $24.00 per ton?

$V_n = V_0 \times (1 + i)^n$

$V_5 = \$24.00 / ton \times (1 + 0.005)^5 = \$24.00 / ton \times (1.005)^5 - \underline{\$24.61 / ton}$

Answer: After five years pine sawtimber price will increase to $24.61 per ton.

Example:

A forest landowner plans to deposit $20,000.00 into a savings account that pays an annual interest rate of 2.00%. How much money will accumulate in this account if a forest landowner deposits $20,000.00 for three years?

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$V_n = V_0 \times (1 + i)^n$
V_5 = $\$20,000 \times (1 + 0.02)^3 = \$20,000 \times (1.02)^3 =$ $\underline{\$21.224.16}$

Answer: After three years, a forest landowner will accumulate $21,224.16.

b) Calculating a future value of terminating annual cash flows

i) A future value of annual item cash flows can be calculated using a formula for calculating a future value of a terminating annual series. The formula assumes that the first cash flow occurs at the end of the first year and that cash flows stop at some time in the future (Klemperer 2003, Bullard and Straka 1998, Gunter and Haney 1984). We will assume that it stops at the end of the last year. While perpetual item annual cash flows can be encountered in forest financial analysis, the future value of these cash flows cannot be calculated because they never stop.

$$V_n = a \times \left[\frac{(1+i)^n - 1}{i} \right]$$

Where: V_n stands for the future value of annual cash flows, *a* stands for an annual cash flow, *i* is an interest rate, and *n* is a number of years in which annual cash flows are scheduled to occur.

Example:
A forest landowner plans to make annual deposits of $5,000.00 for the next five years into savings account that pays an annual interest rate of 1.50%. How much money will accumulate in this account after five years?

$$V_n = a \times \left[\frac{(1+i)^n - 1}{i} \right] = \$5,000 \times \left[\frac{(1+0.015)^5 - 1}{0.015} \right] = \$5,000 \times \left[\frac{(1.015)^5 - 1}{0.015} \right]$$
$= \underline{\$25,761.33}$

Answer: A forest landowner will accumulate $25,761.33 after five years. This answer can be verified by compounding each deposit separately as a single sum over the number of years that the deposit will be kept in the savings account. For example, the first deposit will be invested for five years, the second for four years, and so on.

c) Calculating a future value of terminating periodic item cash flows

i) A future value of a periodic item cash flow can be calculated using a formula for calculating a future value of a terminating periodic series. The formula assumes that the first item cash flow occurs at the end of the first period and that cash flows stop at some time in the future (Klemperer 2003, Gunter and Haney 1984). We will assume that it stops at the end of the last year. Periodic item cash flows also occur perpetually; however, the future value of such cash flows cannot be calculated because they never stop.

$$V_n = p \times \left[\frac{(1+i)^{n \times t} - 1}{(1+i)^t - 1} \right]$$

Where: V_n stands for the future value of periodic cash flows, p is a periodic cash flow, n is a number of intervals (rotations), t is interval (rotation) length, and i is an interest rate.

Example:
Calculate a future value of a $2,400.00 per acre net income from a pine plantation that will occur every 25 years during the next four rotations. Assume that the income can be deposited into a savings account that pays a 2.50% annual interest rate.

$$V_n = p \times \left[\frac{(1+i)^{n \times t} - 1}{(1+i)^t - 1}\right] = \$2{,}400.00/ac \times \left[\frac{(1+0.025)^{4 \times 25} - 1}{(1+0.025)^{25} - 1}\right]$$
$$= \$2{,}400.00/ac \times \left[\frac{(1.025)^{100} - 1}{(1.025)^{25} - 1}\right] = \underline{\underline{\$30{,}391.82}}$$

Answer: In 100 years (four rotations of 25 years each), a forest landowner will accumulate $30,391.82.

2) Discounting is a process of calculating a present value (at year 0) of an item's cash flow scheduled to occur in the future. A present value can be calculated for single item cash flow and annual and periodic item cash flows that stop at some time in the future as well as those annual and periodic item cash flows that continue in perpetuity (Klemperer 2003).

a) Calculating a present value of single item cash flow

i) A present value of single item cash flow can be calculated using a formula for calculating a present value of a single sum (Klemperer 2003, Bullard and Straka 1998, Gunter and Haney 1984):

$$V_0 = \frac{V_n}{(1+i)^n}$$

Where: V_0 stands for the present value of the cash flow, V_n stands for the future value of the cash flow, i is a discount rate, and n is a number of years, over which future value is calculated.

Example:
Calculate a present value of harvest revenue of $1,800.00 per acre scheduled to occur in 25 years. Assume that a forest landowner expects to earn a 5.00% Minimum Acceptable Rate of Return (MARR). MARR will serve as the discount rate.

$$V_0 = \frac{V_n}{(1+i)^n} = \frac{\$1{,}800.00/ac}{(1+0.05)^{25}} = \frac{\$1{,}800.00/ac}{(1.05)^{25}} = \underline{\underline{\$531.54/ac}}$$

Answer: A present value equivalent of a $1,800.00 per acre cash flow scheduled to occur in 25 years is $531.54 per acre.

b) Calculating a present value of terminating annual cash flows

i) A present value of annual item cash flows that start at the end of the first year and stop at some time in the future, (we will assume that it stops at the end of the last year), can be calculated using a formula for calculating a present cash value of a terminating annual series (Klemperer 2003, Bullard and Straka 1998, Gunter and Haney 1984):

$$V_0 = a \times \left[\frac{(1+i)^n - 1}{i \times (1+i)^n} \right]$$

Where: V_0 stands for the present value of annual cash flows, a stands for an annual cash flow, *i* is a discount rate, and *n* is a number of years, in which annual cash flows are scheduled to occur.

Example:
Calculate a present cash value of a series of annual hunting lease revenues of $5.00 per acre that start at the end of the first year and ending after five years. Assume that a forest landowner requires an 8.00% MARR.

$$V_0 = a \times \left[\frac{(1+i)^n - 1}{i \times (1+i)^n} \right] = \$5.00 / ac \times \left[\frac{(1+0.08)^5 - 1}{0.08 \times (1+0.08)^5} \right] = \$5.00 / ac \times \left[\frac{(1.08)^5 - 1}{0.08 \times (1.08)^5} \right] = \underline{\underline{\$19.96/ac}}$$

Answer: This series of annual hunting lease revenues will generate a present cash value of $19.96 per acre.

c) Calculating a present value of perpetual annual item cash flows

i) A present value of annual item cash flows that start at the end of the first year and continue forever can be calculated using a formula for calculating a present value of a perpetual annual series (Klemperer 2003, Bullard and Straka 1998, Gunter and Haney 1984):

$$V_0 = \frac{a}{i}$$

Where: V_0 stands for the present value of annual cash flows, *a* stands for an annual cash flow, and *i* is a discount rate.

Example:
What is the present value of annual tax liability of $3.00 per acre that starts at the end of the first year and continues forever? Assume a 5.00% MARR.

$$V_0 = \frac{a}{i} = \frac{\$3.00 / ac}{0.05} = \underline{\$60.00 / ac}$$

Answer: The present value of a perpetual annual tax liability is $60.00 per acre.

d) Calculating a present value of terminating periodic item cash flows

i) The present value of periodic item cash flow that starts at the end of first period and ends at some point in the future, which we can assume is the end of the last period, can be calculated using a formula for calculating a present cash value of a terminating periodic series (Klemperer 2003, Bullard and Straka 1998, Gunter and Haney 1984):

$$V_0 = p \times \left[\frac{(1+i)^{n \times t} - 1}{\left((1+i)^t - 1\right) \times (1+i)^{n \times t}} \right]$$

Where: V_0 stands for the present value of periodic cash flows, *p* is a periodic cash flow, *n* is a number of intervals (rotations), *t* is the interval (rotation) length, and *i* is a discount rate.

Example:
Calculate a present value of a periodic net income of $40,000.00 from a pine plantation that will occur every 25 years during the next four rotations. The first income will occur in 25 years (the end of the first rotation) and the forest landowner will require a 9.00% MARR.

$$V_0 = p \times \left[\frac{(1+i)^{n \times t} - 1}{\left((1+i)^t - 1\right) \times (1+i)^{n \times t}} \right] = \$40{,}000.00 \times \left[\frac{(1+0.09)^{4 \times 25} - 1}{\left((1+0.09)^{25} - 1\right) \times (1+0.09)^{4 \times 25}} \right]$$

$$= \$40{,}000.00 \times \left[\frac{(1.09)^{100} - 1}{\left((1.09)^{25} - 1\right) \times (1.09)^{100}} \right] = \underline{\underline{\$5{,}246.27}}$$

Answer: The present value of these four periodic cash flows is $5,246.27.

e) Calculating a present value of perpetual periodic item cash flows

i) The present value of periodic item cash flows that start at the end of the first period and continue forever can be calculated using a formula for calculating a present value of a perpetual periodic series (Klemperer 2003, Bullard and Straka 1998, Gunter and Haney 1984):

$$V_0 = p \times \left[\frac{1}{(1+i)^t - 1} \right]$$

Where: V_0 stands for the present value of periodic cash flows, *p* is a periodic cash flow, *t* is the interval (rotation) length, and *i* is the discount rate.

Example:
A pine plantation is scheduled to generate a net income of $50,000 every 20 years forever. Calculate a present value of this series of cash flows assuming a forest landowner requires a 10.00% MARR.

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$$V_0 = p \times \left[\frac{1}{(1+i)^t - 1} \right] = \$50{,}000.00 \times \left[\frac{1}{(1+0.10)^{20} - 1} \right] = \$50{,}000.00 \times \left[\frac{1}{(1.10)^{20} - 1} \right] = \underline{\$8{,}729.81}$$

Answer: This series of perpetual cash flows has a present value of $8,729.81.

3) **Calculating payments necessary to pay off a loan.** A payment necessary to pay off a loan within specified time period can be calculated using a capital recovery formula (Klemperer 2003, Bullard and Straka 1998, Gunter and Haney 1984). In fact, this is a formula used for calculating a present value of a terminating annual series, but in this case the formula is solved for *a* (an annual payment). If payments are made on monthly basis instead of annual, the formula needs to be modified to account for additional payments.

a) Annual payments to pay off a loan

$$a = V_0 \times \left[\frac{i \times (1+i)^n}{(1+i)^n - 1} \right]$$

Where: *a* is an annual payment necessary to pay off a loan, V_0 is a loan amount (present value), *n* is a number of years, during which loan is to be paid off, and *i* is the annual interest rate.

b) Monthly payments to pay off a loan

$$a = V_0 \left[\frac{\frac{i}{m} \times \left(1 + \frac{i}{m}\right)^{n \times m}}{\left(1 + \frac{i}{m}\right)^{n \times m} - 1} \right]$$

Where: *a* is a monthly payment necessary to pay off a loan, V_0 is the loan amount (present value), *n* is a number of years during which the loan is to be paid off, *i* is the annual interest rate, and *m* is a number of payment periods in a year (for monthly payments, it is 12).

Example:
Calculate an annual payment necessary to pay off a loan of $120,000 in five years. Annual interest on the loan is 6.00%.

$$a = \$120{,}000.00 \times \left[\frac{0.06 \times (1+0.06)^5}{(1+0.06)^5 - 1} \right] = \$120{,}000.00 \times \left[\frac{0.06 \times (1.06)^5}{(1.06)^5 - 1} \right] = \underline{\$28{,}487.57/year}$$

Answer: An annual payment of $28,487.57 will pay of this loan in five years.

Example:
Calculate a monthly payment necessary to pay off a loan of $120,000 in five years. Annual interest on the loan is 6.00% = <u>*$2,319.96/month*</u>.

$$a = V_0 \times \left[\frac{\frac{i}{m} \times \left(1 + \frac{i}{m}\right)^{n \times m}}{\left(1 + \frac{i}{m}\right)^{n \times m} - 1} \right] = \$120{,}000.00 \times \left[\frac{\frac{0.06}{12} \times \left(1 + \frac{0.06}{12}\right)^{5 \times 12}}{\left(1 + \frac{0.06}{12}\right)^{5 \times 12} - 1} \right]$$

$$= \$120{,}000.00 \times \left[\frac{0.005 \times (1+0.005)^{60}}{(1+0.005)^{60} - 1} \right] = \$120{,}000.00 \times \left[\frac{0.005 \times (1.005)^{60}}{(1.005)^{60} - 1} \right] = \underline{\$2{,}319.94/month}$$

Answer: The monthly payment necessary to pay off this loan in five years is $2,319.94.

4) **Calculating payments necessary to accumulate a specified amount of money in the future.** A payment necessary to accumulate a specified amount of money in the future can be calculated using a sinking fund formula (Klemperer 2003, Bullard and Straka 1998, Gunter and Haney 1984). This is the same formula as the future value of a terminating annual series, except that it is solved for a (annual payment). The formula also can be used to calculate a monthly payment, but it needs to be modified accordingly.

a) Annual payments necessary to accumulate a specified amount of money in the future:

$$a = V_n \times \left[\frac{i}{(1+i)^n - 1} \right]$$

Where: *a* is an annual payment necessary to accumulate a specified amount of money, V_n represents an amount to be accumulated (future value), *n* is a number of years during which the amount needs to be accumulated, and *i* is the annual interest rate.

b) Monthly payments necessary to accumulate a specified amount of money in the future:

$$a = V_n \times \left[\frac{\frac{i}{m}}{\left(1 + \frac{i}{m}\right)^{n \times m} - 1} \right]$$

Where: *a* is a monthly payment necessary to accumulate a specified amount of money, V_n represents an amount to be accumulated (future value), *n* is the number of years during which the amount needs to be accumulated, *i* is the annual interest rate, and *m* is the number of payment periods in a year (for monthly payments, it is 12).

Example:
Calculate an annual payment necessary to accumulate $75,000.00 in four years. Payments will be deposited into a sinking fund account that pays a 2.40% annual interest rate.

$$a = V_0 \times \left[\frac{i}{(1+i)^n - 1} \right] = \$75{,}000 \times \left[\frac{0.024}{(1+0.024)^4 - 1} \right] = \$75{,}000 \times \left[\frac{0.024}{(1.024)^4 - 1} \right]$$
$$= \underline{\underline{\$18{,}088.34 / year}}$$

Answer: The annual payment necessary to accumulate $75,000.00 in four years at 2.40% annual interest rate is $18,088.34.

Example:
Calculate a monthly payment necessary to accumulate $75,000.00 in four years. The payments will be deposited into sinking fund account that pays a 2.40% annual interest rate.

$$a = V_0 \times \left[\frac{\frac{0.024}{12}}{\left(1 + \frac{0.024}{12}\right)^{4 \times 12} - 1} \right] = \$75{,}000.00 \times \left[\frac{0.002}{(1 + 0.002)^{48} - 1} \right]$$

$$= \$75{,}000.00 \times \left[\frac{0.002}{(1.002)^{48} - 1} \right] = \underline{\underline{\$1{,}490.26 / month}}$$

Answer: The monthly payment necessary to accumulate $75,000.00 in four years at 2.40% annual interest rate is $1,490.26.

5) **Financial criteria used to evaluate financial viability of forest investments***.* There are several financial criteria that can be used to determine whether a forest investment is financially acceptable or not. They include a Net Present Value (NPV), Benefit/Cost Ratio (B/C), Rate of Return (ROR), and Land Expectation Value (LEV).

a) Net Present Value (NPV) represents a difference between investment's discounted revenues and discounted costs. All revenues and costs are discounted to the present (year 0) and the value obtained represents the investment's net value in present value terms. According to NPV, a forest investment is acceptable if NPV is greater or equal to zero and not acceptable if NPV is smaller than zero (Klemperer 2003, Bullard and Straka 1998, Gunter and Haney 1984). NPV represents a net amount (in present value terms) that will be earned in addition to MARR (the discount rate that was used to calculate NPV) (Bullard and Straka 1998).

NPV = Present value of investment 's revenues - Present value of investment 's costs

Example:
Calculate NPV at 5.00% MARR for a pine plantation managed on a 25-year rotation with the following cash flows:

Site preparation and planting at year 0 at $180.00 per acre
Herbicide treatment at year 1 at $30.00 per acre
Annual management cost and taxes at $8.00 per acre per year
Thinning revenue at year 15 at $250.00 per acre
Harvest revenue at year 25 at $1,500.00 per acre

Preparing a discounted cash flow table (Table 1) can be helpful in calculating the value of a selected financial criterion.

Table 1. Present values calculated at 5.00% Minimum Acceptable Rate of Return (MARR) for cash flows associated with management of a pine plantation on a 25-year rotation.

Activity	Year	Cash Flow ($/ac)	Present Value@5.00% ($/ac)
Site preparation and planting	0	-180.00	-180.00
Herbicide	1	-30.00	-28.57
Annual management and taxes	1-25	-8.00	-112.75
Thinning revenue	15	250.00	120.25
Harvest revene	25	1,500.00	442.95

$$NPV = (\$120.25/ac + \$442.95/ac) - (\$180.00/ac + \$28.57/ac + \$112.75/ac)$$
$$NPV = \$563.20/ac - \$321.32/ac = \underline{\$241.88/ac}$$

Or alternatively, cost and revenues can be summed up as they appear in the table:

$$NPV = \$120.25/ac + \$442.95/ac - \$180.00 - \$28.57/ac - \$112.75/ac = \underline{\underline{\$241.88/ac}}$$

Answer: This forest plantation investment is acceptable, because NPV is $241.88 per acre and, therefore, it is greater than zero. In addition to earning a 5.00% MARR, a forest landowner will earn a lump sum of $241.88 per acre (in present value terms).

b) Benefit/Cost Ratio (B/C) represents a ratio of investment's discounted revenues to discounted costs. A forest investment is acceptable if B/C is greater or equal to one and not acceptable if B/C is smaller than one (Klemperer 2003, Bullard and Straka 1998). The B/C represents (in present value terms) a per dollar return generated by the investment (Bullard and Straka 1998).

$$B/C = \frac{\text{Present value of investment's revenues}}{\text{Present value of investment's costs}}$$

Example:

For the pine plantation investment presented Table 1, the B/C is calculated in the following way:

$$B/C = \frac{\$563.20/ac}{\$321.32/ac} = \underline{1.75}$$

Answer: The forest plantation investment is acceptable, because B/C is 1.75 and, therefore, it is greater than one. In present value terms, each dollar invested in this plantation will generate a return of $1.75 or $0.75 over every invested dollar.

c) Equivalent Annual Income (EAI) is a criterion that converts NPV into equal annual amounts of money that will generate the NPV during the life of the investment. Therefore, this criterion expresses NPV on annual basis. The key advantage of using this criterion is that it allows for comparing investments with different duration periods (Klemperer 2003, Bullard and Straka 1998).

$$EAI = NPV \times \left[\frac{i \times (1+i)^n}{(1+i)^n - 1}\right]$$

Where: *EAI* is Equivalent Annual Income, *NPV* is the Net Present Value, *i* is the discount rate and *n* is a time period (number of years) for which EAI is calculated.

Example:
Calculate an EAI for a pine plantation investment described in Table 1. Assume a 5.00% MARR.

$$EAI = \$241.88 / ac \times \left[\frac{0.05 \times (1+0.05)^{25}}{(1+0.05)^{25} - 1} \right] = \$241.88 / ac \left[\frac{0.05 \times 1.05^{25}}{1.05^{25} - 1} \right]$$
$$= \underline{\$17.16 / ac / yr}$$

Answer: The pine plantation investment generated an EAI of $17.16 per acre per year. Twenty-five annual income flows of $17.16 per acre during the 25-year rotation will generate NPV of $241.88 per acre.

d) Rate of Return (ROR) is a discount rate, at which NPV equals to 0. A forest investment is acceptable if ROR is greater than or equal to a landowner's MARR. If ROR is smaller than MARR, a forest investment is not acceptable (Klemperer 2003, Bullard and Straka 1998).

i) If a forest investment has only two cash flows the ROR can be calculating using the following formula (Klemperer 2003, Bullard and Straka 1998):

$$i = \sqrt[n]{\frac{V_n}{V_0}} - 1 \qquad \textit{or alternatively} \qquad i = \left(\frac{V_n}{V_0} \right)^{\frac{1}{n}} - 1$$

Where: *i* stands for the rate of return, V_n is a future value, V_0 is a present value, and *n* represents the number of years over which the rate of return is being calculated.

Example:
A pine plantation was purchased in the year 1990 at a cost of $100,000.00 and sold for $170,000.00 in 2002. What the rate of return this investment generated?

$$i = \sqrt[n]{\frac{V_n}{V_0}} - 1 = \sqrt[12]{\frac{\$170{,}000.00}{\$100{,}000.00}} - 1 = \sqrt[12]{1.7} - 1 = 1.0452 - 1 = \underline{\underline{0.0452}} \quad or \quad \underline{\underline{4.52\%}}$$

Or alternatively:

$$i = \left(\frac{V_n}{V_0} \right)^{\frac{1}{n}} - 1 = \left(\frac{\$170{,}000.00}{\$100{,}000.00} \right)^{\frac{1}{12}} - 1 = (1.7)^{\frac{1}{12}} - 1 = 1.0452 - 1 = \underline{\underline{0.0452}} \quad or \quad \underline{\underline{4.52\%}}$$

Answer: The pine plantation investment generated a 4.52% rate of return.

ii) If there are more than two cash flows as in the example presented in Table 1, an iterative process needs to be used to determine a rate of return. In this process, it is necessary to find two discounts rates, at which NPV changes from positive to negative or vice versa. Therefore, two discounts rates should be identified: one, at which NPV is positive and a second one, at which NPV becomes negative. It is important that these two discount rates are as close to each other as possible, because this will result in a more accurate approximation of ROR (Klemperer 2003, Bullard and Straka 1998).

$$ROR = Low\ discount\ rate + \left[Difference\ between\ discount\ rates \times \frac{Positive\ NPV}{Incremental\ NPV} \right]$$

Where: ROR stands for the rate of return, low discount rate is a discount rate that generates a positive NPV, high discount rate is a discount rate that generates a negative NPV, difference between discount rates is a difference between high and low discount rates, a positive NPV is a NPV generated by a low discount rate, and an incremental NPV is an incremental change from a positive to a negative NPV.

Example:

Consider a pine plantation investment described in Table 1. At a 5.00% MARR the investment generated a NPV of $241.88/acre. Therefore, it is necessary to identify another discount rate, at which NPV is negative. There is an inverse relationship between a discount rate and NPV: as the discount rate increase, NPV decreases. Therefore, to identify a discount rate, at which NPV is negative, it is necessary to increase the discount rate above 5.00%. Let's try a 9% MARR. At this discount rate, a pine plantation generated a NPV of -$43.52/acre.

$$ROR = Low\ discount\ rate + \left[Difference\ between\ discount\ rates \times \frac{Positive\ NPV}{Incremental\ NPV} \right]$$

Therefore:

$$ROR = 5.00\% + \left[4.00\% \times \frac{\$241.88 / ac}{\$241.88 / ac + \$43.52 / ac} \right] = 5.00\% + \left[4.00\% \times \frac{\$241.88 / ac}{\$285.40 / ac} \right]$$ Answer:

$$= \underline{\underline{8.39\%}}$$

The ROR on this investment is 8.39%. It is important to note that this value is only an approximation. For example, at an MARR of 8.00% this pine plantation generates a NPV of $4.66/acre. Knowing this information, the ROR should be recalculated using 8 and 9% discount rates. In this case, ROR is 8.10% and it is a closer estimate. A precise ROR for this investment calculated using FORVAL Online is 8.08%. (FORVAL is a forest valuation calculator available online from Mississippi State University's Forest and Wildlife Research Center at www.cfr.msstate.edu/forval/)

e) Land Expectation Value (LEV) is a criterion used to calculate the maximum amount of money that can be paid for a bare land that will be used for timber production in perpetuity (Klemperer 2003, Bullard and Straka 1998).

$$LEV = \frac{Net\ income\ at\ the\ end\ of\ the\ rotation}{(1+i)^n - 1}$$

Example:

Calculate LEV for a pine plantation that generates a net income of $2,000.00 per acre at the end of a 25-year rotation and will be managed under the same forest management regime in perpetuity. Assume that a forest landowner requires a 10.00% MARR.

$$LEV = \frac{Net\ income\ at\ the\ end\ of\ the\ rotation}{(1+i)^n - 1} = \frac{\$2{,}000.00 / ac}{(1+0.10)^{25} - 1} = \frac{\$2{,}000.00 / ac}{(1.10)^{25} - 1}$$

$$= \underline{\underline{\$203.36 / ac}}$$

Answer: A pine plantation that produces and net income of $2,000.00 per acre every 25 years will generate an LEV of $203.36 per acre. This represents the maximum amount of money an investor can pay for bare land that will be managed under this forest management regime and still earn a 10.00% MARR.

Example:
Consider a pine plantation investment as described in Table 1. Information presented in Table 1 can be used in two ways to calculate LEV. In the first way (Table 2), it is necessary to calculate a future value (at the end of the rotation) of each cash flow and then calculate a net future value (NFV) at the end of the rotation. A net future value represents a net income at the end of the rotation.

Table 2. Future values calculated at 5.00% Minimum Acceptable Rate of Return for cash flows associated with management of a pine plantation on a 25-year rotation.

Activity	**Year**	**Cash Flow ($/ac)**	**Future Value@5.00% ($/ac)**
Site preparation and planting	0	-180.00	-609.54
Herbicide treatment	1	-30.00	-96.75
Annual management and taxes	1-25	-8.00	-381.82
Thinning revenue	15	250.00	407.22
Harvest revenue	25	1,500.00	1,500.00

$$NFV = (\$407.22/ac + \$1{,}500.00/ac) - (\$609.54/ac + \$96.75/ac + \$381.82/ac)$$

$$NPV = \$1{,}907.22/ac - \$1{,}088.11/ac = \underline{\underline{\$819.11/ac}}$$

$$LEV = \frac{NFV}{(1+i)^n - 1} = \frac{\$819.11/ac}{(1+0.05)^{25} - 1} = \frac{\$819.11/ac}{(1.05)^{25} - 1} = \underline{\underline{\$343.25/ac}}$$

In the second way, the LEV can be calculated by utilizing the NPV previously determined for a pine plantation investment (Table 1). However, this NPV needs to be compounded to the end of the rotation to calculate the NFV (this process is equivalent to calculating a future value of a single sum).

$$NFV = NPV \times (1+i)^n = \$241.88/ac \times (1+0.05)^{25} = \$241.88/ac \times (1.05)^{25} = \underline{\underline{\$819.09/ac}}$$

Therefore:

$$LEV = \frac{NFV}{(1+i)^n - 1} = \frac{\$819.09/ac}{(1+0.05)^{25} - 1} = \frac{\$819.09/ac}{(1.05)^{25} - 1} = \underline{\underline{\$343.24/ac}}$$

Answer: The LEV for bare land that will be managed under a forest management regime described in Table 1 is $343.24 per acre (one cent difference is due to rounding).

6) Inflation

a) Inflation indicates a general increase in prices (Klemperer 2003). Inflation can be calculated using the U.S. Consumer Prices Index (CPI), which expresses prices in terms of a selected base year (BLS 2012, Klemperer 2003). The formula for calculating inflation using the CPI is as follows (Klemperer 2003):

$$f = \sqrt[n]{\frac{CPI_n}{CPI_0}} - 1 \qquad \textit{or alternatively} \qquad f = \left(\frac{CPI_n}{CPI_0}\right)^{\frac{1}{n}} - 1$$

b) A nominal dollar value for any item is a value that includes inflation, whereas a real dollar value is a value, from which inflation is excluded.

c) A nominal rate of return for any investment is a rate of return that includes inflation, whereas a real rate of return is a rate of return that doesn't include inflation.

Example:
What was the annual inflation rate during 1975-1995 if the CPI in 1975 was 53.8 and the 1995 CPI was 152.4?

$$f = \sqrt[n]{\frac{CPI_n}{CPI_0}} - 1 = \sqrt[20]{\frac{152.4}{53.8}} - 1 = \sqrt[20]{2.83} - 1 = \underline{0.0534} \quad \textit{equvalent to } \underline{5.34\%}$$

or alternatively

$$f = \left(\frac{CPI_n}{CPI_0}\right)^{\frac{1}{n}} - 1 = \left(\frac{152.4}{53.8}\right)^{\frac{1}{20}} - 1 = (2.83)^{\frac{1}{20}} - 1 = 0.0534 \quad \textit{equivalent to } 5.34\%$$

Answer: The annual inflation during 1975-1995 averaged 5.34%.

If an annual inflation rate is known, it is possible to calculate a real or a nominal rate of return (Klemperer 2003).

$$i = \sqrt[n]{\frac{V_n}{V_0}} - 1 \qquad \textit{or alternatively} \qquad i = \left(\frac{V_n}{V_0}\right)^{\frac{1}{n}} - 1$$

Where: i stands for a nominal rate of return, V_n is a future value, V_0 is a present value, and n represents the number of years over which a rate of return is calculated.

$$r = \frac{1+i}{1+f} - 1$$

Where: i stands for a nominal rate of return and f is an annual inflation rate, and r is a real rate of return.

Example:
A pine plantation tract was purchased in the year 2000 for $145,000.00 and sold in 2010 for $220,000.00. What was a nominal rate of return?

$$i = \sqrt[n]{\frac{V_n}{V_0}} - 1 = \sqrt[10]{\frac{\$220,000.00}{\$145,000.00}} - 1 = 1.0426 - 1 = \underline{0.0426} \quad \textit{equivalent to } \underline{4.26\%}$$

or alternatively

$$i = \left(\frac{V_n}{V_0}\right)^{\frac{1}{n}} - 1 = \left(\frac{\$220,000.00}{\$145,000.00}\right)^{\frac{1}{10}} - 1 = 1.0426 - 1 = \underline{0.0426} \quad \textit{equivalent to } \underline{4.26\%}$$

Answer: This pine plantation investment generated a nominal rate of return of 4.26%.

Example:

If a nominal rate of return on a forest investment was 4.26% (as calculated in the previous example) and inflation during that period was 2.39%, what was a real rate of return on this investment?

$$r = \frac{1+i}{1+f} - 1 = \frac{1+0.0426}{1+0.0239} - 1 = \frac{1.0426}{1.0239} - 1 = \underline{0.0183} \quad \textit{equivalent to } \underline{1.83\%}$$

Answer: The real rate of return on this pine plantation investment was 1.83%.

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CHAPTER 5

TIMBER HARVESTING

John B. Auel[1]

Harvesting is a silvicultural tool, as has been discussed previously in this study guide. It is a method of achieving landowner objectives with the goal of maintaining a stand or establishing a future stand. The foresters' responsibility during harvesting is contract administration and helps ensure that all contract specifications are met by the independent contractor and the goals of the landowner are not compromised by improper BMP work, excessive residual stand damage or other detrimental practices.

1) **Harvesting Systems**

   a) All harvesting operations can be broken down into 4 distinct phases; felling trees, primary transport, loading, and trucking.

   b) The most common combination in Mississippi is a feller buncher for felling, a grapple skidder for primary transport, a knuckleboom for loading, and a tractor trailer for hauling to the mill.

   c) Some systems use a harvester, which cuts the tree, delimbs, bucks, and piles.

   d) A forwarder then transports the wood to the truck. This type of system is gaining popularity.

2) **Equipment systems** will change again with the advent of an energy market using wood residues.

   a) In-woods chippers have long been an option for loggers, but the recent push in bio-energy may increase their popularity.

   b) Harvesting equipment comes in a variety of sizes and configurations.

   c) Some loggers are better suited than others to thinning stands than final harvests and some are better suited to conducting final harvests and not thinning.

   d) Foresters quickly learn the capabilities of the loggers working in their procurement area.

3) **Contract Administration**

   a) Complete contracts are crucial.

   b) Both parties must abide by the terms of the contract to reduce liability exposure.

   c) A contract can be as simple or as complicated as is necessary for the job.

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d) The more specific the contract the less confusion there will be about the harvest parameters.

e) The goal for a forester is to protect the landowner and to enter into a mutually beneficial contract with the logger.

4) What to Include in a Contract

a) All contracts must include owner's information, buyer's information, and a legal property description.

i) This establishes both parties' right to enter into a contract and provides legal property boundaries.

b) A harvesting contract should also include a Scope of Work Clause.

i) This clause outlines the specific parameters of the harvest. The Scope of Work Clause includes:

(1) Independent Contractor Status – the logger is an independent contractor and not an employee of the forester or landowner.

(2) How it is being harvested – is this a thinning? A clearcut?

(3) Contract dates – the length of the contract. The logger has from this date to this date to complete the contract.

(a) This can be 6 months or a year, but will change depending on the company buying the timber.

(4) Clean up/BMP work – to be completed by the logger in accordance with state BMP guidelines.

(5) Weather delays – who has the right to stop harvesting and when?

(6) Severance Taxes paid by whom?

(7) Who has the right to supervise?

(8) Identification of special sites with harvest restrictions.

(9) Rare, threatened and endangered species concerns.

c) After the scope of work is defined, a payment method should be included.

i) This section on a cut and haul contract will tell the logger what products are to be delivered where and for what price per unit.

d) Another important clause to include on contracts is a penalty clause.

i) This clause includes information about what occurs when certain provisions are not met or when something unexpected happens during the harvest.

(1) For example, if a contractor accidentally knocks down a fence, what are his responsibilities in terms of repair?

e) Also, what is the penalty if the logger cannot complete the harvest in the given time period?

i) Other examples include overcutting and unreasonable residual stand damage.

f) All of these potential issues have a monetary consideration that, if not listed in the contract, may cause problems between the forester and the logger should they occur.

g) Insurance coverage clauses are also important.

i) The logger should have proof of general liability insurance.

ii) A common figure that is used on many contracts is 1 million dollars.

5) Independent Contractor Status

a) Perhaps the most important job a forester has is the preservation of the independent contractor status of the logger.

b) Failure to honor this relationship may result in the forester incurring liability for the logger's actions.

c) First and foremost, loggers are professional businessmen and the relationship should reflect this fact.

d) Basically, independent contractor status is a matter of who has the right to control the work.

e) An independent contractor controls how and when the work gets done under the provisions of the contract.

f) Foresters who exert too much control over the harvesting operation are in danger of violating this principle.

g) There are three tests that the government uses to determine if an independent contractor is by law independent or an actual employee of the company he is contracting with; Safe Harbor, Common Law and Economic Reality.

i) Each is used to determine the amount of control exercised over the contractor and different government organizations use different tests.

ii) The toughest opponent to any company being considered an independent contractor is the IRS.

(1) They use the Common Law test in their determination which is also referred to as the 20 Questions.

(2) The IRS uses these questions to gauge the relationship between the two parties.

h) Foresters need to ensure that they act in a manner that supports the independent contractor relationship.

i) There is a key point to remember. Always deal with the business owner or the foreman assigned to the job with respect to contract provisions.

ii) Foresters cannot tell the employees of a contractor what to do. Only under imminent danger conditions can a forester tell a contractor's employee how to act.

6) **An excellent resource** that all foresters should have is a publication from the Forest Resources Association entitled "How to Stay at Peace with your Government".

a) This book describes all of the legal concerns of forestry and logging and how to comply with laws and regulations governing the industry.

CHAPTER 6

PROFESSIONAL ETHICS

Stephen G. Dicke[1]

Having public confidence in the propriety of all dealings is essential to the practice of forestry. In fact, the practice of forestry could not exist without it. This section covers the principles of professional ethics in forestry that are covered in the BORF examination.

1) Introduction to the Code of Ethics

a) A Code of Ethics for foresters is a system of morals or appropriate behavior expected from forestry professionals.

b) The Mississippi Board of Registration for Foresters (BORF) was given responsibility to establish and enforce a Code of Ethics through the Foresters Registration Law of 1977, amended in 1989.

c) BORF has the power, after notice and hearing, to suspend or revoke the license of any registered forester found guilty of unprofessional or unethical conduct. Miss. Code Ann. Section 73-36-33.

d) There are several reasons Mississippi adopted a professional Code of Ethics (see next page). Reasons include (from Flanagan 1981):

   i) Promote the pride of foresters in their occupations. Standards of behavior for foresters are to be higher than the minimum government allows. Foresters are special, professional, and take pride in the quality of their work.

   ii) Protect the consuming public from unfit practitioners. The fair application of a code of ethics and any resultant disciplinary action is not for punishment but for protection of the public. The outcome is an increased public confidence in foresters and the services they provide.

   iii) Guide the professional forester's own decision-making process in deciding difficult issues of conduct. Foresters, just like everyone, go through a daily internal struggle to do what is right (Irland 1994). The Code along with experience and the guidance of a mentor can help a forester develop an ethical basis for decisions and recognize dangerous unethical situations.

e) Four questions foresters should ask themselves (Patterson 1984):

   i) What does my conscience say?

   ii) What would it be like if everyone did this?

   iii) How would I feel if everyone knew about this?

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iv) How would I feel about this tomorrow?

2) Code of Ethics for the Registered Forester

a) I will strive to be accurate in my knowledge of forestry and will disseminate this knowledge and speak out against the spreading of false or misleading statements concerning forestry.

b) I will advise only in a worthy and truthful manner, refraining from misleading or exaggerated statements concerning what I am prepared to perform.

c) When participating in a public or private fact-finding session, I will base my testimony on adequate knowledge of the subject, and will not withhold data in order to substantiate my point of view.

d) I will perform services of only the highest standards and with complete loyalty to my employer or client and will not voluntarily disclose information about the business affairs of my employer or client which the employer desired to keep confidential.

e) I will provide only the services for which I am qualified by experience or education, and, in practice, will not agree to deviate from accepted professional standards without first advising the employer or client of the expected consequences.

f) I will not obligate myself to a potential employer or client where I have a business interest which might influence their judgment concerning the activity I am expected to carry out.

g) I will not accept compensation for the same service from more than one employer or client without full disclosure and consent of all parties concerned.

h) I will engage or recommend other experts and specialists in forestry or related fields whenever my employer or client will be best served by such action, and will work cooperatively with them.

i) I will aid the Board in keeping persons, unqualified because of lack of good moral character or inadequate training, from being registered.

j) If I have evidence of violation of any of these canons by any Registered Forester, I will present the information to the State Board of Registration for Foresters.

k) I will obligate myself, without reservation, to utilize all of my forestry knowledge and experience for the use, benefit, and betterment of my fellow man and his environment.

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CHAPTER 7

FIRE

Andrew J. Londo[1]

This section covers the major topics related to fire and its use in forestry. Topics covered here that may be asked on the BORF examination include legal issues, weather, fuels, wildfire, heat transfer, and firing techniques.

1) Legal Issues Surrounding Prescribed Burning in Mississippi

a) The Mississippi Prescribed Burning Act of 1992 provides liability coverage for the burner. This liability coverage is based upon four mandatory requirements being met for each tract burned.

i) A Certified Prescribed Burn Manager (CPBM) supervises the burn.

(1) You can become a burn manager by:

(a) Taking and passing the prescribed burning short course offered by the Mississippi Forestry Commission (MFC) and Mississippi State University (MSU).

(b) Enrolling in Forest Fire (FO 3203) at MSU and passing accordingly.

(c) MFC may accept certification from another state.

ii) A permit should be obtained from the MFC on the day of the burn for the county in which the burn is taking place.

(1) A permit is issued when atmospheric conditions are appropriate for adequate smoke dispersal. This is the way in which the state meets federal air quality standards.

(a) Mixing height of 500m (~ 1,750 feet)

(b) Transport Wind Speed of 3.5m/s (8 mph)

(2) A permit will be issued when these conditions are met, along with no burn bans in place for the county in which the burn is planned.

(3) Length of time a permit is valid is based upon the stagnation (stag) index.

iii) A burn plan for the site in question must be notarized at least one day prior to the burn.

(1) The plan should be site specific and include information on fuel types, burning methods to

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be used, and evidence of smoke management screening.

(2) Once notarized, the plan is a legally binding document.

iv) The burn must be in the public interest.

b) Liability under the Prescribed Burning Act

i) Prescribed burners that conduct prescribed burns in conformity with the law will not be held liable for damage or injury caused by fire or smoke unless negligence is proven.

ii) Simple Negligence:

(1) You followed the four mandatory requirements, but damages still happened.

(a) Pay Actual Damages

(b) Up to $150 fine

iii) Gross Negligence:

(1) You didn't follow the four mandatory requirements and damages happened.

(a) Shall be guilty of a misdemeanor

(b) Pay Actual Damages

(c) Up to $500 fine

(d) Up to 3 months in county jail

iv) It's important to remember that negligence can be determined by a jury.

2) Fire Weather

a) Wind

i) Properties of Wind

(1) Wind speed directs the rate of spread and course of fire

(2) Wind is diurnal, changing during the day

(3) Canopy reduces wind speed, which reduces the rate of spread of fire

ii) Types of Wind

(1) Frontal Winds

(a) As a cold front passes, wind shifts from the S or W to the NW

(b) As a warm front passes, wind shifts from the E to SW

(2) Sea Breezes (Near to the coast or other large bodies of water)

(a) During the day, the land warms faster than the water, causing a sea breeze, with winds blowing from the water, onto land.

(b) During the night, the land cools faster than the water, creating a land breeze, with wind blowing from the land to the water.

b) Precipitation

i) Length and amount of precipitation determine fuel moisture conditions based on the fuels Time Lag category.

(1) Short duration precipitation events impact the moisture content of small time lag fuels faster than longer time lag fuels.

(2) Longer lasting precipitation events are needed to change the moisture content of larger time lag fuels.

c) Temperature

i) Temperature affects fuel moisture content, as warm fuels tend to dry quicker, and burn hotter and easier than cold wet fuels.

d) Relative Humidity

i) Amount of moisture in the air relative to what the air can hold for a given temperature.

ii) Rules of Thumb

(1) Every 20ºF increase in temperature reduces relative humidity by 50%.

(2) Every 20ºF decrease in temperature increases relative humidity by 50%.

iii) Relative humidity virtually always changes during the day, along with the passage of warm/cold fronts, as temperatures change. This can lead to changes in fine fuel moisture content and fire behavior.

iv) Extreme burning conditions occur when temperature is high, humidity is low, and wind speeds are high.

e) Atmospheric Stability

i) Tendency of air to rise

ii) Important for smoke management. Part of the reason for getting a permit is to ensure that the atmosphere is sufficiently unstable so as to allow smoke to rise.

iii) The tendency of air to rise impacts how well your fire will burn (fire behavior is more active under more unstable conditions).

iv) Unstable atmosphere

(1) "Puffy" cumulus clouds

(2) Encountered under periods of low atmospheric pressure

v) Stable atmosphere

(1) "Flat" cirrus clouds

(2) Encountered under periods of high atmospheric pressure

f) Stagnation (Stag) Index

i) A measure of atmospheric stability

ii) Need to list a stagnation index on your burn plan

(1) Limits the time you can burn (the fire you set must be significantly out by the time indicated on the stagnation index on your burn plan).

iii) Daytime stag indices

(1) 0-burn from sunrise to sunset

(2) 1-burn from 1 hour after sunrise to sunset

(3) 2- burn 2 hours after sunrise to sunset

(4) 3-burn 2 hours after sunrise, to one hour before sunset

iv) Night time stag indices

(1) 0-burn from sunset to sunrise

(2) 1-burn from sunset to 2 hours before sunrise

(3) 2-burn from sunset to 4 hours before sunrise

(4) 3-night time burning is not allowed

g) Inversions

i) Defined as warm air over cold air.

ii) Reduced fire activity due to the inability of air to rise and prevents the rise of smoke.

iii) Not recommended to burn under these conditions as smoke can "pancake" out at the height of the inversion. This can be a bigger problem when inversion is at ground level not allowing smoke to rise.

3) Fuels (Anything that will burn)

a) Fuel Moisture Content (MC)

i) $\%MC = (\text{wet weight} - \text{oven dry weight})/(\text{oven dry weight}) \times 100$

ii) Live versus Dead Fuel

(1) Based on equation above, live fuel moisture contents can be as high as 300%, dead fuel moisture contents can also exceed 100%.

b) Time Lag

i) The amount of time it takes a fuel to lose or gain 63% of its moisture content (MC). The National Wildfire Coordinating Group has produced tables to predict fuel moisture content based on time lag category, temperature, and relative humidity. These tables are available at http://www.nwcg.gov.

(1) 1 hour fuels: < ¼ inch in diameter, get MC from tables

(2) 10 hour fuels: ¼ to 1 inch in diameter, MC from tables, "fuel sticks"

(3) 100 hour fuels: 1-3 inches in diameter, MC from tables

(4) 1000 hour fuels: 3-6 inches in diameter, MC from tables

(5) 10000 hour fuels, 6-9 inches in diameter, MC from tables

c) Moisture of Extinction

i) Moisture of extinction is the fuel moisture content at which fuels won't burn.

(1) 20% for Loblolly pine

(2) 40% for Longleaf/Gallberry (difference is due to resins and waxes present which allow these fuels to burn hotter, and at higher MC).

d) Fuel loads

i) Fuel loads can be complex and contain many different time lag fuels.

e) Topography effects on fire

i) North and east aspects tend to be cooler and wetter than south and west facing aspects which are warmer and drier.

4) **Wildlife Management** - How does fire benefit wildlife?

a) Works by setting back succession

i) Perpetuates a grass/forb understory

ii) Eliminates young woody stems

b) Repeat burning:

i) Eliminates small hardwoods

ii) Increase herbaceous cover resulting in mixed forbs and woody plants, increases in fire followers (legumes).

iii) Burning ever three years maximizes fruit production (soft mast), but annual burns will severely limit soft mast production.

iv) Typically, it is recommended to burn on a 3 year rotation (quail) or 5 year rotation (turkey and deer).

c) Endangered Species

i) Frequent burns are important for removing mid and understory vegetation for the red cockaded wood pecker (RCW) and Gopher Tortoise.

5) **Heat Transfer Methods**

a) Radiation - Transfer of heat by electromagnetic waves

i) Light

ii) Main means of heat transfer in backing fires

iii) Can pre-dry fuels as the fire advances.

b) Convection - Transfer of heat by the movement of air.

i) Instability in the atmosphere allows air to rise

ii) One of the main causes of thunder head (Cumulonimbus cloud) formation

iii) Will preheat fuels downwind,

c) Conduction - Transfer of heat from one molecule to another.

i) Heat transfer through a fuel as it burns

ii) Preheating/drying of fuel

iii) Most important heat transfer method for fire behavior.

6) Firing Techniques

a) There are many different methods available for prescribed burning, any given burn will usually consist of a number of these different techniques.

i) Fire Lanes are important to keep your prescribed burn in the area you want burned. Also useful for keeping wildfire out.

ii) Can also serve as food plots, and access to the stand.

b) Backing fires

i) Used on nearly all burns to secure fire lanes, and to keep the fire in where you want it.

ii) The fire is set along a fire lane, and allowed to burn against or back into the wind. Burns slowly.

iii) Can be used to burn an entire tract, but is costly to use in the coastal plain as the fire burns slowly.

c) Strip Head Fires

i) Second most commonly used firing technique. Used once the backing fires have secured the boundaries.

ii) At intervals of 1-2 chains upwind from the backing fire, strips are set across the entire site. These strips burn with the wind direction, moving towards the backing fire. The strip goes out as it encounters the backing fire.

iii) Subsequent strips are set at the same intervals. As these strips burn, they will encounter where the previous strip burned, going out.

iv) Large acreages can be burned relatively easily and quickly in this manner.

d) Grid or Point Source Firing

i) Once the backing fires are set, a person walking through the area to be burned will start spot fires at intervals of ½ to 1 chain. Ideally, these spots will slowly burn into areas that have already been burned.

ii) These spot fires can easily merge, to create head fires.

iii) This can also be done from the air using a helicopter. Used by the USFS and USFWS to burn large acreages.

e) Center Ring Firing

i) Used for site preparation burns in clearcuts.

ii) Once the backing fire is established, a spot fire is started in the center of the clearcut. Then, a fire is set around the edge of the area to be burned. The spot fire in the middle pulls in the fire from the edges towards the middle resulting in a fast moving, hot fire.

iii) Need to watch for spot fires starting downwind of the convection column formed by the fire.

f) Flanking Fire

i) Most frequently used later in the day when temperatures increase and humidity decreases. Fine fuel moisture decreases, making burning more intense.

ii) Once the backing fire is established, fire is set off at 30-45 degree angles, instead of straight across the site.

iii) Ideally, this results in a less intense fire.

iv) Need to be sure that the flanks don't merge to form a head fire.

7) Fire Suppression

a) Protection of life and property are the main concerns.

i) Stop the forward spread (head) of the fire, regardless of where the fires started.

ii) Flanking the fire may keep it from out flanking you, protecting life and property.

CHAPTER 8

INSECTS

John J. Riggins[1] and Andrew J. Londo[2]

This section covers possible questions that may be asked on the BORF examination related to forest health and insects.

1) The Concept of Forest Health

a) Understand that there are different views and definitions of forest health.

i) Different user groups have vastly different objectives.

(1) E.g. Commercial production, Landowner, Manager of private lands, Conservation agency, Watershed scientist, Environmentalist, Forester, Hunter.

b) The first and most important information each forester needs to address in a recommendation regarding forest health is to find out what a landowner's goals and objectives are for a given piece of property.

c) There are various definitions of forest health.

i) Utilitarian

(1) Emphasizes forest conditions that directly satisfy human needs.

ii) Ecocentric

(1) Management practices should result in a fully functional, sustainable community of plants and animals and their physical environment.

iii) Forest Ecosystem Health

(1) Compromise between utilitarian and ecocentric

(2) USDA Forest Service Definition:

(a) "a condition wherein a forest has the capacity across the landscape for renewal, for recovery from a wide range of disturbances, and for retention of its ecological resiliency while meeting current and future needs of people for desired levels of values, uses, products, and services."

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(b) Managing forests under the auspices of the Endangered Species Act and the Multiple Use Sustained Yield Act.

2) Introduction to Forest Insects

a) Principles of Forest Insect Management

i) Forest insects are harder to manage than insect pests in many other systems, such as row crops.

(1) Forests are complex environments, and it is more difficult and costly to:

(a) Monitor insect populations

(b) Conduct damage assessments

(c) Spray chemicals

(2) Treatment thresholds for many forest insects either don't exist, or are subjective.

(3) Long rotation ages

(4) Impacts of insects in forests measured in terms of mortality, growth loss, and degrade in value.

ii) The single best approach to minimize forest insect-related health problems is to practice proper forestry techniques such as site selection, plant resistant varieties, proper site prep, proper planting density, and proper thinning and residual stand density management.

3) Important Forest Insects

a) Evergreen Bagworm (*Thyridopteryx ephemeraeformis*)

i) Hosts:

(1) Primarily evergreens

(a) E.g. Junipers, cedars, and arborvitae

(2) But can also attack certain deciduous trees

(a) E.g. cypress, sycamore, black locust, oaks, willows, and poplars

ii) Impact:

(1) One of the most important shade tree, ornamental and nursery pests in the south.

(2) Feeding by larvae defoliates tree, and can cause tip and branch death.

(3) The “bags” the larvae form are unsightly, and when connected to twigs with silk by the female occupants, can girdle and kill tips of branches and twigs.

iii) Control:

(1) Natural

(a) There are many natural enemies that usually regulate bagworm populations.

(2) Cultural

(a) Hand remove and destroy bags during late fall, winter, or early spring before the eggs they contain hatch.

(3) Chemical

(a) Various pesticides can be utilized if bagworms are too numerous to handpick.

(b) Applications generally work better on young larvae.

b) Hymenoptera: sawflies

i) General Introduction

(1) Named for the female’s sawlike ovipositor, which she uses to lay eggs in neat rows on needles or shoots.

(2) There are eight families of sawflies.

(a) The family Diprionidae contains the most damaging species

(3) Sawflies are not actually flies.

(a) They are in the order Hymenoptera, related to wasps, ants, etc…

ii) E.g. Redheaded pine sawfly (*Neodiprion lecontei*)

(1) Hosts

(a) Preferred: loblolly and longleaf pine

(b) Others: shortleaf, pitch, and slash pine

(2) Impacts

(a) Important pest of both planted and natural young pine stands, capable of causing decreased productivity and in severe cases seedling mortality.

(b) Generally, larvae feed on needles of trees <15 ft. in height.

(3) Control

(a) Can be controlled three ways:

1. Natural control: do nothing

a. Natural enemies are usually sufficient.

2. Polyhedrosis virus: sprayed on

3. Chemical control: various pesticides are available.

c) Coleoptera (beetles)

i) Cottonwood leaf beetle (*Chrysomela scripta*)

(1) Hosts: Willows, poplars, aspens, and alders

(2) Range: Throughout the U.S.

(3) Impacts

(a) The most economically important pest of intensively managed poplar plantations.

1. Stunting and multiple-forked tops can be severe.

2. Can cause mortality

(4) Damage

(a) Young larvae feed in groups on undersides of leaves and are leaf skeletonizers.

(b) Older larvae separate and freely feed on entire leaves, except for the main leaf veins.

(c) Larvae prefer young leaves and stem terminals.

d) Regeneration/Nursery Insects

i) Examples

(1) Tip Moth (Lepidoptera: Tortricidae): *Rhyacionia* spp.

(a) One of two insects of primary concern in newly regenerated pine stands.

(b) New larvae (which are quite small) feed on surface of terminal and lateral bud for a short time, and eventually enter bud (tip) and feed inside.

(c) Browning or reddening of the tips is often the first apparent symptom.

(d) Careful inspection often reveals fine silken webbing and an accumulation of resin on the bud.

(e) Damage:

1. Damage occurs to pines in different settings.

    a. Naturally regenerated and planted forests, nurseries

    b. Number one problem in Christmas tree plantations, and ornamental plantings

    c. Longleaf pine is immune to tip moth damage

2. Most infestations occur in small seedling or sapling-size trees less than 10 ft. in height.

3. Feeding on terminal or lateral buds as well as stems results in:

    a. Foliage discoloration

    b. Deformation (result of destruction of terminal and lateral buds and shoots)

    c. Reduced growth

    d. Damage is worse in plantations

ii) Seedling Debarking Weevils (Pales weevil, etc.)

(1) Impact of Seedling Debarking Weevils

(a) Rarely considered pests in naturally regenerated stands, although they are commonly present.

(b) The problems caused by seedling debarking weevils are associated with seedling mortality following harvest and site preparation.

(c) Weevils are attracted to recently harvested stands.

1. Abundant sites for offspring to feed in pine stumps, weakened trees, and buried slash.

(d) Problems with seedling debarking weevils can usually be avoided by utilizing one or more of the following strategies, but not all strategies will be applicable in every situation.

1. Disperse harvest areas

2. Restrict harvesting to spring months

3. Delay planting after harvest
   6-12 months = no attacks, depending on time of harvest

4. Use seedling protective treatments: i.e., insecticides

   a. Possibly cheaper than loss of growth during planting delay

   b. Roots can be dipped in a systemic insecticide prior to shipment from the nursery. A systemic soil based insecticide can also be applied prior to planting, during planting, or following planting..

(2) Examples of seedling debarking weevils

(a) Pales Weevil (Coleoptera: Curculionidae): *Hylobius pales*

1. One of two insects of primary concern in newly regenerated pine stands.

2. Damage is caused by adult feeding on regenerating or newly planted pines. Heavy feeding results in girdling of the stem.

3. Signs and symptoms include dead or dying saplings with patches of missing bark or completely girdled stems.

4. Severe seedling mortality can occur in plantations established in the winter immediately after logging during the previous autumn.

5. Planting following winter usually requires no special control measures if harvest and site prep is done before July.

6. Planting following winter will often result in infestations that require control measures if harvesting and site prep is after July.

e) Bark Beetles

i) In the Southeastern U.S., the five species that make up the southern pine bark beetle guild are collectively the most destructive pests of pine forests.

(1) The southern pine bark beetle guild

(a) *Dendroctonus* (Black Turpentine and Southern Pine Bark Beetles)

1. Beetles within the genus *Dendroctonus* are the most important group of insects causing mortality to pine stands in the Southeastern U.S.

2. Differ from *Ips* engraver beetles because phloem galleries do not engrave slightly into the surface of the sapwood.

   a. Southern pine beetle (SPB): *Dendroctonus frontalis*

i. SPB has been the most destructive pest in Southern pine forests.

ii. Generally attacks the mid-bole region of a tree with the larvae feeding under the bark in the sapwood.

iii. SPB outbreaks usually have occurred cyclically (every 6-9 years).

iv. It is believed that SPB rely on stressed, weakened, Ips beetle attacked, or lightning-struck trees during low SPB population levels.

v. The major difference between SPB and other bark beetle species in the Southeast is that the SPB is capable of creating multiple tree infestations that may expand rapidly and kill large numbers of otherwise healthy pines.

vi. Southern pine beetles prefer overstocked pines, especially loblolly or shortleaf pine.

vii. Has been known to attack RCW trees in the fall.

b. Control

i. Control options are mostly limited to salvage cuts, cut and leave, cut, pile and burn control measures (slash from cut and leave operations should be piled and burned, or tarped to kill SPB larvae in the slash).

ii. Uses of insecticides on a stand level are limited in effectiveness and generally cost prohibitive.

iii. Thinning stands to reduce stand basal area and increase spacing between residual trees is the single best management tool for prevention of the SPB.

c. Black turpentine beetle: *Dendroctonus terebrans*

i. The largest (physically) of the southern pine bark beetles generally infesting the bottom 6 ft. section of trees.

ii. Often the first species to attack lightning-struck trees.

iii. Often attacks drought stressed trees, trees damaged during logging, or trees with root pathogens or soil compaction.

iv. Creates much larger pitch tubes than its relatives in the S.E.

v. Generally not an economically important pest.

(b) *Ips* Engraver Beetles

1. Generally not primary economic pests.

a. Do not usually kill healthy trees or have massive outbreaks.

b. Most infestations are scattered and limited to a few trees in size.

c. Usually pests of sick, weakened, damaged, or especially fire, storm damaged, flood stressed, or drought-stressed pines.

2. All three species inoculate host trees with various bluestain fungi.

3. The three species generally partition themselves based on the portion of host trees they prefer, but often are found infesting the same trees.

a. Four-spined engraver: *Ips avulsus*

i. Prefers smaller diameter branches in upper crown.

b. The eastern five-spined ips: *Ips grandicollis*

i. Prefers lower crown, larger diameter branches, and upper bowl.

c. The six-spined engraver: *Ips calligraphus*

i. Prefers the upper and mid bole of the tree.

4. *Ips* control strategies should generally focus on maintaining tree vigor through proper silviculture, especially thinning stands to maintain proper basal area.

5. Distribute slash across the site, which will dry out slash quicker making it less suitable habitat.

6. Chemical controls are too expensive and have limited effectiveness and therefore are usually limited to high value urban trees.

f) Wood Borers

i) Insects that infest the sapwood and/or heartwood of trees and/or wood products.

(1) Many feed in the phloem for a time, especially as young larvae.

(a) But they enter the heartwood at some point during lifecycle.
1. This differentiates them from bark beetles.

ii) Many species, in many different insect orders.

iii) Nearly all tree species serve as hosts for one or more woodboring insect species.

iv) Representative examples:

(1) Long-horned beetles (Cerambycidae)

(a) Named for their long antennae; males can have antennae 1.5x the length of their bodies.

(b) Elongate, robust beetles with long antennae.

(c) Adults are short-lived, and lay eggs on the bark of their preferred host trees.

(d) Larvae feed in the phloem tissue for a short time, and then enter the heartwood forming long oval shaped galleries as they feed.

1. E.g., Pine Sawyer Beetles

a. There are several species within the genus *Monochamus.*

b. They derive their common names from the loud chewing sounds larvae often make inside of trees.

c. Pine sawyer beetles mainly attack stressed, unhealthy, damaged, recently cut, or fallen pines.

d. Additionally, pine sawyer beetles can vector the pine wilt nematode (*Bursaphelenchus xylophilus*), which cause pine wilt.

i. Pine wilt disease is native to North America, and is usually not a primary pathogen of pines in the South; however, it can contribute to the decline of already weakened trees.

ii. Pine wilt disease has been introduced to other countries, such as Japan and China, where it is considered a very destructive invasive disease.

iii. International trade regulations and treaties, which impact U.S. exporters, exist to try and control the introduction of pine wilt nematode into other continents around the globe.

CHAPTER 9

DISEASES

Stephen G. Dicke[1]

Continuing from the previous section on insects and forest health, this section covers the basic topics related to forest diseases that may be asked on the BORF examination.

1) **Disease** - Any deviation in the normal functioning of a plant caused by some type of persistent agent or condition.

2) **Classification of Diseases**

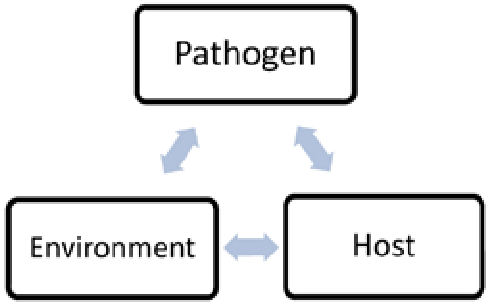
   a) Biotic Diseases – Caused by living agents or pathogens. Pathogens include fungi, bacteria, virus, phytoplasmas, and nematodes (microscopic roundworms). Parasitic plants like mistletoe can also cause a disease.

      i) Disease Triangle – When a disease is caused by a biotic agent, we sometimes incorrectly think the pathogen and the disease they cause are the same thing. They are not.

         (1) Before a pathogen can cause a disease there must first be a host that is susceptible to the pathogen.

         (2) Secondly, there must be a favorable environment for the pathogen to grow (and/or an environment unfavorable to the host to resist infection).

         (3) A biotic disease is thereby produced when there is an interaction between a host tree, the environment, and a pathogen. All three are needed to produce a disease.



      ii) But not all the living agents or microorganisms listed above are pathogens. Many have beneficial roles. Examples: Saprophyte and Symbiont

         (1) Saprophyte - An organism that secures its food directly from nonliving organic matter (e.g. decay fungi).

         (2) Symbiont – An organism that is in a long term beneficial or symbiotic relationship to its host (e.g. mycorrhizae, lichens).

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b) Abiotic Diseases – Caused by non-living agents including air pollution, frost, winter injury, drought, flooding or excessive wetness, nutrient deficiency, salt, wind, lightning, and girdling roots (for containerized seedlings). So can trees have a disease without a pathogen? Yes.

3) **Forest Disease Management** – a four step process

a) Detection – Observation of abnormal trees during management activities.

b) Recognition – Identification of the disease and root causes.

c) Appraisal – Determine if control of the disease will be worth the effort.

i) Will the disease kill infected trees or severely reduce their growth?

(1) Foliage diseases usually look bad but rarely kill or stunt trees. Exception – pine seedlings with brown spot needle blight.

ii) How fast will this disease spread if left on its own?

(1) Some diseases like needle blight will spread quickly if nothing is done.

(2) Others like fusiform rust will not.

d) What type of management is appropriate?

i) A disease can be prevented if any one of the three corners of the disease triangle is removed. Therefore we have many options available to effectively reduce disease problems. Changing the environment, changing the host, or removing the pathogen can all be equally effective.

4) **Recognition of Tree and Forest Problems**

a) Diagnosing tree and forest problems requires knowledge, experience, keen observation, and deductive reasoning.

i) Trees that die or are declining in health are suffering from a combination of stress factors.

ii) Thus, insects and diseases that we identify on trees are often secondary. They are attacking an already weakened tree. You must find the root cause of stress to correct the problem. There are two types of stress that can lead to tree health problems.

(1) Acute Stress – Stress occurs in a definable moment and results in immediate tree reaction. Acute stress may include extended droughts, floods, wind storms, logging damage, hard freezes, lightning, herbicides, and fire. Severe acute stress can be fatal but is rarely immediate. It takes some hardwood species up to 8 years to die following a fatal acute stress while pines can die in a few weeks.

(2) Chronic Stress – A stress is considered chronic when it is over the lifetime of the tree. Trees

will grow slowly and diagnosis is sometimes difficult. Examples of off-site related problems include nutrient deficiencies, the wrong soil pH, the soil is too wet, too dry, too much sun or not enough, etc.).

iii) Remember that "Prescription without diagnosis is malpractice". Be systematic in your diagnosis to find the root causes of stress. Only then can you make a recommendation on how to correct the problem. You will need to look for symptoms and signs to determine the causal agent.

(1) Symptom (appearance of host) - Alterations in the appearance of the host due to the disease. Examples: Chlorosis, necrosis, wilting, leaf malformations, twig dieback, cankers, and swellings.

(2) Sign (appearance of pathogen) - Anything you see that is primarily made of pathogen tissue can be called a sign. Examples: Fruiting bodies (mushrooms, conks, rust), decay, and hyphae or mycelia mats.

iv) Steps in tree health diagnosis (i.e., how to become a tree detective).

(1) Obtain a history of the forest (or tree) from the landowner. This is of utmost importance.

(2) Identify the tree species in decline or dying. Most insects and diseases are specific to a species. When multiple species are dying and showing decline together, a red flag should go up. In this case insects and disease may not the root cause – consider floods, droughts, herbicides, logging damage, or fire.

(3) Examine the site. Are the species matched to the site?

(4) Describe the damage patterns (symptoms and signs).

(5) Note any problems in the foliage (sparse, small, off-color), amount of twig growth and twig dieback in upper crown, cankers and damage in scaffold branches and wounds on the main stem.

(6) Does the root collar and structural root plate show any problems?

(7) If the source of the problem is still unclear, then it is time to seek help. Guessing the diagnosis and a recommended treatment based on that guess are serious mistakes.

5) What type of disease management is appropriate? Remember that you may change the environment, change the host, and/or remove the pathogen to effectively manage a disease.
a) Silvicultural: Clearcutting, pruning, thinning, sanitation (inoculum removal), species selection, fertilization, and prescribed fire.

b) Chemical: Soil fumigation in nurseries (especially for Fusiform rust); borax stump treatment for Annosum root rot; herbicides to remove alternate host; growth regulators to remove mistletoe; injections for vascular wilts; and foliar spraying Christmas trees.

c) Biological: Control the spread of Annosum root rot by inoculating stumps with decay fungi that outcompetes the pathogen. Another example is inoculating seedlings with mycorrhizae to protect them from root diseases in the field.

d) Genetics: Breeding for resistance has been successful against native pathogens but not against invasive ones (failures include chestnut blight and Dutch elm disease). One of our greatest successes has been the genetic selection of loblolly and slash pine for resistance to fusiform rust. Genetic selection has not been as effective against root diseases.

e) Avoidance: Time thinning and pruning treatments when pathogen spores are not present. Change the species planted and/or management in high hazard sites (E.g. Annosum Root Rot).

f) Quarantine: Prevent the movement of infected plants or forest products to healthy forests to prevent the spread of pathogens and pests. Example is firewood quarantines up north.

6) Important Diseases

a) Southern Fusiform Rust, caused by the fungus Cronartium fusiforme, is regarded as the most serious disease affecting pines in the Southern United States. The fusiform rust fungus produces five spore types and requires two different hosts (pine and oak) to complete its life cycle. A life cycle (pine to oak and back to pine) takes approximately 2 years to complete.

i) Susceptible pines are infected in early spring by wind-disseminated fungus spores produced on oak leaves. The spores first penetrate the needles, cotyledons, and/or tender stems of seedlings. The fungus then moves into woody tissues (branches and main stem of seedlings) causing swellings within 3 to 4 months after infection. Branch infections can later move into stems. The secondary host is oak which includes most species of the red, white, and willow oak groups. Heavily infected oak leaves may drop earlier than normal but this rarely affects overall tree health.

ii) Hosts: The primary host for fusiform rust is pine. As species, loblolly and slash pines are most susceptible; pitch, pond, and longleaf pines are moderately resistant, and shortleaf pine is immune. Breeding programs have been very successful in improving the resistance of loblolly and slash pine to fusiform rust.

iii) Identification: Infected pines are easily identified by the fusiform or spindle-shaped swellings (galls) on branches and main stems. Older infected trees develop open sunken cankers, which provide openings for wood decay, fungi, and insects. A useful sign is the bright yellow-orange spores that are produced on the surface of fusiform-shaped galls in the spring.

iv) Damage: Seedling stems infected in the nursery or within the first five years of growth usually result in death. Losses have exceeded 80 percent in some cases. Infections that occur after 5 years of age cause cankers that weaken the stem and result in wind breakage.

v) Control: Fusiform rust is readily controlled in seedling nurseries with the careful application of appropriately registered fungicides. Avoid out planting infected nursery stock. Planting pines which are genetically resistant to fusiform rust infections is recommended. Avoid excessive site preparation that may over stimulate growth and increase the incidence of infections. Apparently very fast growing young pines have either a greater susceptibility, or larger target areas for infection (shoots of tender, succulent tissues). Delaying fertilization of young pine stands until about 8 years of age is often advisable for similar reasons.

vi) Trees with stem cankers should be salvaged in thinning, provided their removal does not open the stand more than is silviculturally desirable. Diseased trees are not a direct risk to the surrounding healthy ones. The following rule of thumb may be useful in planning the salvage of trees with trunk cankers:

(1) Less than 50 percent of circumference killed with more than an even chance of salvage for 8 years;

(2) 50 percent of circumference killed but no bend in stem at canker or sunken canker face with an even chance of salvage for 5 years;

(3) 50 percent of circumference killed, with a bend at canker and either a normal or sunken canker face with less than an even chance of salvage for 5 years.

b) Annosus Root Rot is caused by the fungus Heterobasidion annosum. Root rot is among the most important and destructive diseases affecting conifers in North America. Annosum root rot occurs in both natural and planted forest stands, but is most prevalent and serious in stands following thinning or harvest operations.

i) Hosts: Susceptible conifer genera include Abies, Juniperus, Larix, Picea, Pinus, Pseudotsuga, and Tsuga. Longleaf pine shows the most resistance of all pines to this disease.

ii) Annosum root rot also depends on numerous edaphic and biotic factors. Low hazard sites are characterized by soils with silty and clayey A horizons, pH below 6.5, high organic matter, and poor internal drainage or high water tables. These soils tend to inhibit, although not necessarily exclude, development of the fungus.

iii) High hazard sites have deep, well-drained, sandy or sandy-loam soils. Of particular concern are soils with a deep sandy A horizon over a clayey subsoil. Other high hazard factors include low organic matter and relatively high pH values (6.5 or higher). On high hazard sites these general guidelines should be considered.

iv) Identification: Look for thin-crowned, dead or dying, and/or wind thrown pines, especially in stands thinned 3-6 years earlier. Dead or dying red cedars may also be good indicators.

v) Remove the litter/duff layer(s) around stumps and suspect tree bases to reveal small conks up to 1 inch wide. Conks can range from grayish-brown to dark brown in color on top and creamy white underneath. The presence of conks is highly seasonal. Conks are abundant from fall to spring, but are absent in the summer.

vi) Excavate and examine roots for resinosis (staining and resin-impregnation), and/or typical white stringy rot that looks like shredded wheat. In the absence of definitive conks or white stringy rot, laboratory isolation is required for confirmation.

vii) Damage: Annosum root rot causes a decline in tree health which leads to reduced growth rates, tree mortality, susceptibility to attack by bark beetles, and regeneration failure.

viii) Control: Several measures, including preventive silviculture, chemical stump treatments, and biological control have been effective at minimizing losses. However on low hazard sites, preventive measures are generally not required.

ix) In disease-free stands on high hazard sites, time thinnings and harvests in the summer to reduce the risk of infection. Following thinnings and partial cuts, the application of appropriately registered, granular or soluble borax to fresh-cut stump surfaces may also be warranted. Prescribed fire and a reduction in the number of thinnings and other partial harvests during a management rotation are advisable. Planting longleaf pine, where silviculturally acceptable, may be worth considering.

x) Badly diseased stands on high hazard sites may need to be salvaged to minimize economic losses. When faced with such situations, age of the infections (i.e., time since previous harvests) should be considered, as mortality and wind throw maximize after 4-8 years and tends to stabilize thereafter. Do not treat fresh-cut stumps with borax in diseased stands. Applying borax on stumps can actually make matters worse by inhibiting the action of competitive microorganisms. Alternatively inoculate stumps with decay fungi. Clearcut stands may be reforested (planted) on normal schedules.

c) Pitch Canker is caused by the fungus, Fusarium circinatum. It is generally regarded as a disease found in intermediate to older-aged trees. Occasionally, it can attack regeneration. The pitch canker fungus is a wound pathogen and normally does not penetrate intact pine tissues. Thus, infections are commonly associated with environmental (e.g., storm damage, etc.) or insect outbreaks.

i) Hosts: Pitch Canker can infect most southern pines but the most susceptible species are slash, shortleaf, and Virginia pines. The fungus is most damaging to pines adjacent to poultry houses apparently because the fungus likes the high concentrations of ammonia that's absorbed by pine needles and shoots. Severe disease episodes have also been found in excessively fertilized pine plantations and stands fertilized and/or irrigated with nutrient laden industrial wastes. Loblolly pines near poultry houses are occasionally attacked.

ii) Identification: Pitch Canker gains entrance into trees through wounds and insect feeding sites. Common insect vectors are pine tip moths, the deodar weevils, and/or black turpentine beetles.

iii) Pitch canker is usually first detected in 10-20 year old trees by the appearance of characteristic reddening or “flagging” of infected terminal or lateral shoots. Dying shoots appear most frequently from late fall through spring. Infected shoots typically exude copious amounts of resin (pitch) at or near infection loci. Internally, infected tissues are necrotic and xylem (wood) tissues are impregnated with resin, the degree of resinosis being variable among different host pines. Infected shoots usually die within a matter of months due to girdling action of the pathogen. Old infections can often be identified by the dull gray-brown appearance of the dead shoots and needles. Dead shoots often persist for months and even years. Dead needles frequently adhere for extended periods of time because they are often matted and stuck in exuded resin.

iv) Damage: Tip and branch dieback reduces stem quality and tree health. Some trees are killed. Main stem cankers on larger trees may or may not be lethal, depending upon the location, number, and severity of individual cankers. On older trees, high numbers of cankers can also reduce tree vigor, resulting in dieback and tree death.

v) Control: Prevention is the most effective means of reducing losses. Use pines best adapted to specific sites and/or genetically resistant planting stock if available. Avoid water stress induced by excessive or unnecessary site drainage and avoid excessive fertilization. Overstocked plantations should be thinned to improve health. Sanitation harvests to remove trees infested with the insect vectors and/or the pitch canker disease can be very effective at controlling this disease.

d) Brown Spot Needle Blight is caused by the fungus Mycosphaerella dearnessii. Spores are spread to pine needles by rain and wind. Spores overwinter in dead and infected needle tissue.

i) Hosts: Longleaf pine seedlings are the most susceptible to brown spot needle blight. The fungus also infects seedlings of slash, loblolly, spruce, and Virginia pines.

ii) Identification: Lesions on leaves commonly appear from May to October. Look for small, grayish-green spots, which become a straw-yellow color and then light brown with chestnut-brown margins. Needles with multiple lesions appear mottled. As spots coalesce, the needle tissue dies beyond and between groups of spots. The fungus can also infect the cut ends of pruned longleaf pine seedlings.

iii) Damage: Infected seedlings are seldom killed outright, but severe defoliation reduces vigor, which leads to poor survival and growth. The breaking out of the grass stage in longleaf pine can be delayed up to 10 years.

iv) Control: Use longleaf pine varieties that are resistant to the disease. A seedling root-dip treatment in a 5-percent active ingredient benomyl-kaolin mixture prior to packing at the nursery or at the reforestation site is very effective in reducing brown spot in the field. This treatment is very economical and significantly improves both growth and survival of out planted seedlings. Infected leaves can be removed with prescribed fire during site preparation. If the disease is prevalent, a winter burn can also be used on longleaf seedlings a year after planting to remove diseased needles.

e) Littleleaf Disease is the most serious disease of shortleaf pine in the southern United States. Affected trees have reduced growth rates and usually die within 6 years. The disease is caused by a complex list of factors including the fungus Phytophthora cinnamomi, low soil nitrogen, and poor internal soil drainage. Often, microscopic nematodes are also associated with the disease. In the most recent general survey, littleleaf disease was found over 35 percent of the commercial range of shortleaf pine and was severe enough to be a factor in timber management on about 1.4 million forested acres. Losses attributed to littleleaf exceed $15 million per year.

i) Hosts: Primarily affects shortleaf pine in the Piedmont area but occasionally affects loblolly pine. Copeland and Campbell (1954) developed a hazard rating system for littleleaf disease. They found the highest hazard sites have severe erosion and poor internal drainage (i.e., clayey subsoil, a hardpan, and subsoil mottling). Low hazard sites have a deep A horizon and good internal soil drainage.

ii) Identification: The first symptoms are those of nutrient deficiency: a slight yellowing and shortening of the needles and reduction of shoot growth. In later stages the crown of an infected tree appears thin and tufted: new needles are discolored and shorter than normal, and the tree loses all but the new needles near the tips of the branches. Branches begin dying, starting in the lower crown and progressing upward through the crown. About 3 years before death, diseased trees commonly produce abundant crops of small cones. Most of the seeds in these cones are sterile. Littleleaf killed trees can often be recognized by these undersized cones, which remain attached to the branches.

iii) Damage: As the disease progresses, tree health deteriorates and diameter growth is markedly reduced.

iv) Control: On sites where hazard is low (i.e., no littleleaf is present and the site hazard is low) land managers need not consider the disease and normal management of shortleaf pine will be possible.

v) Where the disease is present or the site hazard is high, prevention can be accomplished through species manipulation or site rehabilitation.

vi) Planting resistant species (e.g., hardwoods or loblolly pine) will avoid the problem. If shortleaf pine is still desired in an affected area, the best uninfected trees should be left as seed trees. The best site preparation technique to combat littleleaf is subsoiling or ripping through the bricklike, extremely compact layer of clayey soil (hardpan) before planting or seeding.

f) Wood rot or decay is a serious problem. The annual loss is estimated at 20 billion board feet, an amount more than that caused by fire and insects combined. Wood rot is primarily caused by decay fungi but some are caused by bacteria.

i) Hosts: All trees are susceptible to wood rot. Some species resist rot better than others (e.g. live oaks). Trees resist rot by erecting internal chemical barriers which is called compartmentalization. Healthy trees have more energy reserves and a greater ability to compartmentalize rot and grow over wounds.

ii) Identification: Heart rot is easily observed on trees through physical evidence of hollows, rotten wood, irregular or lumpy stems, cankers, catfaces, and scars. Most wood-rotting fungi also produce fruiting structures that are either bracket (shelf) or hoof shaped conks or the mushroom (toadstool) type.

iii) Because wood is essentially cellulose and lignin, wood rot are identified by the parts of wood that they leave (do not eat).

(1) White Rot – the white color of decayed wood comes from cellulose that is left after the decay fungi have eaten the lignin that holds the cells together. The typical white stringy rot looks like shredded wheat.

(2) Brown Rot – the brown color of decayed wood comes from the lignin that is left after fungus has eaten all the cellulose or cell wall structure. As a result of this type of decay, the wood shrinks, shows a brown discoloration, and cracks into roughly cubical pieces (e.g., cubical brown rot in pine).

iv) Damage: Degraded wood leads to tree hollows, health decline, breakage, and mortality.

v) Control: Prevention is your only option. Once the decay process begins, there is no control. Grow species adapted to the site. Provide thinnings and improvement cuts to improve tree health and remove infected stems. Avoid stem damage during logging and other forest activities. When clearcutting for coppice regeneration, stumps should be cut as close to the ground as possible.

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