Statistics? We Don't Need No Stinking Statistics!

or

Using Stem Maps to Compare Cruising Methods
For Allowable Cut Calculations in
Uneven-aged Longleaf Pine

by

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Abstract

This study examines sampling methods to determine current stocking of uneven-aged longleaf pine stands for determining allowable cut. Heretofore it has often been assumed that stands smaller than 100 acres should receive a 100 percent inventory to accurately determine current stocking. The variability inherent in uneven-aged stands generally, and in longleaf pine particularly, compels the forester to take an excessive number of samples to achieve statistical confidence in the estimate. A 100 percent inventory is often deemed the simplest, if not the easiest, solution to the quandary. The expense of a full inventory is a deterrent to applying uneven-aged management to tracts under 100 acres. Tracts under 100 acres comprise a large portion of the current land ownership across the original longleaf pine range, and will be a critical component of any meaningful restoration effort.

Estimates from different sampling intensities and techniques were compared to known populations. Two 40-acre study sites were stem-mapped pinpointing the location of each tree $\geq$3.1” dbh. Samples were constructed based on tree coordinates and tree dbh using several traditional sampling methods. A simple method of prescribing target stand structure called Whole Stand Regulation (WSR) was used to determine the target number of tree per acre by dbh class. This method was applied to estimated stocking and results compared to the residual structure of the stand based on a 100% inventory.

An acceptable error of $<\pm6\%$ of tree count in each of three size categories was achieved through different combinations of methods. A 10BAF prism sample in combination with a 1/20 or 1/10 acre plot sample provided the data necessary to incorporate adjustments using point-double sampling to yield estimates well within the acceptable limits. Based on these results, foresters should be confident in pursuing uneven-aged management without relying on costly 100% inventories to determine allowable cut.

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would still count the experience as a personal success for having had the privilege of learning from the most intelligent man I have ever known.

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1. INTRODUCTION

Longleaf pine (*Pinus palustris* Mill.) once dominated the landscape across much of the eastern and southern United States. Frequent fires maintained an open park-like forest. Gaps and openings in the crown canopy were sporadically but persistently caused by both large disturbances, such as hurricanes and tornadoes, and smaller disturbances such as lightning strikes. These gaps and openings would regenerate, resulting in a mosaic of age classes across the landscape (Brockway, et al. 2005). The sub-stands within the mosaic ranged from small clumps of trees occupying a fraction of an acre each to larger stands of trees many acres in size (Schwarz 1907). Longleaf pine is a long-lived species, capable of living five hundred years or more, so the age classes across the landscape could range from seedlings to ancient veterans of the forest. Even on a smaller scale, many age classes were often present (Chapman 1910). The overall impression, though, was of an open, mature forest, punctuated by clumps and patches of younger trees.

Perhaps in a desire to recreate this aesthetic, along with other benefits of growing this venerable species, there is a burgeoning interest among private landowners in restoring and maintaining longleaf pine on their lands (Butler and Leatherberry 2004; Butler, et al. 2007). Great strides have been made in the artificial regeneration of longleaf pine (South, et al. 2005), and natural regeneration in existing stands using the shelterwood method has proven to be successful (Boyer 1990). Either way, the resulting even-aged stands are familiar to foresters today, and are easily managed through traditional even-aged silvicultural methods, given that the forester is familiar with the management requirements peculiar to longleaf pine. Often, usually for aesthetic reasons, landowners want to maintain mature trees in the forest without clearcutting on any sizeable scale, leading the forester to seek alternative silvicultural methods to fit management goals (Browning, et al. 2009).

Uneven-aged management mimics the original structure of the forest, albeit on a smaller scale and within a tighter range of ages, by maintaining a mosaic of age classes across a tract. Uneven-aged management fits with many landowners' goals by producing a regular flow of wood from a tract, while maintaining a forest canopy. The tract may be divided into management units, depending on the acreage owned, but rather than relegating an age class to a specific area, each management unit contains all, or at least several, age classes within a prescribed range (Farrar 1996). As with even-aged management, the uppermost age or size class represents the desired end-product size or rotation age.

The goal of uneven-aged management, then, is to perpetuate several age or size classes within the stand ranging from regeneration through the desired end-product size (Brockway, et al. 2005; Farrar 1996). The simplest form of maintaining this structure would be through diameter-limit cutting; that is, removing all trees above a specified diameter, leaving the smaller trees to grow. This crude system of selection is usually referred to as "high-grading", in that it tends to favor the harvest of the largest, and presumably the most vigorous trees, leaving smaller, possibly inferior trees for future growth. Repeated diameter-limit harvests often lead to a forest of poor quality and low productivity in most forest types (Kenefik, et al. 2005), and probably also in longleaf pine (Brockway, et al. 2005). To avoid the pitfalls of high-grading, a system of regulating the entire stand structure, not just the upper diameters, becomes necessary.

To assure sustainability through natural regeneration, the forester must maintain several age classes from seedlings through cone-producing trees within the managed stand. These age or size classes should exist in proportion to one another such that adequate ingrowth will occur from one age or size class to the next, allowing for periodic removal of excess trees from different size classes in a merchantable harvest.

The periodically harvested excess trees are called the “allowable cut”; that is, the amount of trees in any merchantable size class in excess of the prescribed stocking of that size class at time of harvest. Two things must be determined to calculate the allowable cut. A target residual stocking after harvest (target stand) must be prescribed by the forester specifying the amount of trees in each size class to be retained. There are several methods available to determine the target diameter distribution. The other information necessary to calculate allowable cut is current stocking, which must be estimated through some sort of inventory.

Determining the allowable cut is a challenge and often an impediment to the forester pursuing uneven-aged management. Regulation systems can be difficult to understand and cumbersome to implement, although that difficulty can be overcome through experience. The inventory, however, remains a significant challenge. Experts on the subject often stress the need for a 100 percent inventory on stands less than 100 acres in size, or a 10 or 20 percent sample on larger stands using fixed radius plots (Farrar 1996). Such an intensive inventory is necessary to achieve a statistically acceptable confidence level in the estimate, but it is expensive and time-consuming to accomplish.

At the beginning of this study, it was believed that a simplified method of defining the target stand would be most helpful to the forester in determining allowable cut. While a simple regulation method may be helpful, it became apparent during the course of the study that the inventory would be the more challenging aspect. In addition to determining the allowable cut, the forester must mark the allowable cut for harvest. Maps and marking rules or guidelines can improve efficiency. The goal of this study is to find ways to simplify the implementation of uneven-aged management by:

1) Using a simple regulation method to determine the target stand structure or diameter distribution of a tract;
2) Comparing results of different inventory methods to known populations to determine effectiveness at estimating current stocking;
3) Creating a map from inventory data useful to the forester in marking the allowable cut; and
4) Suggesting and explaining marking rules to guide the forester in decision making when marking the allowable cut.

2. BACKGROUND AND LITERATURE REVIEW

2.1 History

The natural range of longleaf pine extends along the Atlantic and Gulf Coastal Plains from southern Virginia to east Texas, and from central Florida into the Piedmont and mountains of Alabama and northwest Georgia (Stout and Marion 1993). Within its range, longleaf pine occupies a variety of sites as diverse as xeric sandhills, poorly drained flatwoods, rolling mesic hills and rocky, mountainous ridges (Boyer 1990). One of the most extensive ecosystems in North America prior to European settlement, longleaf pine was the dominant tree species on an estimated 60 million acres, and occurred in mixed stands on another 30 million acres (Frost 1993; Landers, et al. 1995). The number and diversity of plants associated with the longleaf pine forests make it one of the most species-rich ecosystems outside the tropics (Peet and Allard 1993). The longleaf pine ecosystem has undergone a rapid decline from its original 90 million acres to under 4 million acres in 1985 (Kelly and Bechtold 1990), and is believed to currently occupy less than 3 million acres across its range in fragmented stands of various conditions, much of it degraded (Noss 1989; Frost 1993).

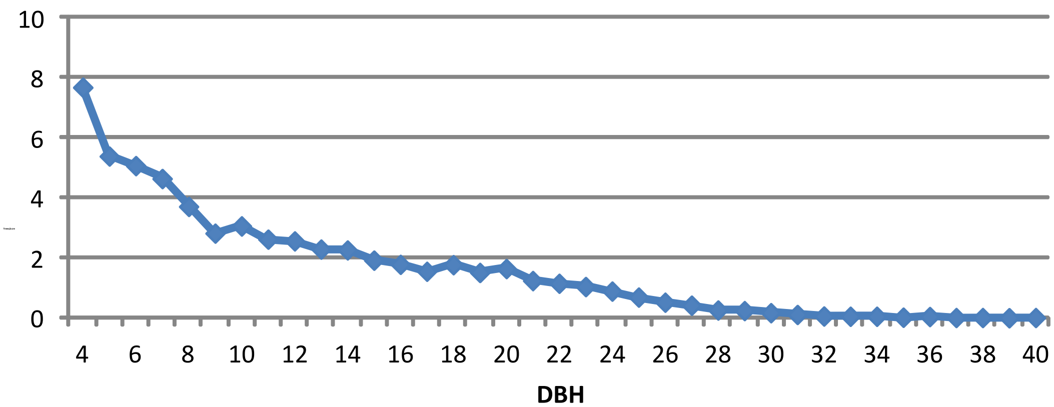
2.2 Structure of the Original Longleaf Forest

Longleaf pine is a long-lived tree capable of living 500 years or more. Shorter lived conifers tend to invade sites following disturbances, forming even-aged, closed canopy stands, whereas long-lived confers tend to be slower-growing, forming more open-canopied stands (Platt et al. 1988). The original structure of the longleaf pine forest was shaped primarily by frequent disturbances including lightning strikes, wind-throw from hurricanes and other storms, and most notably low-intensity surface fires. These surface fires occurred on a frequent basis, every one to ten years, depending on site and weather conditions (Mattoon 1922; Chapman 1932). These disturbances created a mosaic of age classes growing in groups occupying areas as small as a fraction of an acre to many acres in size (Schwarz 1907), depending on the severity of the disturbance.

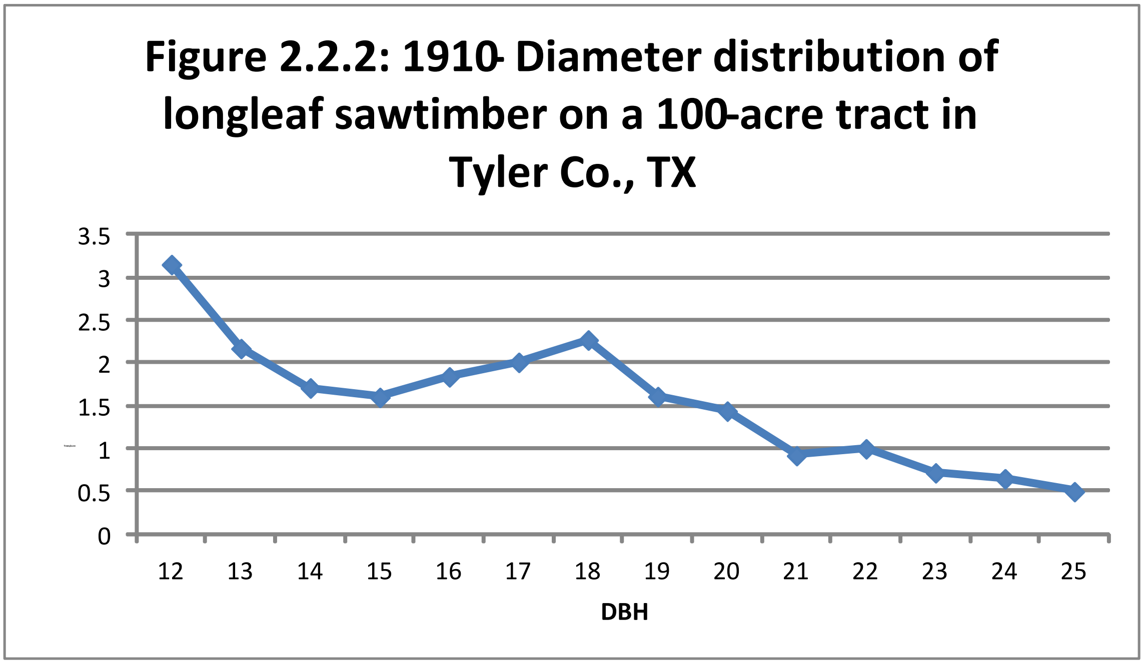
Longleaf pine seedlings typically do not initiate height growth immediately following germination; rather, they put down an extensive root system, with only a tuft of needles surrounding the terminal bud showing at or just above the ground line. Seedlings can persist in this so-called “grass stage” for years until conditions are right for height growth (Chapman 1932). Grass stage seedlings can develop and persist under the sparse canopy of mature trees. When gaps are formed in the canopy from disturbances such as hurricanes or tornadoes, grass stage seedlings are released, and can exhibit rapid height growth, forming larger even-aged patches or sub-stands within the forest. Smaller gaps or openings, such as might be caused by lightning striking a single large tree or an isolated wind-thrown tree or small group of trees, would result in the release of established seedlings, if present, or regeneration to new seedlings once the seedbed was made receptive by fire (Brockway et al. 1998).

Because so much of the landscape was occupied by trees that had reached their full height potential long before reaching the limits of longevity, the original forest had an open, even-aged appearance, punctuated occasionally by small, imbedded stands of noticeably younger age classes (Schwarz 1907), but, in fact, were uneven-aged when viewed on a larger scale. Inventories of the original longleaf pine forest reveal a dbh distribution typical of an uneven-aged stand structure on a landscape scale (Reed 1905), as shown below in Figure 2.2.1.

Figure 2.2.1: 1905- Diameter distribution of longleaf pine 4 " dbh+ on 6,659-acre tract in Coosa Co., AL



This uneven-aged structure was observable on a smaller stand-level scale as well. A 100-acre block in Tyler County, Texas, in 1910 had a similar distribution. Although the data were restricted to sawtimber-sized trees, the inventory revealed an uneven-aged structure (Chapman1910), as shown in Figure 2.2.2, below.



The size of the area studied would necessarily expand or restrict the range of age classes observed, as spatial limitations would prevent all age classes found across a broader range to be present on a smaller site; still, it was observed at the time that as much as 25% or more of the area on each of several 40-acre plots taken within the virgin forest was comprised of young trees ranging from 14" dbh down to seedlings. The remaining mature forest component was seldom, if ever, even-aged (Chapman 1910).

The longleaf pine ecosystem evolved in the presence of frequent, low intensity surface fires. Frequent fires prevented the development of a duff layer, creating a surface soil horizon more typical of grassland than forest soils (Heyward and Barnette 1936). The typical grassy, pyrogenic groundcover was conducive to frequent fires, and the forest type, in the presence of fire, was self-perpetuating, leading some to refer to it as a fire-climax forest (Chapman 1932).

2.3 The Decline of the Original Longleaf Forest

The decline of longleaf pine can be attributed to a combination of factors. Early losses were due to extensive logging and fire exclusion. As the land was cleared it was converted to other uses, such as pasture and crops (Ewel 1990), or replanted to other pine species, primarily loblolly pine *(Pinus taeda)* and slash pine *(Pinus elliottii)* (Brockway et al. 1998). Population growth along the Atlantic and Gulf coastal regions have led to the loss of longleaf acreage to development and to the disruption and sometimes exclusion of normal fire cycles, leading to further losses (Gilliam and Platt 1999). This habitat reduction has resulted in the decline of at least 191 vascular plant species associated with longleaf pine (Hardin and White 1989; Walker 1993), and several animals associated with the longleaf ecosystem are listed as threatened or endangered, including the red-cockaded woodpecker *(Picoides borealis)*, gopher tortoise *(Gopherus polyphemus)*, dusky gopher frog *(Rana capito sevosa)*, and black pine snake *(Pituophis melanoleucus lodingi)*, among others (Noss, et al. 1995; Van Lear, et al. 2005). While these species are not dependent on the presence of the longleaf pine tree specifically, they are adapted to the conditions maintained through a frequent fire regime, and an open-canopied overstory. Other pines may function as overstory surrogates for longleaf pine, but longleaf pine is particularly well adapted to frequent fires. Further, interruptions in the burning cycle where other pines dominate an open-canopied overstory might result in copious regeneration of those species. If fire resistance of those seedlings is achieved, the open nature of the forest would be lost without subsequent mitigation. Longleaf pine is often the preferred species in ecosystem restoration efforts due to its ability to maintain this type of stand structure over long periods of time if properly managed.

2.4 Restoration Efforts

Because longleaf pine still exists in fragmented stands across its range, it is likely that significant restoration of the ecosystem is an attainable goal (Landers et al. 1995). Improved techniques in artificial regeneration have resulted in significantly improved survival rates in reforestation efforts (South et al. 2005). Much of the emphasis of longleaf pine management has been on successful reforestation and perpetuation through even-aged techniques, including artificial regeneration and shelterwood systems; however, interest in uneven-aged regulation methods have grown in part because of the desire to sustain the ecological benefits associated with a continuous crown cover (Brockway et al. 2005). Much of the focus of uneven-aged regulation of longleaf pine has been on public lands, but efforts have been made to present uneven-aged management to non-industrial landowners (Farrar 1996).

Unlike the western United States, most of the southern and eastern forest lands are privately owned (Butler and Leatherberry 2004). If restoration efforts are relegated to public lands, the ecosystem will remain highly fragmented. There are many incentive programs available to private landowners encouraging longleaf restoration. In addition to state programs available to some landowners, federal incentive programs include the Conservation Reserve Program, the Healthy Forest Reserve Program and the Environmental Quality Incentives Program (Browning et al. 2009). The incentives are mainly to encourage landowners to replant their property to longleaf pine after harvest of other pines or when converting land use to forestry. However, for most landowners today, timber production is not the most important aspect of forest ownership, so other management strategies might be appropriate to consider.

According to a National Woodland Owner Survey conducted by the U.S. Forest Service (Butler and Leatherberry 2004; Butler, et al. 2007), other less tangible values rank higher among non-industrial landowners, including aesthetics, family heritage, privacy, nature protection, long-term investment, and hunting and other recreational activities. Most landowners do view timber production as an important value of ownership, but clearly not as the most important value. Uneven-aged management techniques can be used in the restoration of under-stocked and mixed longleaf stands, and in the maintenance of restored stands. While uneven-aged management might be an attractive alternative to many of these non-industrial private landowners, there are concerns of increased cost compared to even-aged regulation, and a perceived complexity of uneven-aged management.

2.5 Even-Aged Regulation

Even-aged regulation, or area regulation, of a forest is the familiar technique of dividing a forest ownership into blocks or management units, and managing each unit using even-aged silviculture. Each management unit is comprised of a single age class, with the upper age class at harvest representing the desired age at rotation. Ideally, many age classes can be represented so that a steady flow of wood is produced from the ownership. Large ownerships, such as might be held by a timber company, might have blocks comprised of age classes ranging from newly-regenerated sites to rotation age, and every age class in between. Knowing the acreage of each unit, site quality and stocking gives the owner the data needed to predict the annual flow of wood from the ownership.

Owners of smaller tracts often emulate this system, but may have to compromise on the size or number of management units or interval between age classes, depending on the size of the tract being managed. These compromises affect the volume and frequency of wood production. Still, the system produces a regular and predictable harvest. For non-industrial landowners, even-aged management has heretofore been promoted, possibly because of the simplicity of implementation (Farrar 1996), even though for many of these landowners, uneven-aged management may provide more of the non-timber benefits they seek to derive from owning forested land.

2.6 Uneven-Aged Regulation

Uneven-aged regulation also produces a regular flow of wood from a tract. The tract may be divided into management units, depending on the acreage owned, but rather than relegating an age class to a specific area, each management unit contains all, or at least several, age classes within a prescribed range. As with even-aged management, the uppermost age class, or size class, (the terms are used interchangeably here), represents the desired end-product size or rotation age.

In its most simple form, a diameter-limit harvest would accomplish this by removing the larger trees, leaving the smaller diameter classes to grow. This crude system of selection has often been called high-grading, in that it tends to favor the harvest of the largest, and presumably the most vigorous trees, leaving smaller, possibly inferior trees for future growth. Repeated diameter-limit harvests often lead to a forest of poor quality and low productivity in most forest types (Kenefik, et al. 2005), and probably also in longleaf pine (Brockway, et al. 2005). More sophisticated regulation systems exist that avoid possible long-term stand degradation from only taking the largest trees, but employing these systems presents a new set of challenges. These challenges on non-industrial private lands are the sophistication and complexity of the techniques used to determine the allowable cut, the cost of obtaining a reliable inventory, and the efficient marking of trees to be removed.

2.7 Determining allowable cut

An objective regulation system to define a target stand structure is required to calculate allowable cut. The allowable cut consists of the surplus trees in each diameter class to be removed in a thinning to leave a target residual stand. There are several systems used to define the target residual stand. A proven regulation method called Basal Area – Maximum DBH – quotient, or “BDq”, takes into account all diameter classes of the target residual stand, as compared to systems relying on volume targets or diameter limits alone (Farrar, R. M. 1996). BDq defines the target residual basal area (B), the maximum retained diameter class (D), and apportions stocking within each diameter class using a quotient (q) defining the exponential relationship of frequency between one diameter class and the next. The result is a “reverse J-shaped" diameter distribution typifying an uneven-aged forest structure. The BDq regulation method was developed by researchers for use in Appalachian hardwood (Trimble and Smith 1976), but is applicable to other species as well.

BDq can be calculated using a computer or calculator. When calculating by hand, BDq is cumbersome requiring trial and error to derive the correct q. Of course, once a BDq structure has been defined, it can be saved and used on other stands as well. Still, few foresters in the private sector use BDq, perhaps because of an unwillingness to learn the system, possibly leading them away from uneven-aged management; or worse, resorting to diameter-limit cutting or some other subjective method which could lead to a high-graded forest condition. A simpler, more understandable regulation system yielding results comparable to BDq might appeal to foresters wanting to use uneven-aged management, but reluctant to tackle BDq. In an attempt to address the issue of determining a target stand structure, a new regulation system has been developed that is as objective as BDq, but may be easier to understand, manipulate and employ.

This system, developed through years of practice and used in this study, is called Whole Stand Regulation (WSR), because it defines the structure of the entire merchantable stand (similar to BDq), not just the upper diameter classes WSR, like BDq, prescribes a target residual basal area and maximum retained diameter class. But instead of diameter classes being distributed using an exponential relationship, basal area stocking is distributed proportionally among the managed diameter classes. The formula used to determine target stocking for each managed diameter class is $(B/b_d)/N$ = trees/acre; where B = target stand basal area/acre, b_d = basal area of a tree in a given diameter class, and N = number of managed diameter classes retained after harvest. The numbers so derived for each diameter class are then multiplied by the number of acres being managed to determine the total number of trees in each diameter class to be retained on the tract.

2.8 Determining stocking

In addition to defining a target stand structure, the current stocking of the stand must be determined through some sort of inventory. Experts on the subject of uneven-aged management often stress the need for a 100% inventory using 1-inch dbh classes on stands less than 100 acres in size, or a 10 or 20% sample on larger stands using fixed radius plots (Farrar 1996). Such an intensive inventory is time consuming and costly. This cost must be absorbed by either the landowner or the forester. Experience has shown that many landowners are not willing to pay more for uneven-aged management than for simpler even-aged management, either through additional fees or a higher commission on timber sales. If uneven-aged management is to be pursued, the added expense, in such instances, must be absorbed by the forester.

While a 100% inventory is generally recommended for smaller tracts, others concede that some other sampling system, including a 10 BAF prism cruise, may produce reliable results (Brockway et al. 2005), although no data were found to support this supposition. Under the systems currently promoted, management costs are estimated to be double those of even-aged management (Brockway et al. 2005), in large part because of the intensive inventory recommended for determining the allowable cut. If adequate results can be obtained using traditional cruise methods on tracts smaller than 100 acres, the cost of uneven-aged management would be reduced. Incorporating a form of point-double sampling into the cruise procedure could be helpful in improving cruise results.

Point–double sampling has been proven effective at improving the accuracy of point sampling and other cruise methods when the purpose of the sample is to estimate stand volume (Oderwald and Jones 1992; Oderwald 2003). As typically applied, a volume to basal area ratio (VBAR) is determined for a stand. The VBAR can be determined through any means, and prism sample points are taken to accurately determine the basal area of the stand. A 10 BAF prism (variable radius) sample is very good at determining basal area (Oderwald 2003). However, the sample radius for pulpwood-sized trees (4" – 8" dbh) is small: 8.525' to 24.75', or a 0.52% to 4.42% sample, if one point is sampled per acre. The sample size increases as tree diameter increases, so estimates of larger diameter trees should be more reliable using prism sampling, but fixed radius plots should produce better estimates of the smaller diameter classes. If the ratio of a variable to basal area can be determined, an accurate estimate of basal area would improve the accuracy of the estimate of that variable (Oderwald 2003). The variable needed to determine the allowable cut is the number of trees in each diameter class, or the diameter distribution of the tract.

When using cruise data to determine diameter distribution, rather than a 100% inventory, it is inevitable that errors will occur. An over-estimate of a particular dbh class will result in the calculation of a higher allowable cut, creating a deficit in that dbh class in the residual stand. The greater the deficit, the longer it will take for the stand to recover from the deficit. For example, if the 8" dbh class were overestimated to be 931 trees, when the actual stocking is 737 trees, and the target stocking under the WSR prescription is 509 trees, the allowable cut would be

422 trees (931-509=422), rather than 228 trees (737-509=228). This would result in an over-harvest of the 8" dbh class, leaving 315 trees, instead of the target 509 trees. The target stocking in the 10" dbh class is 326 trees, so the deficit created in the 8" class by over-cutting will carry forward until the trees have grown beyond the 10" dbh class.

Similarly, an underestimate of stocking will produce a surplus residual, but this is the lesser error, since a surplus, once recognized, can be remedied in the next thinning. Such deficits and surpluses were not unusual in the diameter distribution of virgin forest stands (see Figures 2.2.1 and 2.2.2). They may have been caused by various factors including bumper seed crops or large disturbances. Stand structures conforming closely to prescribed distributions are said to be "balanced" (Leak 1964). While a balanced stand might be theoretically desirable, in practice it is more important to regulate the stand; that is, it is more important to maintain yields over time than to achieve balance (Guldin and Baker 1989). In terms of regulation, such discrepancies, if excessive, could be problematic. An error in one or two diameter classes might not be a great concern, but an error across a larger grouping of size classes might be. For example, if the 8" dbh class was under-stocked due to over-cutting, but the 4" and 6" dbh classes were adequately stocked, there would still be enough pulpwood-sized trees to grow into the pole size class, and yields could be maintained over time. For this reason, error will be examined within subgroups of diameter classes in the stand, rather than focusing on the error in each diameter class.

To address the time and cost issues associated with a 100% inventory or other intensive inventory methods, other less expensive sampling methods incorporating point-double sampling will be tested using 2-inch diameter classes and compared to a 100% inventory to determine accuracy. If adequate, a less expensive inventory system would make uneven-aged management a more affordable alternative for foresters and landowners to consider.

2.9 Marking the Allowable Cut

Another challenge of uneven-aged management is efficiently marking the allowable cut. Recommendations often include dividing the tract into blocks, and removing equal proportions of the allowable cut from each block (Farrar 1996), in hopes that the tract might be marked in one pass. If the age classes are fairly evenly distributed across the tract, this method might work, but on many tracts, some age classes might be concentrated in one or two areas, and missing entirely from others. This study will examine ways to use inventory data to produce a map that will help in tree marking decisions, along with marking rules and suggestions that should help in the marking process.

3. METHODS

3.1 Study Sites

Two study sites were chosen for this study in the Escambia Experimental Forest near Brewton, Alabama. The Escambia Experimental Forest is a 3,000 acre tract of land near Brewton, Alabama. The experimental forest was established in 1947 by the T. R. Miller Mill Company through a 99-year, no-cost lease to the USDA Forest Service to research various aspects of longleaf pine management (Boyer, et al., 1997). Sites selected were Compartment 156, also known as the Farm Forty, described as NE ¼ SE ¼, Section 27, and Compartment 102, described as NW ¼ SE ¼, Section 33, both in Township 1 N, Range 10 East, Escambia County, Alabama, approximately 40 acres each. The Farm Forty was established to demonstrate longleaf pine management on a small scale for the benefit of private landowners. Periodic harvests were made using the shelterwood system to regenerate small patches resulting in an uneven-aged forest structure over time (Barlow et al 2011). Less is known about the thinning history of Compartment 102, other than salvage cuts have been done following disturbances, including Hurricane Ivan in 2004. The current stand is uneven-aged, which is why it was also chosen for study. Both sites have been burned regularly for several decades.

At each site, all pine trees 3.1” dbh and larger were stem-mapped using a Criterion Survey

Laser to determine azimuth and distance of each tree from established points of reference. Coordinates for each reference point were recorded using a Trimble Pathfinder ProXRS. The minimum diameter of 3.1” dbh was chosen because 4” dbh is the smallest 2-inch merchantable size class, and therefore the smallest size that can be regulated in a commercial thinning.

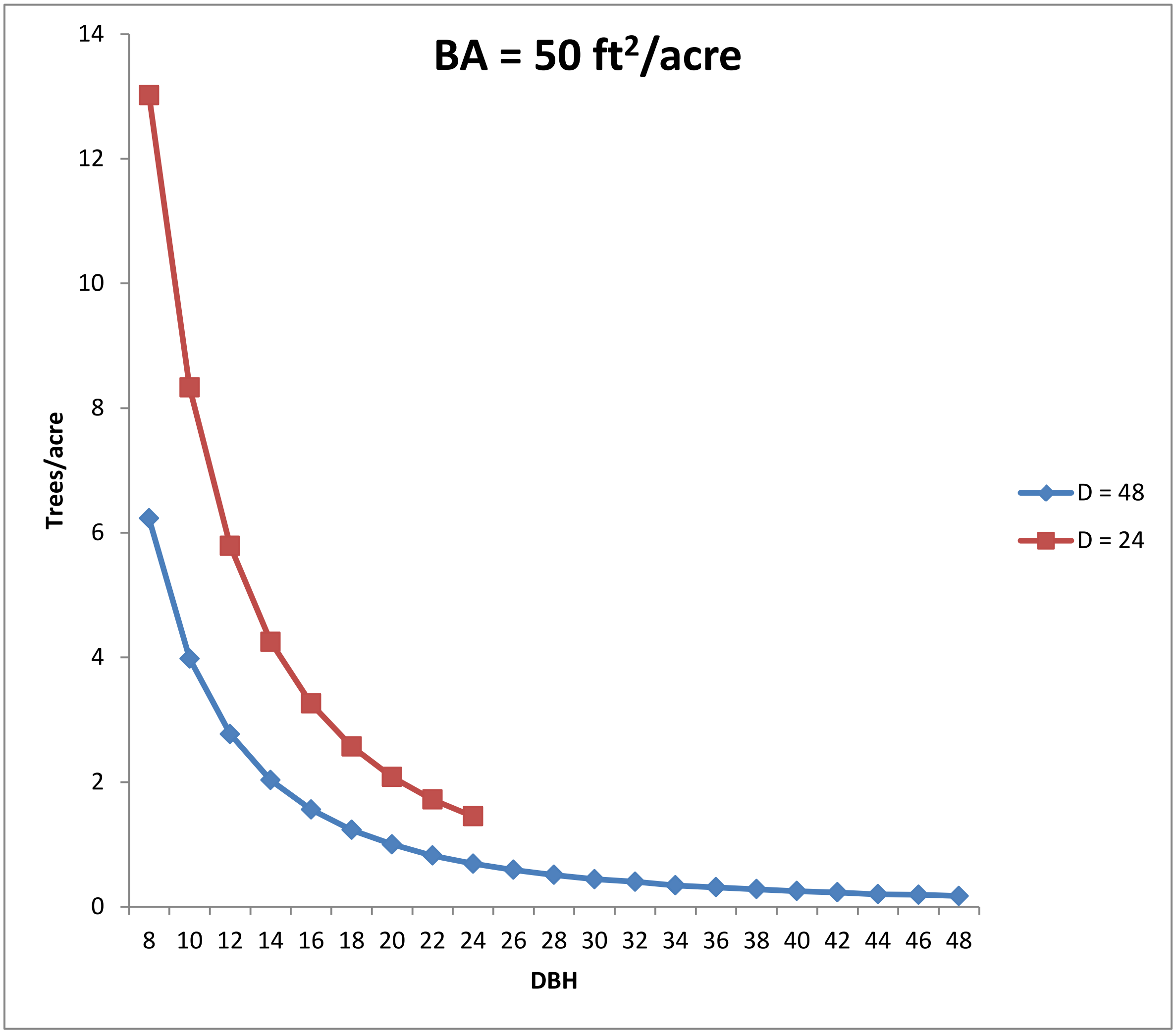
As each tree was counted, it was assigned a unique number which was marked on the tree at about eye level using a lumber crayon. Each tree number was tallied along with its diameter to the nearest 0.1”, species, azimuth and distance from reference point, and condition class, either cull or good. Cull trees included leaning trees, diseased or damaged trees, forked trees, or suppressed trees where lateral branches had assumed apical dominance. Good trees include healthy trees of good form and crown structure regardless of crown position. The resulting data were used to produce a stem map showing the location of each tree on the study sites, and to create a table of current stocking.

3.2 Stand structure determination

While the condition of the original forest might be a worthwhile structure to emulate on large ownerships, spatial and economic constraints are likely to place such goals beyond the reach of owners of smaller tracts, which are the focus of this study. A large block of several hundred acres in the virgin forest could carry trees ranging from seedlings to four feet or more in diameter. However, it would be difficult to manage such a broad range of size classes on 40 acres, even excluding temporal constraints, because there would be so few trees within each size class to draw from for thinning.

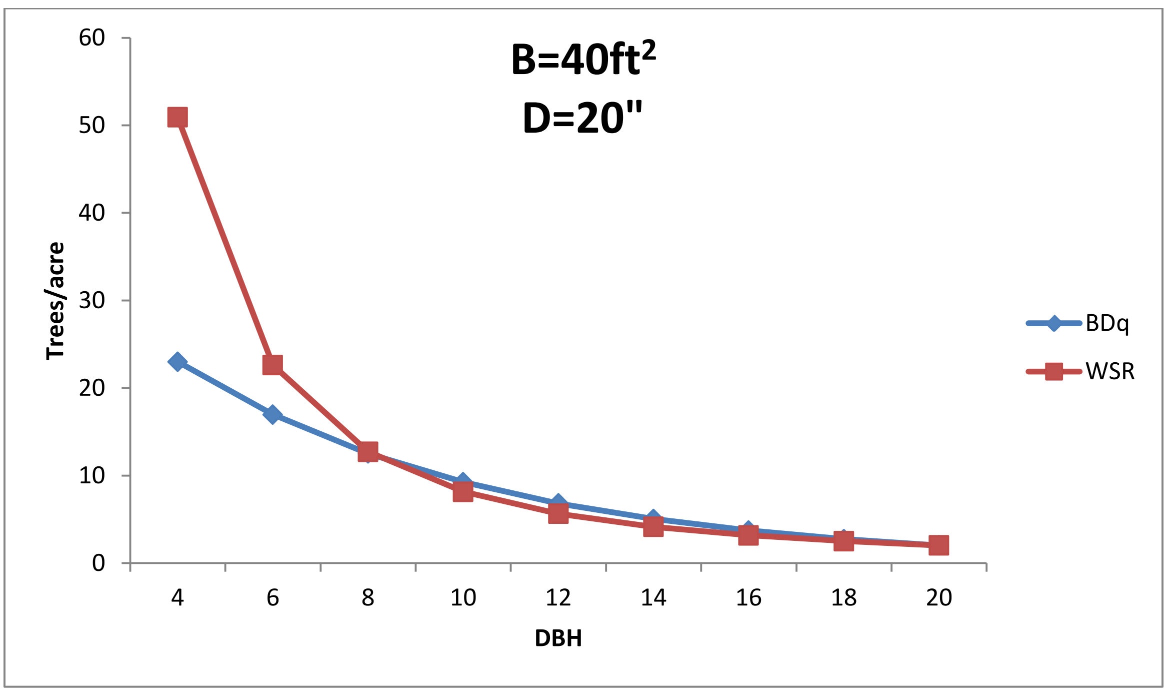
To illustrate, Figure 3.2.1 compares two hypothetical target distributions of size classes, in terms of trees per acre. Target distributions were determined for trees ranging from 4” dbh to a maximum of 48” dbh, and from 4” dbh to a maximum of 24” dbh, each totaling 50ft^2/acre basal area (BA). The graph excludes 4” and 6” trees to reduce vertical distortion. The broader range contains a fractional number of trees per acre in the larger diameter classes, and would be difficult, if not impossible, to manage effectively on a small ownership. While individual specimens of older large trees might be retained indefinitely, the bulk of the stand on a smaller tract would be more efficiently managed within a narrower range.

Figure 3.2.1: Structures of two hypothetical stands, each totaling 50 ft^2 BA/acre, with basal area distributed proportionally among the diameter classes. One retains a maximum dbh of 48”, and the other a maximum dbh of 24”.



To show the similarities between WSR and BDq, Figure 3.2.2 compares the residual stands produced by the two methods. The only noticeable difference between the two methods is that WSR leaves more 4” and 6” dbh trees in the residual stand than does BDq. In the rest of the diameter classes, the difference is only about one tree per acre or less. WSR leaves more trees in the smaller classes, but this discrepancy is not necessarily a defect in the regulation method. It may actually be a benefit of the method when using sampling methods other than a 100% inventory. Over-cutting is the greater error in uneven-aged management, in that a surplus of trees in a diameter class may be remedied in future cuts, whereas a deficit in a diameter class will be carried forward until those trees have grown into a diameter class requiring fewer trees than produced by ingrowth from the deficient class. The greater the error, the longer the recovery time will be. Because WSR will be applied to data derived from sampling methods other than a 100% inventory, the risk of over-cutting is minimized, compared to BDq, if the stocking of these lower diameter classes is over-estimated.

Figure 3.2.2: Comparison of target residual stands using BDq and WSR.



While economic considerations are not unimportant, and optimizing stand structure and cutting cycles on an economic basis is can be considered (Chang 1981), most non-industrial private landowners, who are the focus of this study, are more interested in other management benefits, including recreation and aesthetics, more closely associated with ecosystem management (Guldin 1996). For the purpose of this study, it is assumed that the owner of each study site is managing primarily for quail habitat, and wishes to cut to a low residual basal area. In terms of timber production, the owner is most interested in producing poles, but also desires to retain some larger trees for aesthetics. To achieve these goals, a residual basal are of 40 ft^2/ acre was chosen (B=40) for both sites. Poles (10" to 16" dbh) are the primary product sought to be removed, but to give a more mature appearance to the forest, a maximum diameter of 20" dbh will be retained (D=20), as shown in Figure 3.2.2. Depending on stocking, a tract might not have a surplus in each diameter class from which to draw an allowable cut. Any deficit in the target basal area will be remedied by first adding 22" trees, if needed. Further shortfalls will be filled by adding back 20" and 18" trees, if available. If any additional deficit remains, basal area will be added back proportionally among the pole size classes.

3.3 Sampling Methods

The tree-location data produced from the 100% inventory was used to create a stem map for each study site. This allowed for the comparison of different inventory methods without the necessity of repeated cruises on the ground. The dbh data derived from the 100% inventory were entered in Excel spreadsheets, along with the location of each tree. To accomplish the various cruises, trees were sampled by calculating their distance to coordinates of sample points, and included in the sample if within the limiting distance pertaining to the sample size.

Different sampling methods were run and compared to the 100% inventory to determine accuracy. Methods considered included fixed radius 1/5 acre plots on a 2x5 chain grid; 1/10 and 1/20 acre plots and 10 BAF prism samples on a 2x2.5 chain grid; and 33 ft. wide strips 2.5 chains apart. Plot and strip lines were run east and west. Different combinations of cruise methods were tested with the goal of finding inexpensive sampling methods that sample 20% or less of the population. Additionally, a variation on point-double sampling was developed and applied to cruise data. Also, a third trial was conducted by combining the two study sites, and applying a 2x5 chain cruise spacing to test whether accuracy would remain adequate using a smaller sample on a larger tract.

3.4 Double Sampling

Point–double sampling is known to improve the accuracy of cruise results when the purpose of the sample is to estimate stand volume (Oderwald and Jones 1992; Oderwald 2003). However, the accuracy of any variable with a direct relationship to the basal area of a stand should be improved through point-double sampling, given that a prism sample provides an accurate estimate of basal area of that stand. The variable needed to determine the allowable cut is the number of trees in each diameter class, or the diameter distribution of the tract. In this case, the ratio of number of trees in each diameter class to the basal area of the stand (DBAR) is determined by a fixed radius plot cruise or by a strip cruise, and the basal area is determined by a 10 BAF prism cruise. Of particular concern is improving the accuracy in the smaller diameter classes by using DBAR to adjust the tree count.

DBAR calculations were made by determining the diameter distribution of the trees in each stand, by each sampling method tested other than the 10 BAF prism cruise. The number of trees was then adjusted by the basal area estimated by the 10 BAF prism cruise. As an example, Table 3.4.1 lists the number of trees in each diameter class and the corresponding basal areas on the Farm Forty derived from the 1/20 acre sample.

Table 3.4.1: Total number of trees and basal area for each diameter class on the Farm Forty (40 acres). Estimate is from a 10% sample; 1/20 acre plots on a 2x2.5 chain grid.

dbh	# trees	basal area
4	1960	171.042 ft^2
6	1290	253.291
8	800	279.253
10	690	376.337
12	550	431.969
14	360	384.845
16	200	279.253
18	170	300.415
20	60	130.900
22	60	158.389
24+	10	31.416
total	**6150**	**2797.110 ft^2**

To begin the DBAR calculation, the total number of trees is divided by total basal area, as estimated by the 1/20 acre plot sample, to determine the number of trees per square foot of basal area:

$$\mathbf{6{,}150/2{,}797.110 = 2.1987\ trees/ft^2}$$

DBAR is then calculated for each diameter class by multiplying the number of trees per square foot of basal area by the number of trees in a diameter class, and dividing the product by the total number of trees on the tract, giving the DBAR for that dbh class. For the 4" dbh class, this would be:

(2.1987x1960)/6150 = 0.7007 trees/ft^2 4" class

The DBAR for the 4" dbh class, (0.7007), is then multiplied by 2,650 ft^2, which is the basal area estimated by the 10 BAF prism cruise. The result is the DBAR-adjusted tree count in the 4" dbh class:

0.7007x2650 = 1,857 trees

The process is repeated for each diameter class, as shown in table 3.4.2.

Table 3.4.2: DBAR for each diameter class and adjusted tree count on the Farm Forty on the Escambia Experimental Forest in Brewton, Alabama. Data derived from 1/20 acre plot cruise and 10 BAF prism cruise on 2x2.5 chain grid.

dbh	DBAR	No. trees (DBARxBA)
4	0.7007	1857
6	0.4612	1222
8	0.2860	758
10	0.2467	654
12	0.1966	521
14	0.1287	341
16	0.0715	189
18	0.0608	161
20	0.0215	57
22	0.0214	57
24+	0.0036	10

3.5 Separating Trees by Size Categories

Regardless of sampling methods used, errors are inevitable. Regulation, or a sustainable yield over time, is a more desirable goal than achieving a balanced stand (Guldin and Baker 1989). To that end, rather than focus on error within each diameter class, error within three subgroups or size categories will be examined to determine adequacy of cruise methods. For this study, the tree dbh distribution was divided into three broad size categories: Pulpwood (4" – 8" dbh); Poles (10" – 16" dbh); and Sawtimber (≥ 18" dbh). The chosen ranges reflect different growth stages of longleaf pines, as well as different product categories.

Pulpwood stocking is the most difficult to estimate in uneven-aged stands, because of the irregular distribution of the trees, and the tendency for them to grow in dense clumps. The pole category is fairly easy to estimate as a group using a prism cruise, because this is the class that comprises the bulk of most uneven-aged stands, depending on the range of diameters being retained. The sawtimber category can be difficult to estimate accurately, because it often consists of scattered, individual stems or small groups; however, using a prism, the sample size is quite large, so an adequate estimate can be made if plots are well distributed.

Thinning strategy differs for each of these size categories. Among the pulpwood classes, the primary concern when removing the allowable cut is removing culls. Cull trees include those with crooked or leaning stems, interrupted apical dominance, or evidence of disease. Spacing in the pulpwood category is not a concern. To prevent overcutting in the event of an over-estimate, a good rule-of-thumb is to only remove cull trees from pulpwood, even if it means not removing the entire allowable cut.

The pole category makes up most of the basal area in the uneven-aged stand, and is where the allowable cut is adhered to more rigidly. Any culls that have grown beyond pulpwood should be removed first. Other selections depend on the judgment of the marker, always leaving the best quality and most vigorous trees. While spacing is not of particular concern, large gaps should be avoided unless regeneration is present, because fire intensity in the absence of abundant pine litter can be inadequate to prevent encroachment of hardwood brush, increasing the difficulty of regenerating those gaps (Brockway, et al. 2005).

The sawtimber category includes the mature trees in the stand. These are the best cone producers, and should be removed judiciously, even within the allowable cut. A good marking rule in sawtimber is to not remove a tree if it will drop the basal area of the immediate surroundings to below 30 BA, unless adequate regeneration is present in the gap created by the tree’s removal. Longleaf pine seeds are heavy, and do not disperse as widely as the other southern pines, so reducing the density to below 30 BA is not recommended unless regeneration is established (Boyer 1990).

By grouping diameter classes into broader size categories, the accuracy of the various estimates are less subject to variation in stand structure particular to a specific stand and more considerate of the flexibility required to properly mark trees with respect to spatial constraints. If reasonable accuracy can be attained for each size category and markers are cognizant of the rules when marking the allowable cut, the stand should suffer no long-term ill effects from an underestimate or overestimate in any dbh class. Although a balanced stand might not be attained, a regulated stand could be maintained (Guldin and Baker 1989).

3.6 Cruise methods

The cruise methods chosen for testing include cruising using fixed-radius plots, strip cruising and prism cruising. Three different fixed-radius plot sizes were used including 1/5 acre, 1/10 acre, and 1/20 acre plots. Strip cruising was done using 33' wide strips. A 10 BAF prism was used for the prism sample. Strip cruising was tested using 33' strips running east to west 2.5 chains apart. Strip cruising was included because it is has traditionally been used in the past. Prism sample points were located at the same points as the fixed-radius plot centers. The limiting distance calculation for a 10 BAF prism was used to determine trees included in the sample at each sample point.

Different plot sizes were tested because there are pros and cons inherent to each. Because the 1/5 acre plot yields the largest sample, it should produce the most accurate estimate. However, the larger plot radius and greater tree count increases the time necessary to sample the plot, compared to smaller plots, and could lead to cruiser error. Sampling 1/10 acre and 1/20 acre plots might reduce cruiser error, but would yield smaller samples given equal plot spacing. By drawing samples from stem-mapped forties using limiting distances from plot centers entered on a spread sheet, cruiser error is eliminated, and the sampling methods can be compared based solely on accuracy. The smallest plot size giving acceptable results would be the most efficient.

Plots were sampled on a 2x5 chain grid and on a 2x2.5 chain grid, with plot lines running east to west.

The different cruise methods were analyzed by comparing results to the 100% inventory. The results from the two study sites were compared for accuracy and consistency. Methods or combination of methods producing reasonably accurate, consistent results within each size category were then chosen to determine allowable cut. The resulting allowable cut was then applied to the actual stocking to determine the residual stand produced by an estimate, and compared to the residual stand derived from the allowable cut using the 100% inventory.

3.7 Allowable Cut Calculations

Two variables are required to determine the allowable cut for each dbh class: the current stocking and the target stocking. In this study, the current stocking is determined by the results from the various cruise methods, and by the 100% inventory for comparison. Target stocking is determined by WSR. Using the 100% inventory of the Farm Forty as an example, Table 3.7.1 shows the current stocking, target stocking, allowable cut, and residual stocking before adjusting to remediate deficiencies.

Table 3.7.1: Allowable cut calculations for the Farm Forty using 100% inventory and WSR where B=40, D=20, and N=9. Tabulated values are total number of trees, except residual basal area which is in square feet.

dbh	current stocking	target stocking	allowable cut	residual stocking	residual basal area	deficit tree count
4	2038	2037	1	2037	177.762	0
6	1143	905	238	905	177.696	0
8	737	509	228	509	177.674	0
10	702	326	376	326	177.805	0
12	563	226	337	226	177.500	0
14	286	166	120	166	177.456	0
16	142	127	15	127	177.325	0
18	131	101	30	101	178.482	0
20	70	81	0	70	152.716	11
22	44	0	44	0	0	0
24+	18	0	18	0	0	0
					1574.416	

The target stocking calculation was made by the formula: $(B/b_d)/N$ where B is the target basal area per acre, b_d is the basal area for the diameter class, and N is the number of diameter classes being managed. The result must be multiplied by the number of acres to get the total number of trees on the tract. Using the 8" dbh class as an example:

$$\begin{aligned}
8\text{" dbh target stocking} &= \\
[(B/b_8)/N] \times \text{Acres} &= \\
[\{40/((4^2 \times 3.14159)/144)\}/9] \times 40 &= \\
(114.591/9) \times 40 &= \\
12.732 \times 40 &= 509 \text{ trees}
\end{aligned}$$

Allowable cut is calculated by subtracting the target stocking from the current stocking:

$$737 - 509 = 228$$

If there is an allowable cut, the residual stocking and the target stocking are the same. If there are not enough trees in a dbh class, a deficit results, as with the 20” dbh class, where 81 trees are needed for full stocking under the prescription, but only 70 trees are present. This deficit will result in the stand being under-stocked by the amount of basal area those trees represent. To adjust for this deficit, it was decided that any deficit in the target basal area will be remedied by first adding 22” trees, if needed. Further shortfalls will be filled by adding back 20” and 18” trees, if available. If any additional deficit remains, basal area will be added back proportionally among the pole size classes.

The deficit in this case is 11 trees in the 20” dbh class totaling about 24 ft^2 BA. The total residual basal area prior to adjustment is 1,574.416 ft^2. At 40 ft^2/ acre, the target is 1,600 ft^2. 1,600 – 1,574.416 = 25.584 ft^2 deficit. (The extra basal area deficit is due to rounding to a whole number of trees in the other dbh classes.) The basal area of a 22” dbh tree is 2.640 ft^2, and there are 44 trees 22” dbh to draw from, so the entire deficit can be made up by adding back ten 22” dbh trees. Table 3.7.2 shows the adjusted allowable cut.

Table 3.7.2: Adjusted allowable cut calculations for the Farm Forty using 100% inventory and WSR where B=40, D=20, and N=9. Tabulated values are total number of trees, except residual basal area which is in square feet. Deficit adjustment was made by adding trees in the 22" dbh class to the residual stand. Adjustments are indicated in bold font.

dbh	current stocking	target stocking	allowable cut	residual stocking	residual basal area
4	2038	2037	1	2037	177.762
6	1143	905	238	905	177.696
8	737	509	228	509	177.674
10	702	326	376	326	177.805
12	563	226	337	226	177.500
14	286	166	120	166	177.456
16	142	127	15	127	177.325
18	131	101	30	101	178.482
20	70	81	0	70	152.716
22	44	**10**	**34**	**10**	**26.398**
24+	18	0	18	0	0
				Total =	**1600.814**

The adjusted allowable cut now leaves the prescribed residual density of 40 BA/acre. The same process was applied to Compartment 102, and to the combined forties to determine the target stocking, using the 100% inventory and the same deficit adjustment protocol. The target stand and allowable cut was also calculated using the inventory methods chosen for consistent accuracy, and these results were compared to the residual stands derived from the 100% inventory to determine error. Any cruise method with an error greater than 6.0% in any size category on either tract was rejected as a viable inventory method for that size category.

The adjustment to the allowable cut for Compartment 102 was a bit more complicated, in that a greater basal area deficit was encountered. Table 3.7.3 shows Compartment 102, using the same WSR prescription, before adjusting for deficits in stocking, and Table 3.7.4 shows the final prescription after adjustments.

Table 3.7.3: Allowable cut calculations for Compartment 102 using 100% inventory and WSR where B=40, D=20, and N=9. Tabulated values are total number of trees, except residual basal area which is in square feet.

dbh	current stocking	target stocking	allowable cut	residual stocking	residual basal area	deficit tree count
4	1341	2037	0	1341	117.024	696
6	818	905	0	818	160.614	87
8	639	509	130	509	177.674	0
10	495	326	169	326	177.805	0
12	398	226	172	226	177.500	0
14	381	166	215	166	177.456	0
16	259	127	132	127	177.325	0
18	106	101	5	101	178.482	0
20	28	81	0	28	61.086	53
22	3	0	3	0	0	0
				Total =	**1404.966**	

The target stocking is 1600 ft^2 (40 ft^2 X 40 acres), but the residual only totals 1404.966 ft^2, a 195.034 ft^2 deficit. Adding back the 22" dbh trees increases the basal area by 7.919 ft^2. There are no surplus trees in the 20" dbh class to draw from, and adding back the 5 surplus 18" dbh trees only adds another 8.835 ft^2 to the total. The remaining deficit of 178.280 ft^2 will be added back proportionally to the pole category. The adjusted allowable cut calculations are shown in Table 3.7.4.

Table 3.7.4: Adjusted allowable cut calculations for Compartment 102 using 100% inventory and WSR where B=40, D=20, and N=9. Tabulated values are total number of trees, except residual basal area which is in square feet. Deficit adjustment was made by adding trees in the 22" dbh and 18" dbh classes, and the remaining basal area deficit distributed proportionally among the pole dbh classes. Adjustments are indicated in bold font.

dbh	current stocking	target stocking	allowable cut	residual stocking	residual basal area
4	1341	2037	0	1341	117.024
6	818	905	0	818	160.614
8	639	509	130	509	177.674
10	495	**406**	**89**	**406**	**221.439**
12	398	**283**	**115**	**283**	**222.268**
14	381	**208**	**173**	**208**	**222.355**
16	259	**159**	**100**	**159**	**222.006**
18	106	**106**	**0**	**106**	**187.317**
20	28	81	0	28	61.086
22	3	**3**	**0**	**3**	**7.919**
				Total =	**1600.814**

3.8 Analyzing the Data

Because data from the 100% inventory is available, estimates can be compared to the true values. Errors were calculated by dividing the difference between the actual and estimated values by the actual value, and expressed as a positive or negative percentage. This analysis was repeated for the tree count in each dbh class, and for tree count and basal area in each size category and for the tract total.

4. RESULTS

4.1 Current Stocking and Stem Maps

The current stocking on the study sites are shown in Table 4.1.1 for the Farm 40 followed by the corresponding stem map in Figure 4.1.1; and in Table 4.1.2 for Comp. 102 followed by the corresponding stem map in Figure 4.1.2.

Table 4.1.1: Current stocking of Farm Forty based on 100% inventory.

100% Inventory

dbh	No. Trees	Basal Area
4	2038	177.849
6	1143	224.428
8	737	257.262
Pulpwood:	**3918**	**659.539 ft^2**
10	702	382.882
12	563	442.179
14	286	305.738
16	142	198.269
Poles:	**1693**	**1329.068 ft^2**
18	131	231.496
20	70	152.716
22	44	116.152
24+	18	62.221
Sawtimber:	**263**	**562.585 ft^2**
All:	**5874**	**2551.192 ft^2**

Figure 4.1.1: Stem map of Farm Forty. Each triangle represents one tree ≥3.1" dbh.

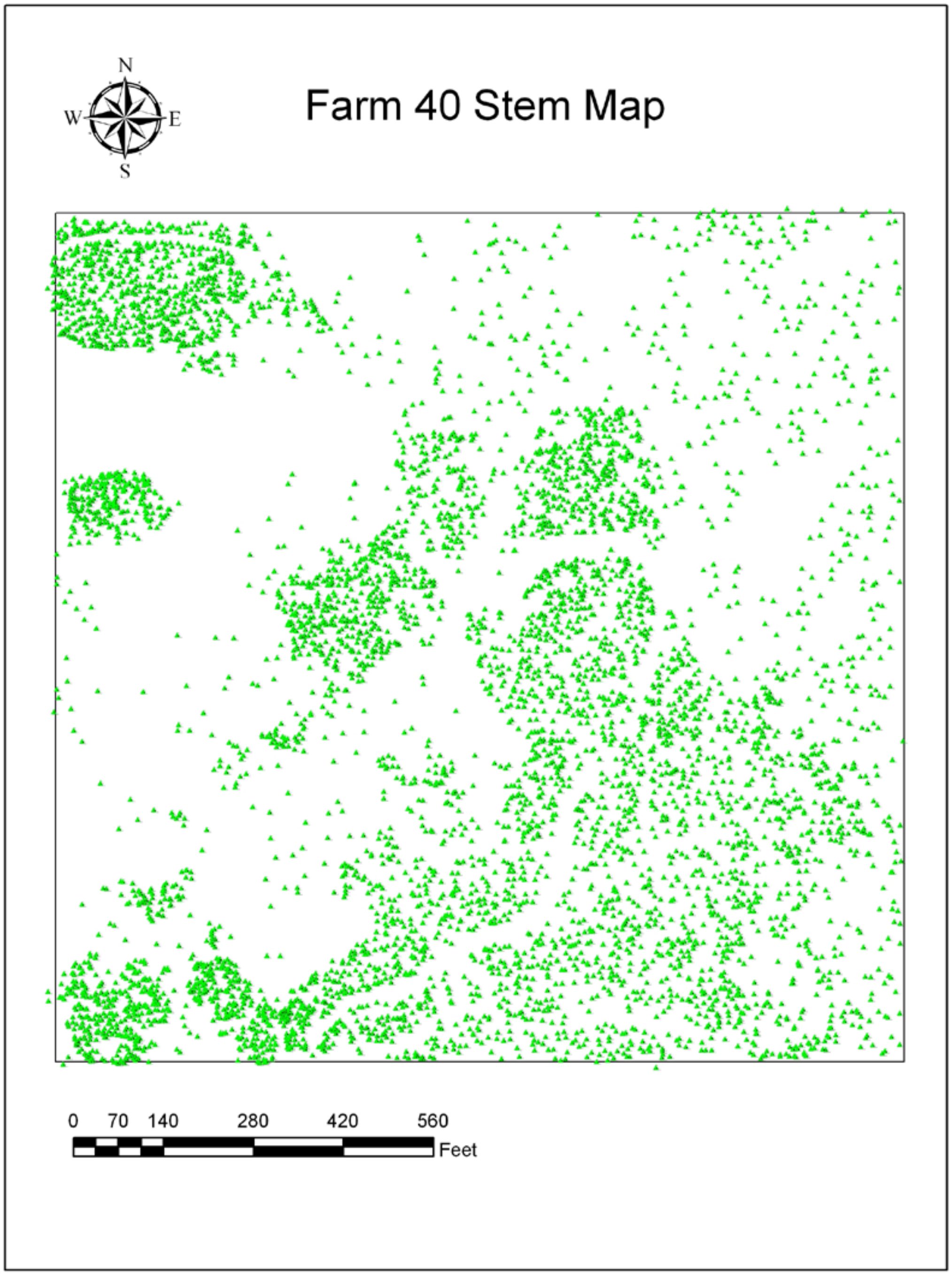
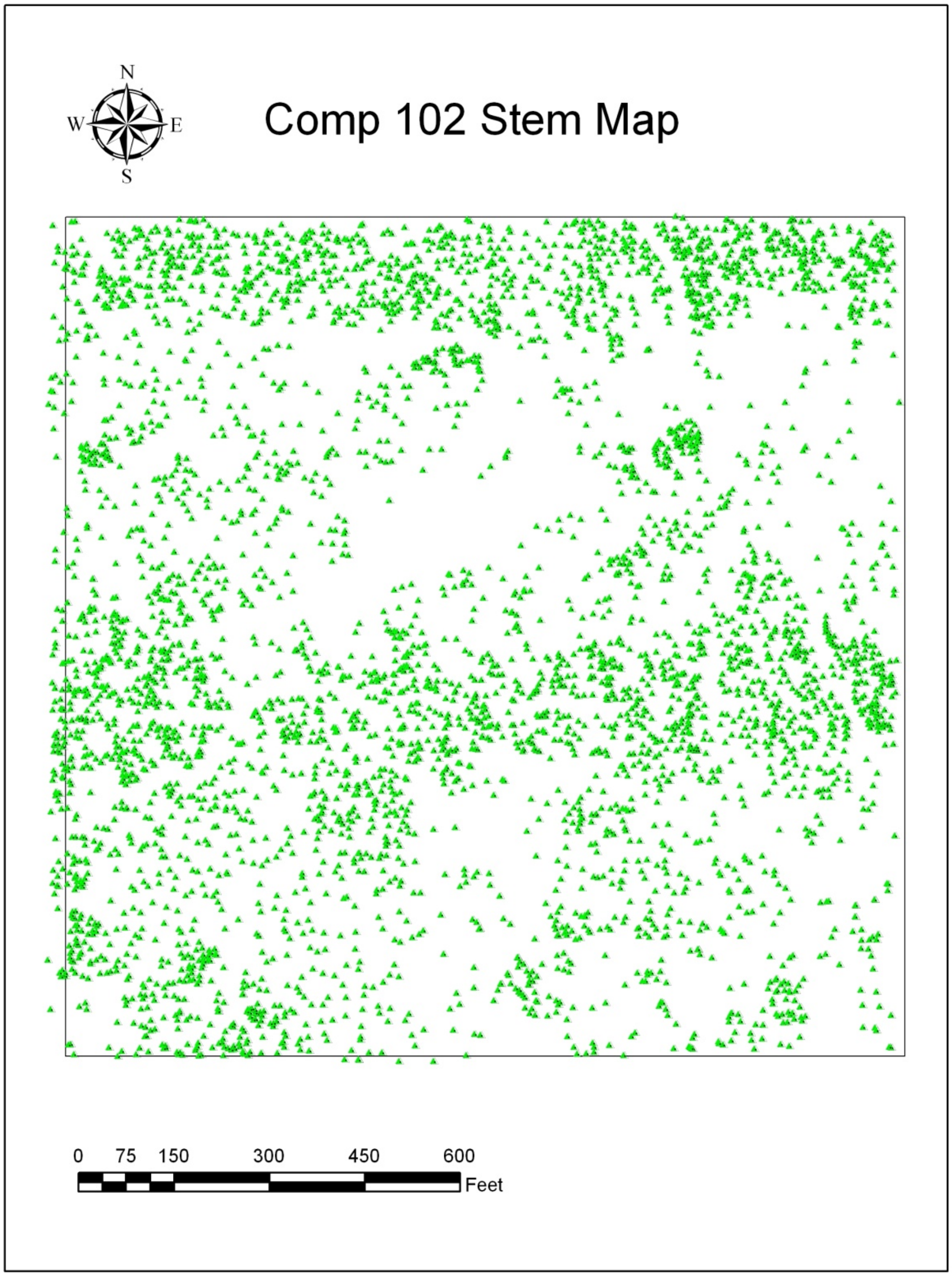


Table 4.1.2: Current stocking of Comp. 102 based on 100% inventory.

100% Inventory

dbh	No. Trees	Basal Area
4	1341	177.024
6	818	160.614
8	639	223.053
Pulpwood:	**2798**	**500.691 ft^2**
10	495	269.981
12	398	312.588
14	381	407.294
16	259	361.632
Poles:	**1533**	**1351.495 ft^2**
18	106	187.317
20	28	61.086
22	3	7.919
Sawtimber:	**137**	**256.322 ft^2**
All:	**4468**	**2108.508 ft^2**

Figure 4.1.2: Stem map of Comp. 102. Each triangle represents one tree ≥3.1" dbh.



4.2 Cruise Results: 2x5 chain grid on 40 acre study sites

The standard established in this study for the “acceptable error” within any size category or for the tract over all was <±6.0% of the tree count. If a method did not produce an estimate within that range, it was rejected. Also, the method tested must produce acceptable results on both study sites, or it was rejected. The standard of <± 6% of the tree count within a size category reflects an error from which the basal area and tree count of the stand should recover within a short amount of time if the stand is overcut. For instance, consider an overestimate resulting in an overcut of 6% of the tree count in each size category. The possible combinations resulting in such a scenario are numerous, such as a surplus in one diameter class and a deficit in another averaging 6%, but it could be argued that the worst case scenario would be all of the error coming from the upper diameter class in each category, as this would have the greatest impact on basal area.

Table 4.2.1, below, tabulates such a scenario. The left column is of a balanced stand using WSR and the prescription in this study; the center column includes a 6% error of the residual tree count in each category taken from the upper diameter class; and the right column is the same overcut stand after two years of growth at 0.1”/year (20 rings/inch). After only two years of growth, the basal area of the overall stand has recovered to within 2% of the target. Assuming 20.2 trees/acre ingrowth from the pre-merchantable component, the pulpwood category will have grown beyond full stocking, even though the 8” dbh class remains under-stocked. The pole and sawtimber categories remain slightly under-stocked, but should recover within another year. A faster average growth rate would accelerate the recovery, which in any case should not protract the time to the next thinning by more than a few years at most, if cruising errors are <±6% in each category. An error resulting in an overstocked condition can be remedied in the next thinning.

Table 4.2.1: Left column is the target diameter distribution and basal area per acre of a balanced stand using WSR where B=40, D=20, and N=9; the center column includes a tree count error of 6% in each category, taken from the upper diameter class of each; and the right column is the same overcut stand after two years of growth at +0.1" dbh/year.

	Balanced		**-6% Error (Yr 0)**		**+Growth (Yr 2)**	
dbh	**Trees/ac**	**BA/ac**	**Trees/ac**	**BA/ac**	**Trees/ac**	**BA/ac**
4	51.1	4.446	51.1	4.446	66.2	5.759
6	22.7	4.449	22.7	4.449	25.5	4.998
8	12.7	4.432	7.5	2.618	9.0	3.141
PW:	**86.5**	**13.327 ft^2**	**81.3**	**11.513 ft^2**	**100.7**	**13.898 ft^2**
Error	0.00%	0.00%	-6.01%	-13.61%	+16.42%	+4.28%
10	8.2	4.469	8.2	4.469	8.2	4.469
12	5.7	4.474	5.7	4.474	5.9	4.632
14	4.2	4.490	4.2	4.490	4.4	4.704
16	3.2	4.467	1.9	2.652	2.1	2.932
PO:	**21.3**	**17.900 ft^2**	**20.0**	**16.085 ft^2**	**20.6**	**16.737 ft^2**
Error	0.00%	0.00%	-6.10%	-10.14%	-3.29%	-6.50%
18	2.5	4.418	2.5	4.418	2.5	4.418
20	2.0	4.364	1.7	3.709	1.7	3.709
22	0.0	0.000	0.0	0.000	0.2	0.488
ST:	**4.5**	**8.782 ft^2**	**4.2**	**8.127 ft^2**	**4.4**	**8.615 ft^2**
Error	0.00%	0.00%	-6.67%	-7.46%	-2.22%	-1.90%
All:	**112.3**	**40.009 ft^2**	**105.5**	**35.725 ft^2**	**125.7**	**39.250 ft^2**
Error	0.00%	0.00%	-6.06%	-10.71%	+11.93%	-1.90%

The first cruise methods tested were on the Farm Forty using a 2x5 chain spacing. Lines were spaced 5 chains apart running east to west, and samples were taken every 2 chains along each line. Because a main premise of this study is to determine an inexpensive cruise method to use in determining allowable cut, any method sampling over 20% was rejected. Using 1/5 acre plots on a 2x5 chain grid produces a 20% sample, and in fact, this produced an acceptable estimate of pulpwood and for the tract over all, but did not produce acceptable results for poles or sawtimber (Table 4.2.2). The same method was tested on Compartment 102, along with other methods, but the results were not consistent. No single method on a 2x5 chain spacing worked well on both tracts, regardless of sample size. The reason might be that at a spacing of 2x5 chains, the samples are not distributed well enough to capture the variability on a tract as small as 40 acres; that a tighter spacing is required to produce accurate and consistent results. For this reason, the 2x5 chain grid was abandoned in favor of a 2x2.5 chain grid, and along with it, the 1/5 acre plot. At 2x2.5 chains, a 1/5 acre plot would sample 40%, which is beyond the desired intensity. Further, the 1/5 acre plot would be cumbersome in the field, requiring frequent limiting distance and diameter measurements. On two of the 1/5 acre plots on the Farm Forty, over 100 trees were within the limiting distance. Such heavy tally on a single plot can lead to frustration and sloppy cruising. After testing the other cruise methods (1/10 acre plot, 1/20 acre plot, 33’ strip, and 10 BAF prism sample) using a 2x2.5 chain grid, the idea of using a 2x5 chain grid will be revisited in section 4.5, applying it to a larger tract by combining the two study sites as one.

Table 4.2.2: Results of 1/5 acre cruise on 2x5 chain spacing compared to 100% inventory on the Farm Forty.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	2190	191.114	2038	177.849	+ 7.46	
6	950	186.532	1143	224.428	- 16.88	
8	755	263.545	737	257.262	+ 2.44	
PW:	**3895**	**641.191 ft^2**	**3918**	**659.539 ft^2**	**- 0.59%**	**-2.78%**
10	775	422.697	702	382.882	+ 7.55	
12	630	494.801	563	442.179	+11.90	
14	315	336.739	286	305.738	+10.14	
16	120	167.552	142	198.269	- 15.49	
PO:	**1840**	**1421.789 ft^2**	**1693**	**1329.068 ft^2**	**+ 8.68%**	**+ 6.98%**
18	160	282.743	131	231.496	+22.14	
20	60	130.900	70	152.716	- 14.28	
22	35	92.393	44	116.152	-20.45	
24+	25	81.267	18	62.221	+38.89	
ST:	**280**	**587.303 ft^2**	**263**	**562.585 ft^2**	**+ 6.46%**	**+ 4.39%**
All:	**6015**	**2650.283 ft^2**	**5874**	**2551.192 ft^2**	**+ 2.40%**	**+ 3.88%**

4.3 Cruise Results: 2x2.5 chain grid on 40 acre study sites

On a 2x2.5 chain grid, consistent results were achieved by several methods, and are tabulated in Appendix 7.1 for the Farm Forty and in Appendix 7.2 for Compartment 102. The last table in each displays the error for each method, and highlights those methods that are within the acceptable error range. Table 4.3.1 compares cruise methods on the Farm Forty to

Compartment 102, compiled from Tables 7.1.8 and 7.2.8. Methods producing acceptable results (<+6.0%) are highlighted. Values listed are percentage of error of the tree count compared to the 100% inventory.

Table 4.3.1: Error results of various cruise methods on Farm Forty (F40) and Compartment 102 (102). Error is expressed as percentage over or under tree count from the 100% inventory. Errors <+6.0% are in bold font.

	Pulpwood		**Poles**		**Sawtimber**		**Overall**	
Cruise	**F40**	**102**	**F40**	**102**	**F40**	**102**	**F40**	**102**
10 BAF	+10.21	**+ 2.86**	**- 2.60**	**- 0.20**	**- 0.38**	**+ 5.84**	+ 6.04	**- 1.68**
1/20 ac.	**+ 3.37**	+ 6.86	+ 6.32	**+ 2.41**	+14.07	+38.69	**+ 4.70**	+ 6.31
1/20 ac. + DBAR	**- 2.07**	**- 4.29**	**+ 0.71**	- 8.28	+ 8.36	+24.09	**- 0.65**	**- 4.79**
1/10 ac.	**+ 0.56**	**+ 3.47**	**+ 1.30**	**- 0.85**	+15.97	+31.39	**+ 1.46**	**+ 2.84**
1/10 ac. + DBAR	**- 0.84**	**- 1.14**	**- 0.18**	**- 5.28**	+14.45	+24.82	**+ 0.03**	**- 1.77**
33’ strip	+14.60	**- 2.97**	**+ 4.55**	**+ 5.02**	- 8.74	+45.98	+10.66	**+ 1.28**
33’ strip + DBAR	+12.25	- 11.33	**+ 2.42**	**- 4.11**	- 10.65	+33.58	+ 8.39	- 7.48

No one method consistently produced acceptable results for each size category; however, certain consistencies were discovered. The 10BAF prism cruise was the only sampling method that produced acceptable results in the sawtimber category. It also consistently estimated the pole category accurately; however, it failed to accurately estimate the pulpwood category on the Farm Forty.

In most cases, adjusting estimates with DBAR improved accuracy. In two cases it did not. On the Farm Forty, the pulpwood error using a 1/10 acre plot went from +0.56% to -0.84%, still well within the acceptable range. On Compartment 102 in the pole category, using a 1/20 acre plot, accuracy went from an acceptable +2.41% to -8.28%. The latter case is one of two instances where DBAR adjusted an acceptable error to an unacceptable error, the other being the strip cruise in Compartment 102 in pulpwood. In all instances, the error was toward a more conservative estimate, and might be interpreted as an improvement, since a conservative error is preferable to an overestimate of current stocking.

Since the 10 BAF prism cruise is, in all instances, the only method that produces acceptable results in the sawtimber class, it must be included in the inventory method used to determine current stocking. It is also necessary to calculate basal area for use in applying DBAR to other cruise methods. Because the 10 BAF prism cruise is inconsistent in its estimate of pulpwood, it will be necessary to incorporate another cruise method to estimate pulpwood. The cruise method used to determine stocking within the pole category is less critical, since all methods produced acceptable or very nearly acceptable results.

Like the other methods, strip cruising estimated the pole category accurately on both sites, and DBAR improved its accuracy. However, it did not consistently estimate pulpwood. In keeping with the desire to produce a simple inventory system, strip cruising was not carried forward as an inventory method, because a third method would have to be incorporated into the cruise to estimate pulpwood, making the cruise too complicated, and requiring the keeping of three separate tallies.

As expected, the 10BAF prism cruise produced the best estimate of basal area of all the methods, so the use of DBAR was incorporated with the plot cruises to determine current stocking for use in allowable cut calculations.

4.4 Comparison of Residual Stands on 40 acre study sites

The cruise methods selected to calculate allowable cut were 10 BAF prism cruise (10BAF), 1/10 acre plot cruise adjusted using DBAR (1/10 DBAR), and 1/20 acre plot cruise adjusted using DBAR (1/20 DBAR). The following combinations were used on each study site:

Pulpwood	**Poles**	**Sawtimber**
1/10 DBAR	10 BAF	10 BAF
1/10 DBAR	1/10 DBAR	10 BAF
1/20 DBAR	10 BAF	10 BAF
1/20 DBAR	1/20 DBAR	10 BAF

These cruise combinations can be achieved in the field by taking a 10 BAF prism sample at each sample point, and a concentric 1/10 acre or 1/20 acre plot at each point, keeping the tally separate. The results from these cruise combinations were used in allowable cut calculations. The allowable cut was then deducted from the 100% inventory on each study site to determine what the actual residual stand would be if these methods were applied. A comparison was made to the residual stand produced by using a 100% inventory in allowable cut calculations, the error being expressed as a percentage over or under the target residual. The results are tabulated in Appendix 7.7 for the Farm Forty and in Appendix 7.8 for Compartment 102. In all cases, the overall results were well within the acceptable limits. Total tree count errors range from -5.67%

to +0.58%; that is, understocked by 5.67% to overstocked by 0.58%. In terms of total residual basal area, the errors range from understocked by 4.72% to overstocked by 3.90%. Table 4.4.1 lists these errors compiled from Tables 7.7.1 through 7.7.4 for the Farm Forty, and Tables 7.8.1 through 7.8.4 for Compartment 102.

Table 4.4.1: Overall error of residual stand, expressed as a percentage, for the Farm Forty (F40) and Compartment 102 (102) using estimates from various cruise methods to determine allowable cut, compared to residual stand based on data from 100% inventory.

cruise combination	F40 tree count	102 tree count	F40 BA	102 BA
1/10 + BAF + BAF	+0.58%	- 5.67%	+1.95%	- 4.46%
1/10 + 1/10 + BAF	- 0.34%	- 3.65%	- 0.75%	- 1.59%
1/20 + BAF + BAF	- 1.07%	- 4.79%	- 1.57%	- 3.12%
1/20 + 1/20 + BAF	- 2.32%	- 1.58%	- 4.72%	+3.90%

Table 4.4.2 is a compilation of the same data used in Table 4.4.1, but expresses overstocking and understocking of the residual stand in terms of trees/acre and ft^2/acre.

Table 4.4.2: Stocking of residual stand on the Farm Forty (F40) and Compartment 102 (102) using estimates from various cruise methods to determine allowable cut, compared to residual stand based on data from 100% inventory. Overstocking (+); understocking (-); tree count is trees/acre (t/ac); basal area is ft^2/acre (ft^2).

cruise combination	F40 tree count	102 tree count	F40 BA	102 BA
1/10 + BAF + BAF	+0.65 t/ac	- 5.48 t/ac	+0.78 ft^2	- 1.78 ft^2
1/10 + 1/10 + BAF	- 0.38 t/ac	- 3.52 t/ac	- 0.30 ft^2	- 0.63 ft^2
1/20 + BAF + BAF	- 1.20 t/ac	- 4.62 t/ac	- 0.63 ft^2	- 1.25 ft^2
1/20 + 1/20 + BAF	- 2.60 t/ac	- 1.52 t/ac	- 1.89 ft^2	+1.56 ft^2

4.5 Cruise Results: 2x5 chain grid on 80 acre combined study sites

A plot spacing of 2x5 chains proved to be inadequate in accurately estimating tree count consistently on the 40-acre tracts. The reason, it was suspected, was that the inherent variability was not captured with such a wide spacing; that a tighter spacing was required on each of the 40-acre study sites to achieve acceptable results. To test whether a wider spacing might suffice on a larger tract, the two study sites were combined to form an 80-acre tract, and a 2x5 chain cruise running east to west using a 10 BAF prism cruise and 1/20 acre plots + DBAR in the combinations done for the separate study sites. The results were within the acceptable accuracy range for the stocking estimates, and tabulated in Appendix 7.6.

The same residual stand prescription was applied using WSR and deficits adjusted in the same manner as for the individual study sites using the combined data from the 100% inventories. Allowable cut was calculated using the combined cruise methods as described before, and the resulting residual stand was compared to the residual stand using the combined 100% inventories, and the results shown in Appendix 7.9. Table 4.4.1 is a summary of 7.9.1 and 7.9.2.

Table 4.5.1: Stocking of residual stand on 80 acres combining the Farm Forty and Compartment 102. Estimates are from 1/20 acre cruise + DBAR and 10 BAF prism cruise to determine allowable cut, compared to residual stand based on data from combined 100% inventories. Overstocking (+); understocking (-); tree count is trees/acre (t/ac); basal area is ft^2/acre (ft^2/ac).

cruise combination	**80 acre tree count**	**80 acre BA**
1/20 + BAF + BAF	+0.78 t/ac	- 1.66 ft^2/ac
1/20 + 1/20 + BAF	+5.18 t/ac	+2.05 ft^2/ac

Both combinations produced good results overall, but the 10 BAF prism cruise overestimated the pole category by 5.89% of the tree count, resulting in an under-stocking of that size category by 11.69%. The error in the pole category was diminished to -0.43% when using the 1/20 acre plot and DBAR, resulting in a residual pole category under-stocked by only 1.35%. Based on this test it appears that acceptable results can be attained spacing samples on a 2x5 chain grid on stands of 80 or more acres, using a combination of prism and fixed-radius plots.

4.6 Mapping

By keeping tally separate by plot, data from the prism sample can be used to create a map showing basal area variations across the stand. On a 2x2.5 chain grid, each sample point is at the center of a 1/2 acre block measuring 2x2.5 chains. The basal area at each point is recorded and entered on a field map, or on GIS as shown in Figure 4.6.1 for the Farm Forty, and in Figure 4.6.3 for Comp. 102. Figures 4.6.2 and 4.6.4 are the same basal area maps with the respective stem maps added as overlays, showing that the basal area maps derived from the cruises produced a good approximation of tree clusters across each tract.

Figure 4.6.1: Farm Forty Basal Area Map.

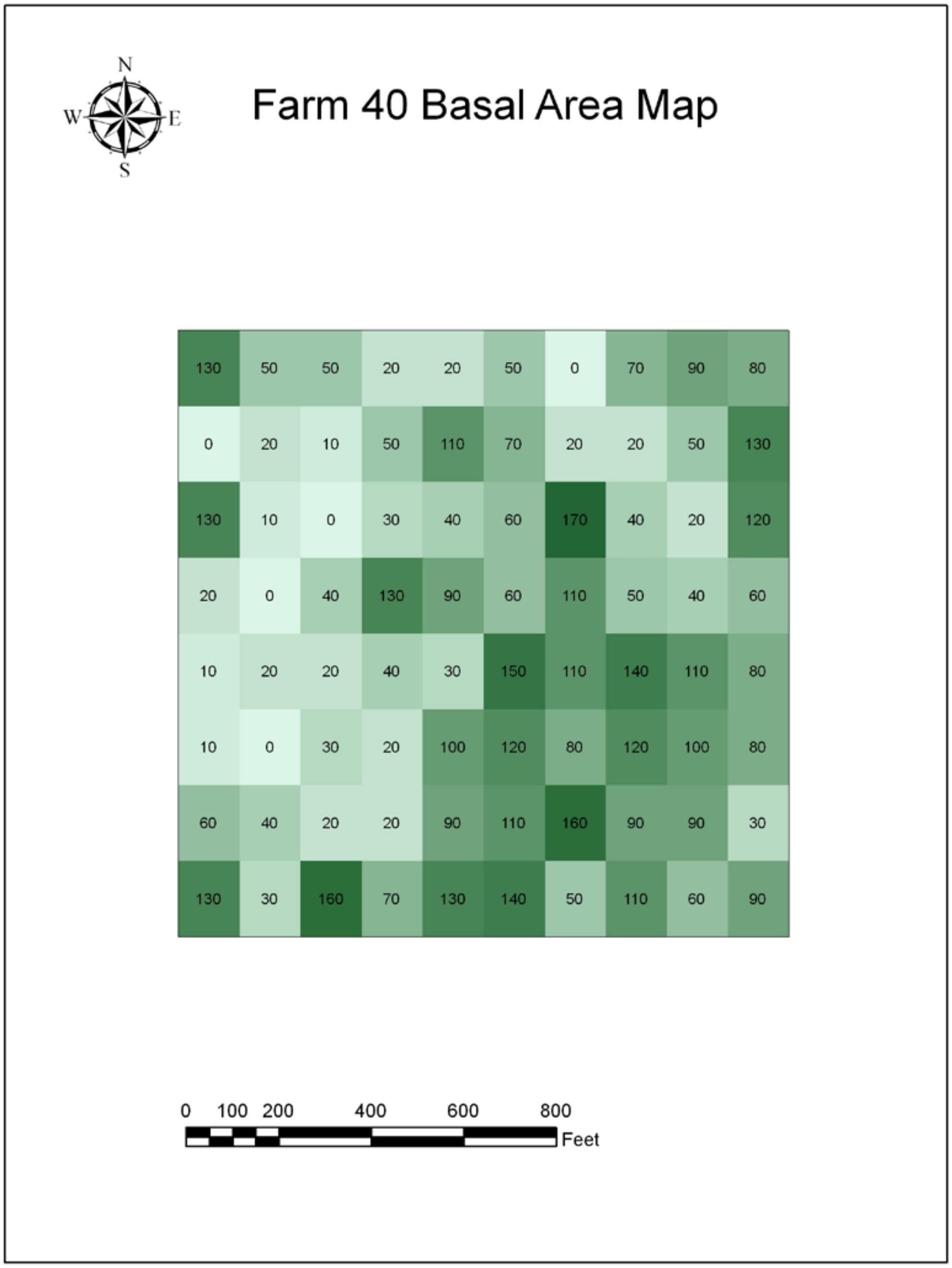


Figure 4.6.2: Farm Forty Basal Area Map with stem map overlay.

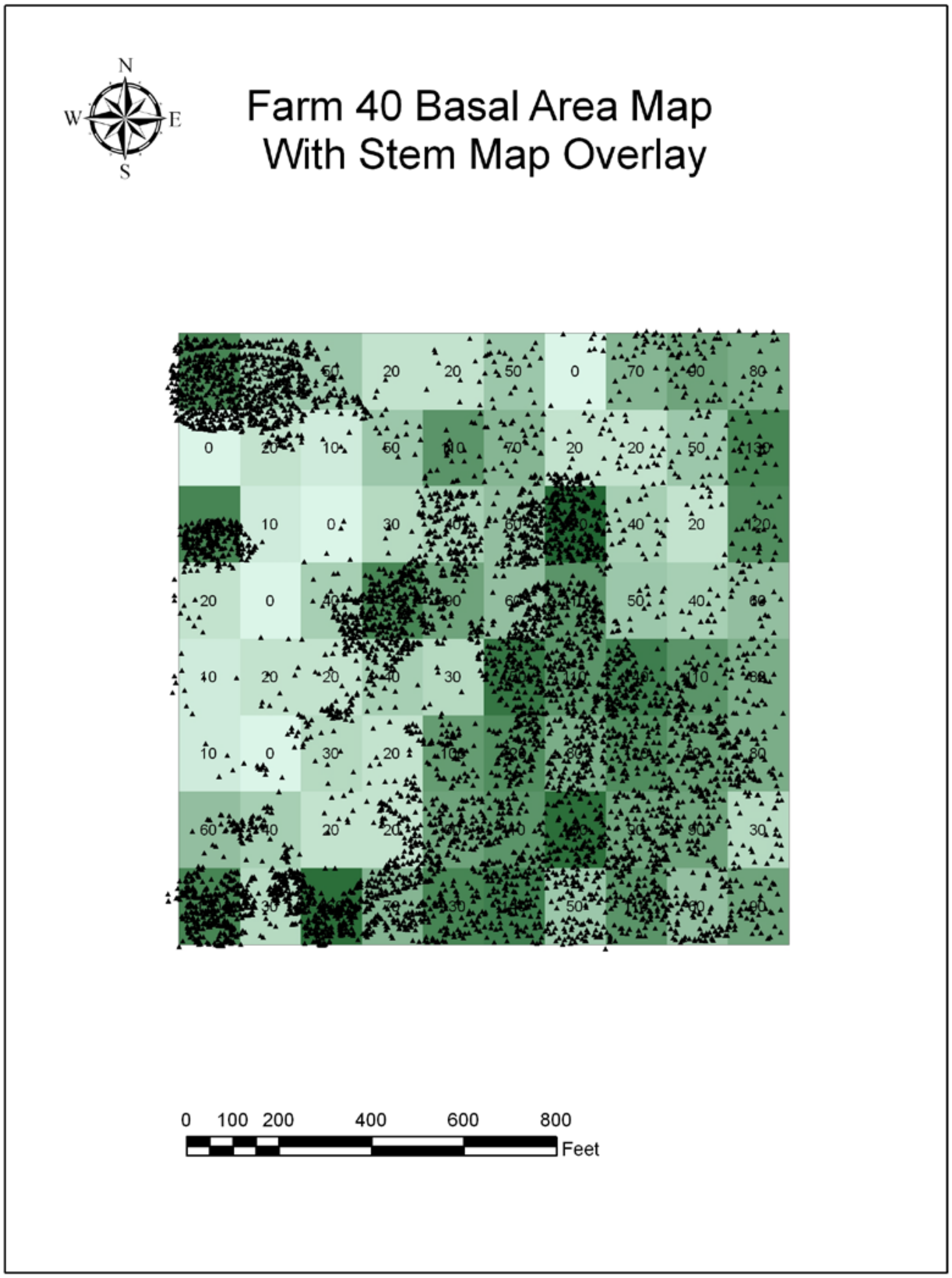


Figure 4.6.3: Comp. 102 Basal Area Map.

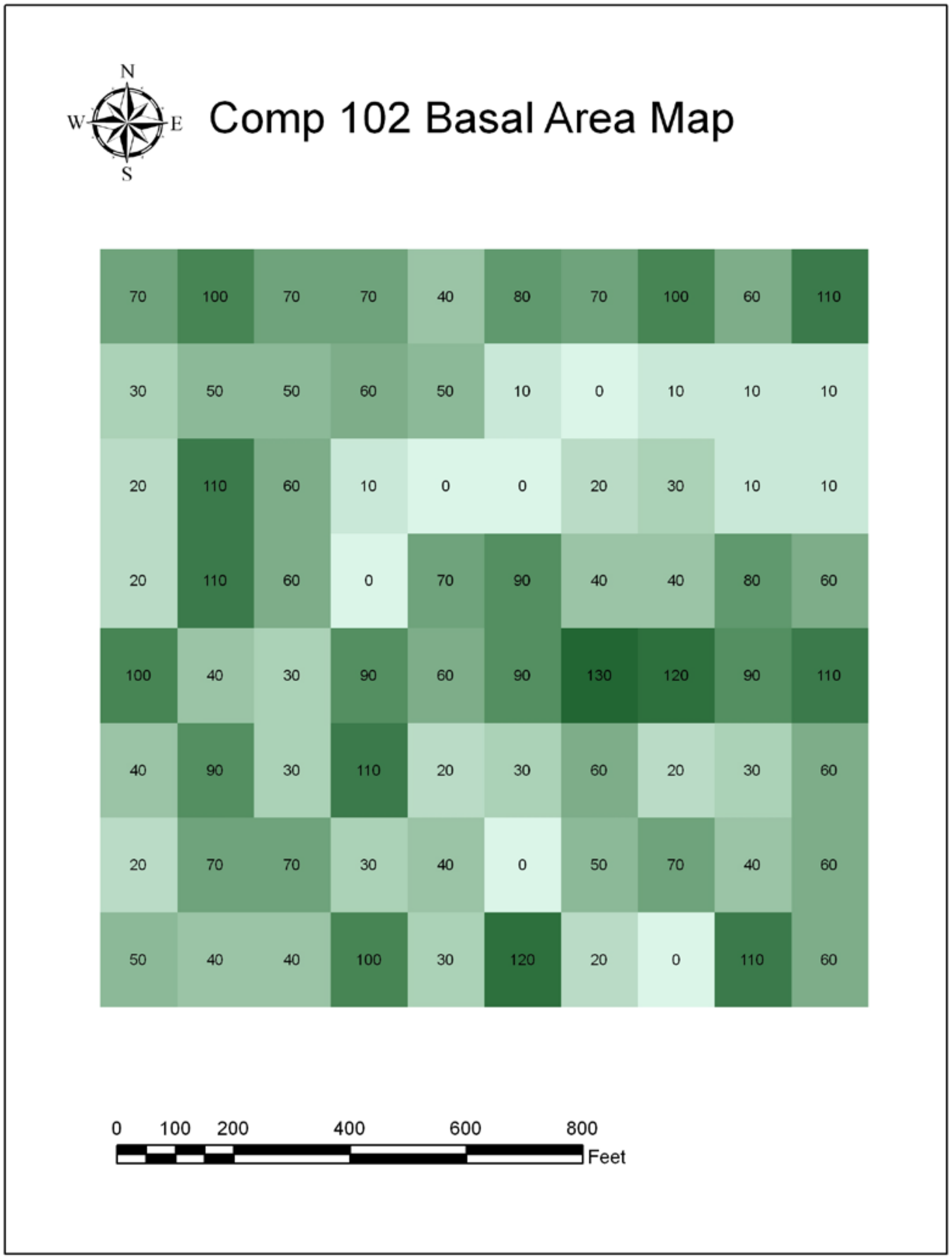
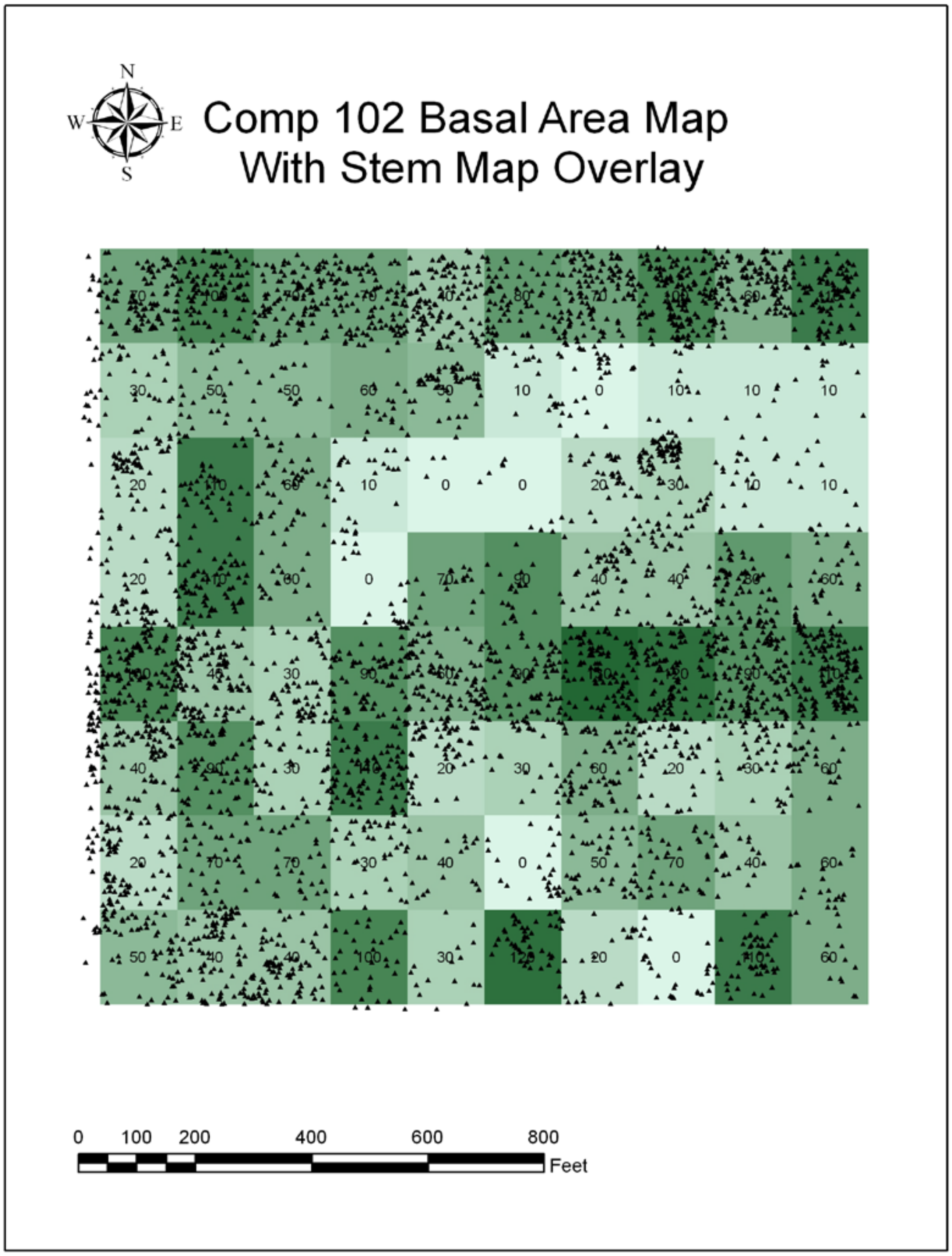


Figure 4.6.4: Comp. 102 Basal Area Map with Stem Map Overlay.



4.7 Marking the Allowable Cut

The final challenge in successfully managing an uneven-aged stand is marking the allowable cut. The goal often expressed is to accomplish the task in one pass, without having to revisit areas already marked. While this is a desirable goal in that accomplishing the task of marking in one pass saves time, and therefore money, it may not always be possible. Still, there are some steps that may be taken to improve marking efficiency. A basal area map derived from the prism cruise data will give the forester a good idea of how trees are distributed on the tract (See Figures 4.6.1 and 4.6.3). Simple marking rules or guidelines further help in the marking process.

The overarching goal of uneven-aged management is to perpetuate a progression of trees from one dbh class to the next over time, and maintaining or improving tree quality in the process. The well-established marking guideline of “take the worst and leave the best” in uneven-aged stands applies as the basic rule. This recommendation for uneven-aged stands dates back at least to European Dauerwald experiments of the late nineteenth century (Fernow 1913), through the Crossett Farm Forty studies in Arkansas (Reynolds 1969; Reynolds et al 1984), with good results over time (Guldin 1996). Building on that principle, if trees in each category can be understood as having a particular job or purpose in the stand structure, it may help in understanding marking guidelines. The purpose of the pulpwood component is to provide enough good quality trees to grow into and fully stock the pole component of the stand (in-growth). The purpose of the pole component is to fill out the bulk of the stand and provide in-growth into mature, cone-producing sawtimber. The purpose of the sawtimber component is to produce seed for regeneration, which provides for ingrowth into pulpwood category, thus continuing the cycle. While this is an oversimplification, marking rules inculcated by this thought process do help in marking efficiency.

Because the main purpose of the pulpwood component is to provide ingrowth to fill out the pole component, the primary marking concern is to remove culls, paying little or no attention to spacing. If the allowable cut from pulpwood is taken almost exclusively from culls, the negative impact from possibly overcutting is minimized. An error leading to overcutting in the pulpwood, if only culls were removed, will right itself in time through a more vigorous development of the over-thinned but high quality residual trees. Little is to be gained by carrying cull trees beyond the pulpwood class unless their presence is required to fill gaps to provide fuel, in the form of pine needles, for adequate fire intensity. Should an error in the estimate lead to undercutting, and a surplus is left, the surplus will likely be detected in subsequent estimates, which will be removed in the allowable cut at that time.

Trees in the pole category usually comprise the bulk of the stand in terms of basal area. Confidence in the estimate of this category is high, even though there may be errors within any dbh class. In this category, allowable cut may be more strictly adhered to as long as the rules for this size group are kept in mind. The first rule is to target culls that may have been missed in previous thinning. The next rule is to always leave the better tree when choosing which one to mark. Finally, never remove a tree if doing so will drop the basal area to 30 ft^2 or below in the immediate area, unless there is adequate regeneration in place. Lower basal areas may lessen the intensity of subsequent fires, increasing the likelihood of hardwood brush encroachment, and lessening effective seedbed preparation (Brockway et al 2005). Also, trees in this group, particularly in the lower diameter classes, are less likely than more mature trees to be reliable cone producers.

As trees mature into the sawtimber category, any culls should have long since been removed. Still favoring the best trees for retention, some attention to spacing may be considered as basal area is gradually reduced to encourage crown development, cone production and regeneration. Basal area should not be reduced below 30 ft^2 in any area unless established regeneration is being released, even if the allowable cut cannot be removed. The primary purpose of these mature trees is to regenerate the forest and it is better to retain a surplus for a time than to create un-regenerated gaps which could become brushy thickets requiring herbicide treatments or other expensive remediation in the future.

A common misperception when thinning to a target basal area is that the basal area should be distributed evenly across the stand, as with even-aged management. This is not the case, particularly with longleaf pine. The development of trees in gaps over time produces a clumpy mosaic of sub-stands of various age classes, characteristic of uneven-aged longleaf pine. Rather than trying to make an uneven-aged stand appear more evenly distributed, it is more important to make sure the best trees are retained, however distributed. A prism is only useful when marking to make sure that the basal area is not being reduced below 30 ft^2 in the absence of regeneration. Above that density, it is not important to try to mark using basal area as a guide. Tree condition and regeneration are more important factors in selecting trees for harvest and retention (Farrar 1996).

Even with experience and planning, it is not unlikely that a second pass may be necessary to finish marking the allowable cut. Once passing through the woods, though, the forester should have a good idea of where to find the needed trees, making short work of the second pass.

5. DISCUSSION

Many of the challenges of restoring and managing longleaf pine forests have been met with practical solutions in recent decades. Better planting techniques have increased successful regeneration of longleaf pine where previous attempts had met with failure. A better understanding of the functioning of the longleaf pine ecosystem and the critical role of fire in the forest have brought about many successful restoration projects across the longleaf range. Because so much of the longleaf pine region is privately owned, any meaningful impact on the continuity of the longleaf forest must be through restoration on private lands.

Most industrial forest ownerships are focused on the rapid production of specific products, and their management goals are achieved efficiently without longleaf pine. These companies have nothing to gain by restoring longleaf pine to their lands. However, most nonindustrial private landowners have a different set of management goals, including aesthetics, wildlife management, and nature protection among other values less tangible than timber production, but no less valuable in their opinion. These landowners are the most likely to benefit from restoration efforts because longleaf pine restoration addresses so many of the values they desire from forest ownership. Another management aspect that is likely to appeal to many landowners of this mind set is the maintenance of a continuous forest cover through the use of uneven-aged management.

The idea of uneven-aged management, while appealing, brings to the forefront a new set of challenges for the landowner and the managing forester. The added expense of obtaining reliable stocking data to determine allowable cut can be prohibitive. A poor understanding of regulation methods can lead a well-intentioned forester away from objective regulation toward some subjective procedure which could impact the long-term productivity of the forest, particularly if it leads to high-grading by favoring the removal of larger trees without recognizing the necessity to manage the rest of the stand.

The use of an easily understandable regulation method like WSR could be a helpful addition to a forester’s knowledge, giving results similar to other proven methods such as BDq. The bigger challenge to the managing forester then becomes obtaining reliable stocking data to determine the allowable cut, an expense not necessary in most phases of even-aged management, but always necessary in uneven-aged management.

The high variability inherent in an uneven-aged forest makes it difficult to obtain a statistically sound estimate through normal cruising methods, particularly on small tracts. For this reason, it has heretofore been recommended that allowable cut calculations should be based on a 100% inventory of the stand. This study has shown through direct comparisons with stem-mapped stands that usable estimates can be obtained through the use of traditional plot cruising and prism cruising methods for determining allowable cut.

Based on this study, it is recommended that foresters combine a 1/20 or 1/10 acre plot with a 10 BAF prism sample to obtain the data needed to estimate stocking for allowable cut calculation, using DBAR to improve accuracy of estimates of the smaller diameter classes. On smaller tracts (<80 acres), a 2x2.5 chain spacing will provide better coverage of the tract. On tracts ≥80 acres, a wider sample spacing should suffice. Adoption of WSR as an alternative method of defining target stand structure further simplifies the process. Adherence to the described marking rules will mitigate any long term damage from any errors that may occur in the estimate.

The focus of this study has been on uneven-aged management of longleaf pine in terms of stand structure. It must be insisted, though, that no longleaf pine restoration efforts can be successful without the frequent use of fire. Longleaf pine can be grown without fire, but the longleaf pine ecosystem cannot be restored or maintained without it. Because successful uneven-aged management is so dependent on continuous natural regeneration, the need for the knowledgeable and skilled use of prescribed fire cannot be overemphasized.

Restoration of the longleaf pine ecosystem is a worthwhile goal becoming popular with many landowners. As uneven-aged management may be a better fit for some of these landowners, it behooves today's foresters to learn more about it, and proceed with confidence.

6. LITERATURE CITED

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7. APPENDICES

Appendix 7.1: Farm Forty, Comparison of cruise methods

Table 7.1.1: Farm Forty. 10BAF Cruise, 2x2.5 chain grid, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	2063	180.031	2038	177.849	+ 1.23	
6	1324	259.967	1143	224.428	+15.84	
8	931	324.980	737	257.262	+26.32	
PW:	**4318**	**764.978 ft^2**	**3918**	**659.539 ft^2**	**+10.21%**	**+15.99%**
10	706	385.063	702	382.882	+ 0.57	
12	509	399.768	563	442.179	- 9.59	
14	276	295.048	286	305.738	- 3.50	
16	158	220.610	142	198.269	+11.27	
PO:	**1649**	**1300.489 ft^2**	**1693**	**1329.068 ft^2**	**- 2.60%**	**- 2.15%**
18	124	219.126	131	231.496	- 5.34	
20	76	165.806	70	152.716	+ 8.57	
22	44	116.152	44	116.152	0.00	
24+	18	60.454	18	62.221	0.00	- 2.84
ST:	**262**	**561.538 ft^2**	**263**	**562.585 ft^2**	**- 0.38%**	**- 0.19%**
All:	**6229**	**2627.005 ft^2**	**5874**	**2551.192 ft^2**	**+ 6.04%**	**+ 2.97%**

Figure 7.1.1: Farm Forty. Graphic comparison of data from Table 7.1.1. 10BAF cruise on 2x2.5 chain grid, compared to 100% inventory.

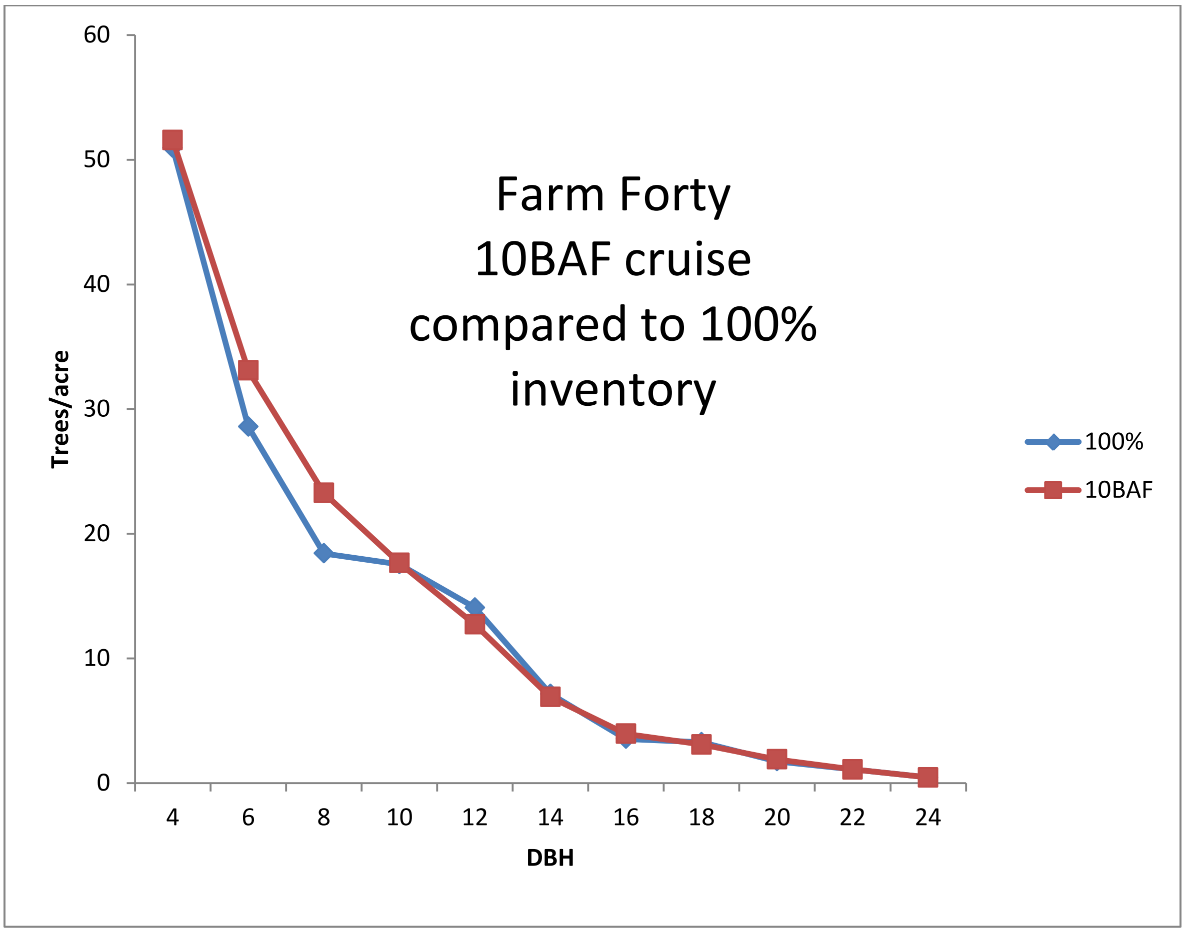


Figure 7.1.2: Farm Forty estimate of current stocking. Detail of results in pulpwood category using 10BAF cruise on 2x2.5 chain grid, compared to 100% inventory.

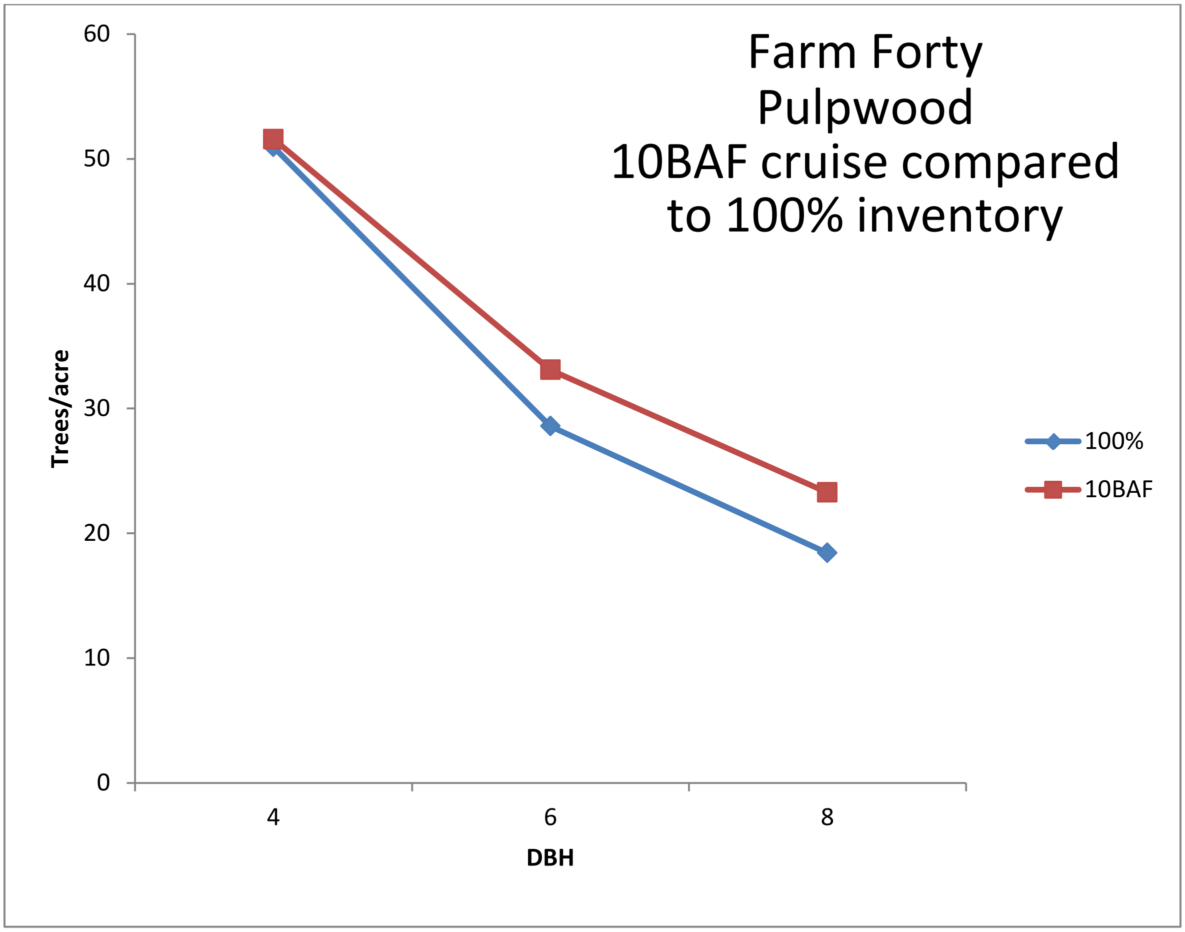


Figure 7.1.3: Farm Forty estimate of current stocking. Detail of results in pole category using 10BAF cruise on 2x2.5 chain grid, compared to 100% inventory.

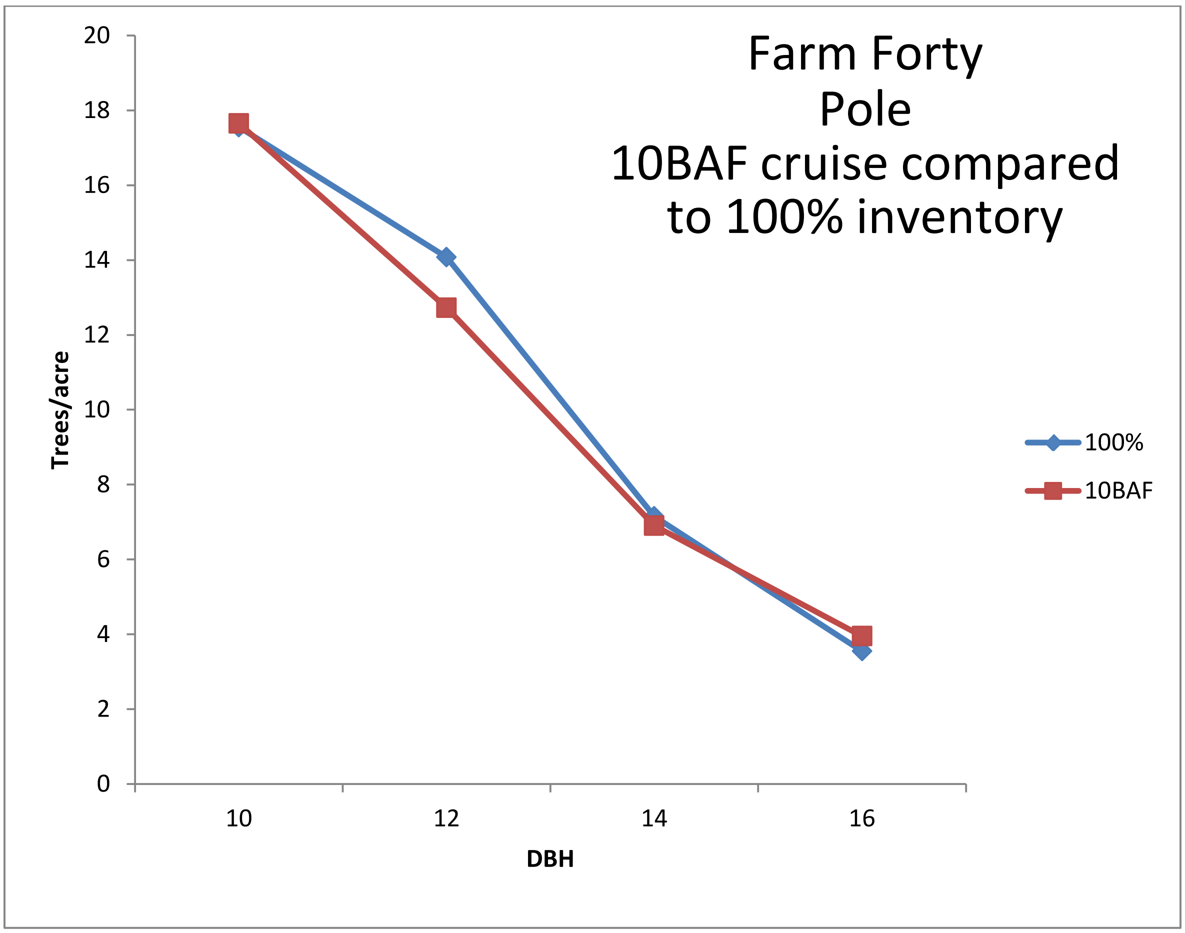


Figure 7.1.4: Farm Forty estimate of current stocking. Detail of results in sawtimber category using 10BAF cruise on 2x2.5 chain grid, compared to 100% inventory.

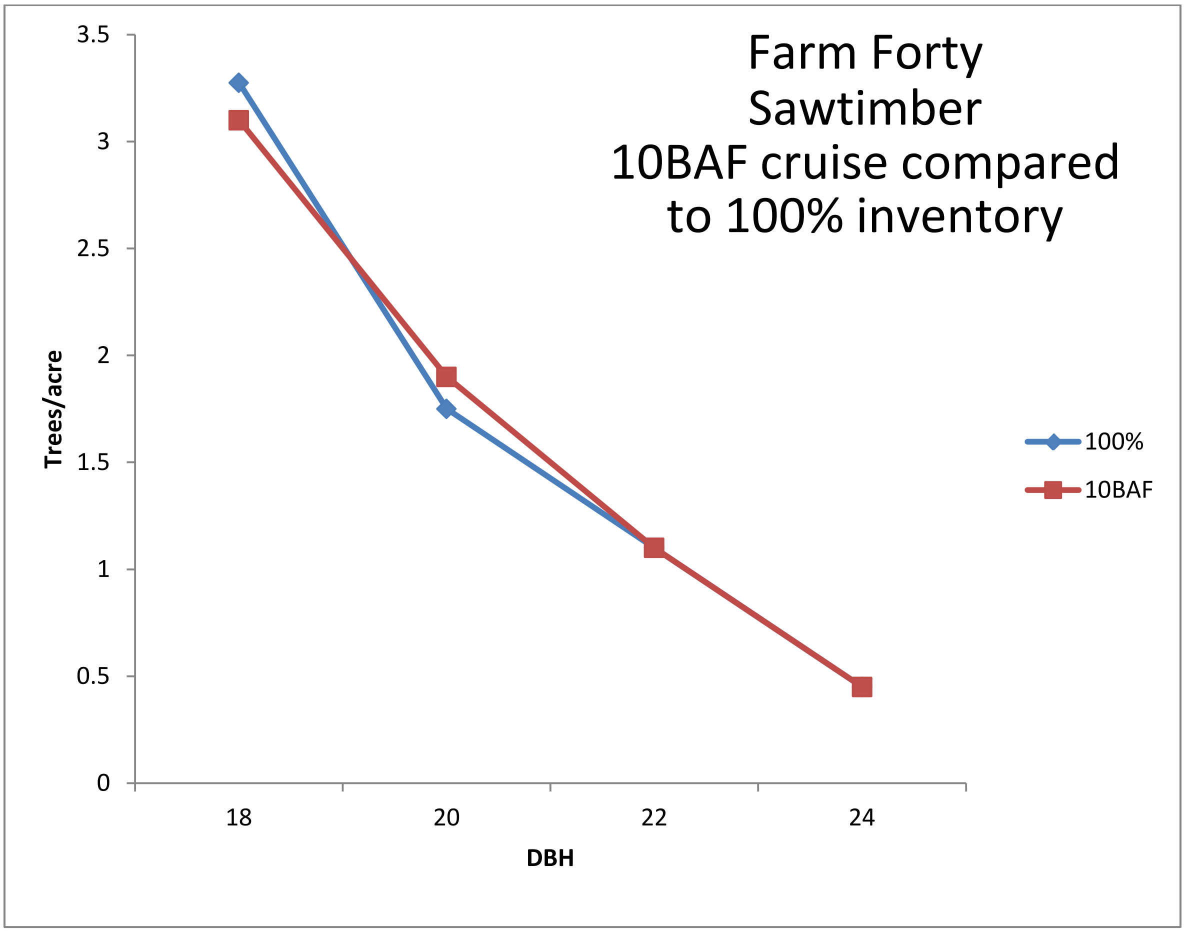


Table 7.1.2: Farm Forty. 1/20 acre (10%) Cruise, 2x2.5 chain grid, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1960	171.042	2038	177.849	- 3.83	
6	1290	253.291	1143	224.428	+12.86	
8	800	279.253	737	257.262	+ 8.55	
PW:	**4050**	**703.586 ft^2**	**3918**	**659.539 ft^2**	**+ 3.37%**	**+ 6.68%**
10	690	376.337	702	382.882	- 1.71	
12	550	431.969	563	442.179	- 2.31	
14	360	384.845	286	305.738	+25.87	
16	200	279.253	142	198.269	+40.84	
PO:	**1800**	**1472.404 ft^2**	**1693**	**1329.068 ft^2**	**+ 6.32%**	**+10.78%**
18	170	300.415	131	231.496	+29.77	
20	60	130.900	70	152.716	- 14.28	
22	60	158.389	44	116.152	+36.36	
24+	10	31.416	18	62.221	- 44.44	- 49.51
ST:	**300**	**621.120 ft^2**	**263**	**562.585 ft^2**	**+14.07%**	**+10.40%**
All:	**6150**	**2797.110 ft^2**	**5874**	**2551.192 ft^2**	**+ 4.70%**	**+ 9.64%**

Table 7.1.3: Farm Forty. 1/20 acre (10%) Cruise + DBAR, 2x2.5 chain grid, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1857	162.053	2038	177.849	- 8.88	
6	1222	239.939	1143	224.428	+ 6.91	
8	758	264.592	737	257.262	+ 2.85	
PW:	**3837**	**666.584 ft^2**	**3918**	**659.539 ft^2**	**- 2.07%**	**+ 1.07%**
10	654	356.702	702	382.882	- 6.84	
12	521	409.192	563	442.179	- 7.46	
14	341	364.534	286	305.738	+19.23	
16	189	263.894	142	198.269	+33.10	
PO:	**1705**	**1394.322 ft^2**	**1693**	**1329.068 ft^2**	**+ 0.71%**	**+ 4.91%**
18	161	284.510	131	231.496	+22.90	
20	57	124.355	70	152.716	- 18.57	
22	57	150.469	44	116.152	+29.54	
24+	10	31.416	18	62.221	- 44.44	- 49.51
ST:	**285**	**590.750 ft^2**	**263**	**562.585 ft^2**	**+ 8.36%**	**+ 5.01%**
All:	**5827**	**2651.656 ft^2**	**5874**	**2551.192 ft^2**	**- 0.80%**	**+ 3.94%**

Figure 7.1.5: Farm Forty estimate of current stocking. Graphic comparison of data from Table 7.1.2 and Table 7.1.3. 1/20 acre and 1/20 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

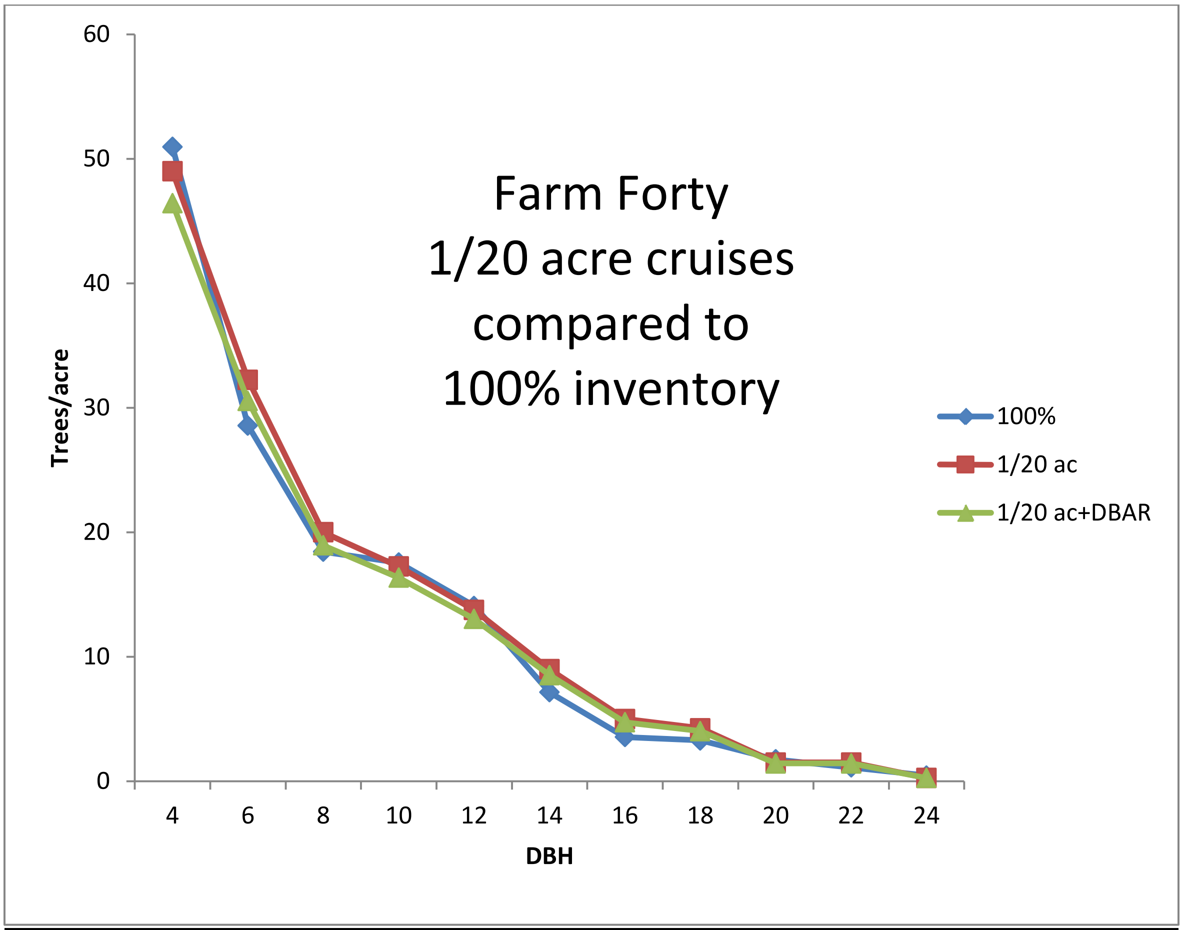


Figure 7.1.6: Farm Forty estimate of current stocking. Detail of results in pulpwood category using 1/20 acre and 1/20 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

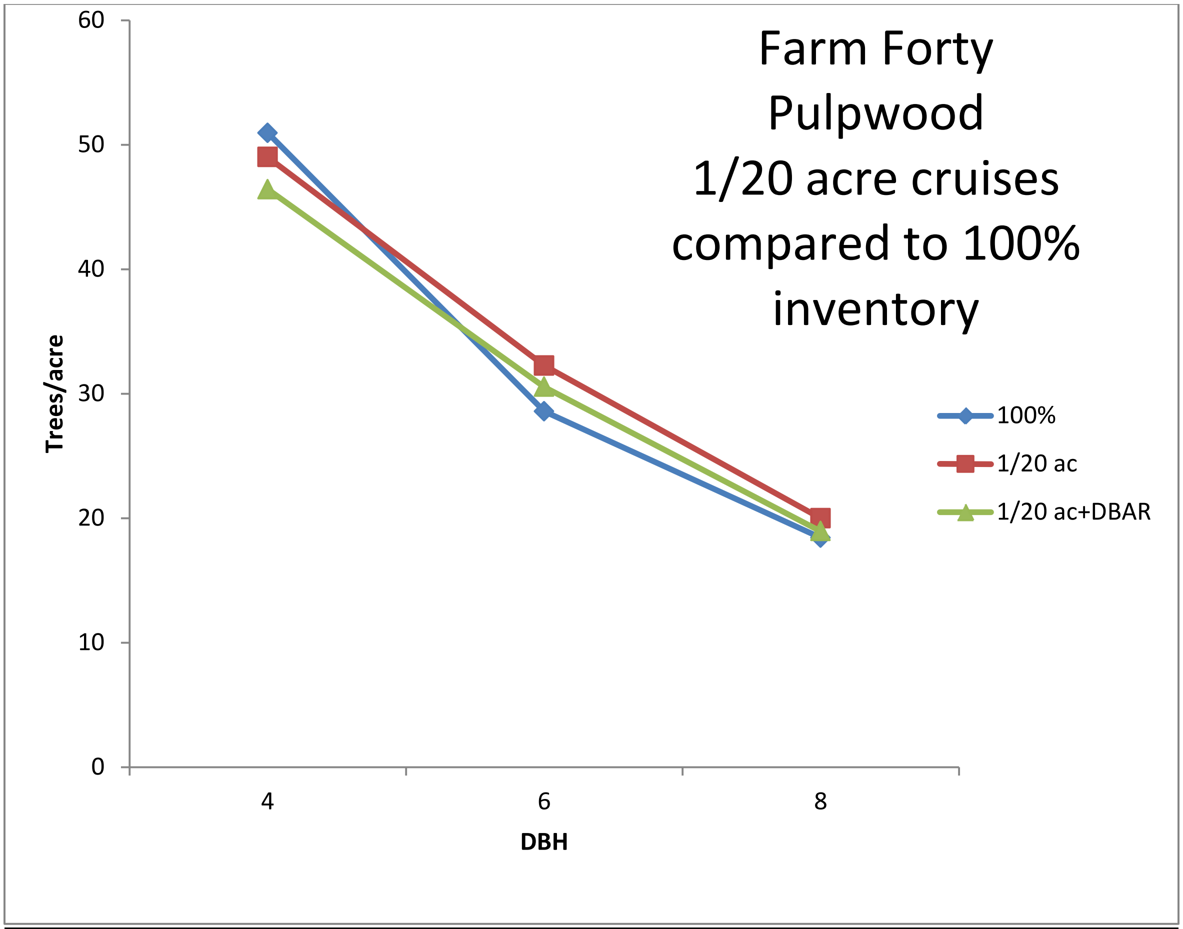


Figure 7.1.7: Farm Forty estimate of current stocking. Detail of results in pole category using 1/20 acre and 1/20 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

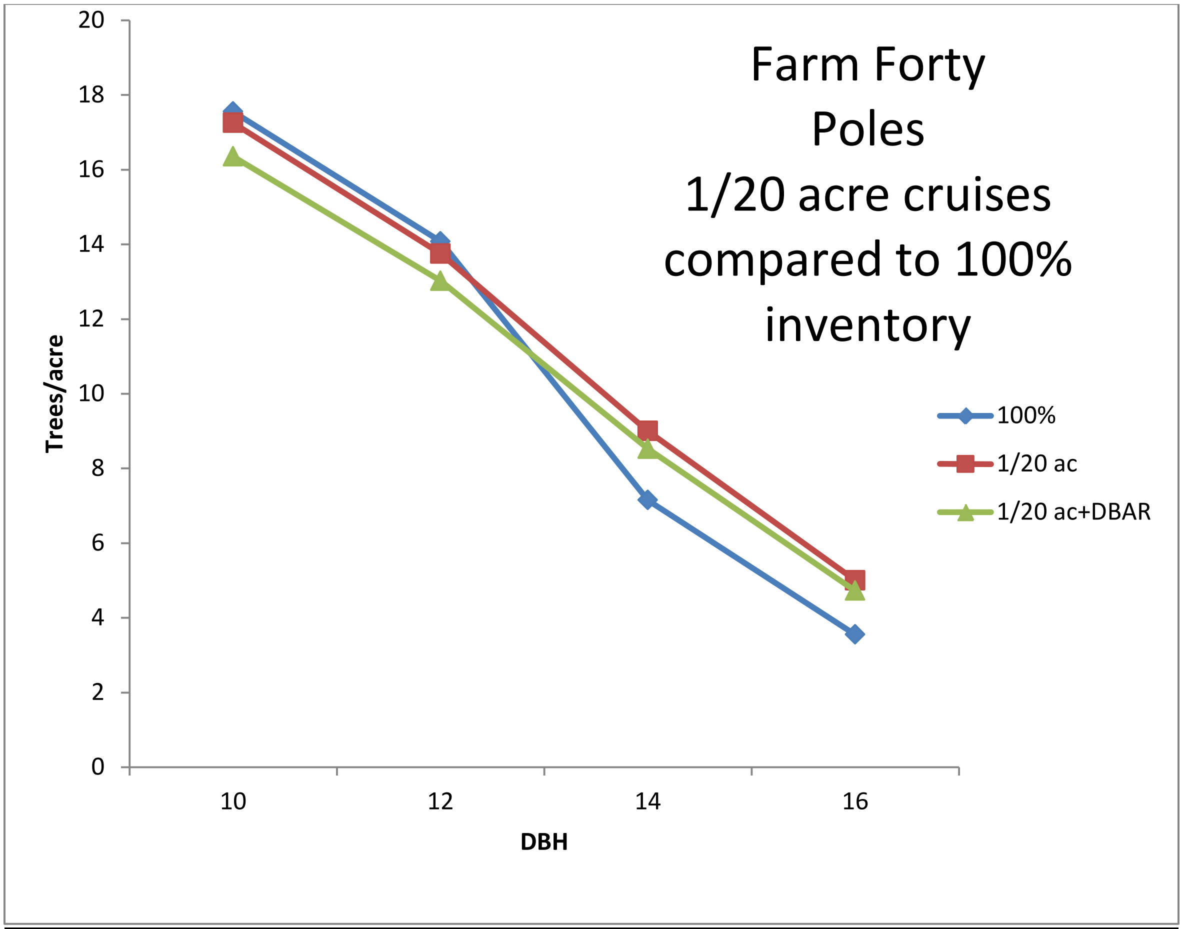


Figure 7.1.8: Farm Forty estimate of current stocking. Detail of results in sawtimber category using 1/20 acre and 1/20 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

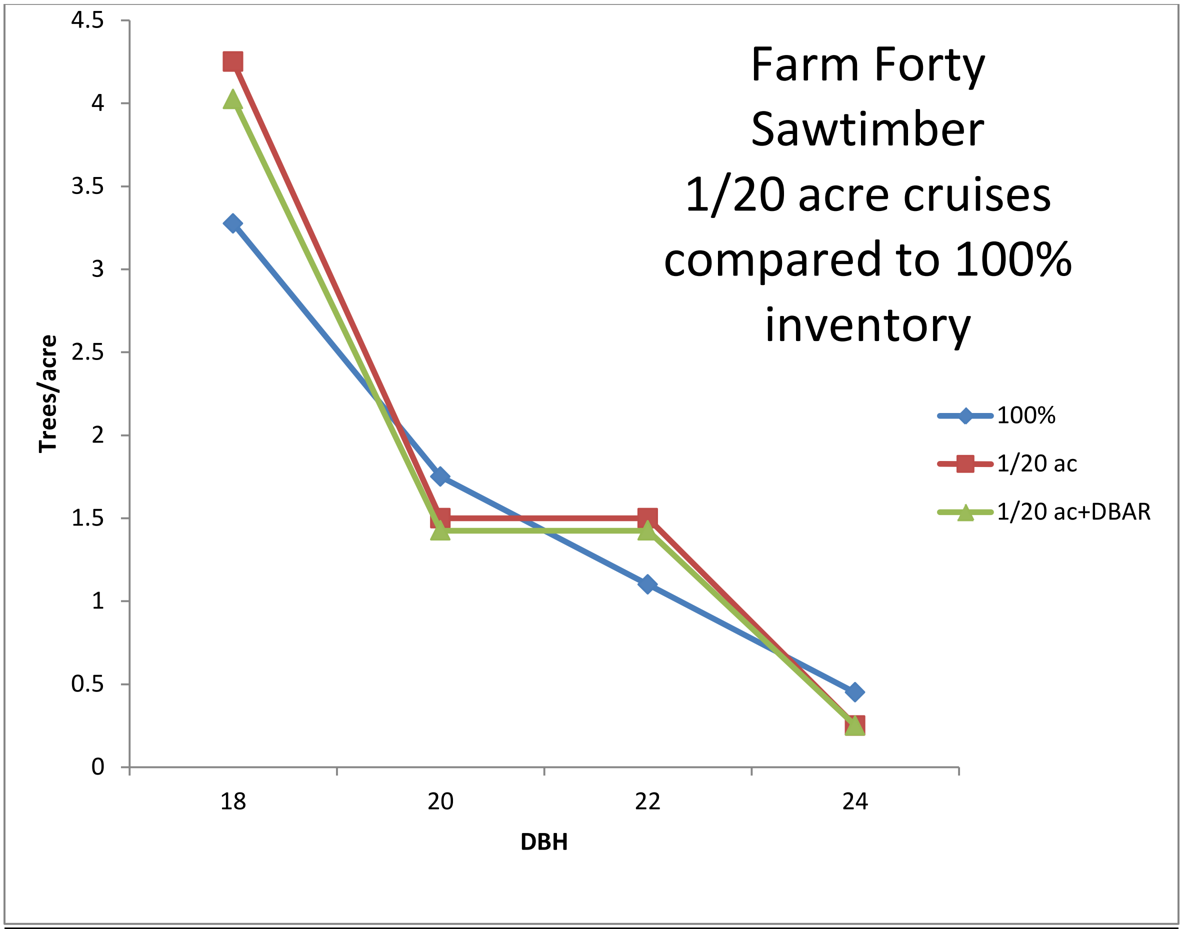


Table 7.1.4: Farm Forty. 1/10 acre (20%) Cruise, 2x2.5 chain grid, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	2010	175.406	2038	177.849	- 1.37	
6	1200	235.619	1143	224.428	+ 4.99	
8	730	254.818	737	257.262	- 0.95	
PW:	**3940**	**665.843 ft^2**	**3918**	**659.539 ft^2**	**+ 0.56%**	**+ 0.96%**
10	725	395.426	702	382.882	+ 3.28	
12	530	416.261	563	442.179	- 5.86	
14	275	293.979	286	305.738	- 3.85	
16	185	258.309	142	198.269	+30.28	
PO:	**1715**	**1363.975 ft^2**	**1693**	**1329.068 ft^2**	**+ 1.30%**	**+ 2.63%**
18	145	256.236	131	231.496	+10.69	
20	85	185.441	70	152.716	+21.43	
22	55	145.190	44	116.152	+25.00	
24+	20	71.231	18	62.221	+11.11	+14.48
ST:	**305**	**658.098 ft^2**	**263**	**562.585 ft^2**	**+15.97%**	**+16.98%**
All:	**5960**	**2687.916 ft^2**	**5874**	**2551.192 ft^2**	**+ 1.46%**	**+ 5.36%**

Table 7.1.5: Farm Forty. 1/10 acre (20%) Cruise + DBAR, 2x2.5 chain grid, compared to 100% inventory.

	CRUISE		**100%**		**% ERROR**	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1982	172.962	2038	177.849	- 2.75	
6	1183	232.282	1143	224.428	+ 3.50	
8	720	251.327	737	257.262	- 2.31	
PW:	**3885**	**656.571 ft^2**	**3918**	**659.539 ft^2**	**- 0.84%**	**- 0.45%**
10	715	389.972	702	382.882	+ 1.85	
12	522	409.978	563	442.179	- 7.28	
14	271	289.703	286	305.738	- 5.24	
16	182	254.120	142	198.269	+28.17	
PO:	**1690**	**1343.773 ft^2**	**1693**	**1329.068 ft^2**	**- 0.18%**	**- 1.11%**
18	143	252.702	131	231.496	+ 9.16	
20	84	183.260	70	152.716	+20.00	
22	54	142.550	44	116.152	+22.73	
24+	20	71.231	18	62.221	+11.11	+14.48
ST:	**301**	**649.743 ft^2**	**263**	**562.585 ft^2**	**+14.45%**	**+15.49%**
All:	**5876**	**2650.087 ft^2**	**5874**	**2551.192 ft^2**	**+ 0.03%**	**+ 3.88%**

Figure 7.1.9: Farm Forty estimate of current stocking. Graphic comparison of data from Table 7.1.4 and Table 7.1.5. 1/10 acre and 1/10 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

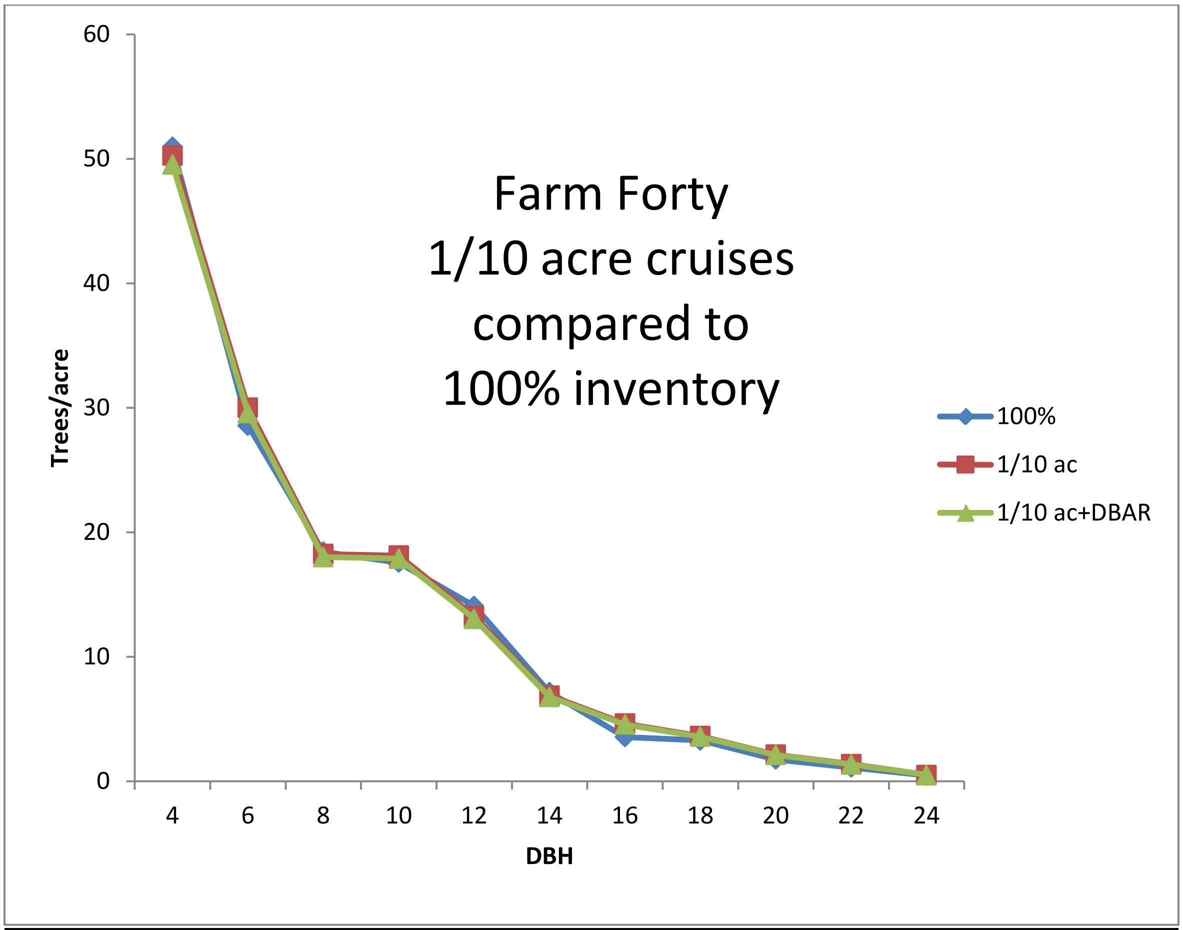


Figure 7.1.10: Farm Forty estimate of current stocking. Detail of results in pulpwood category using 1/10 acre and 1/10 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

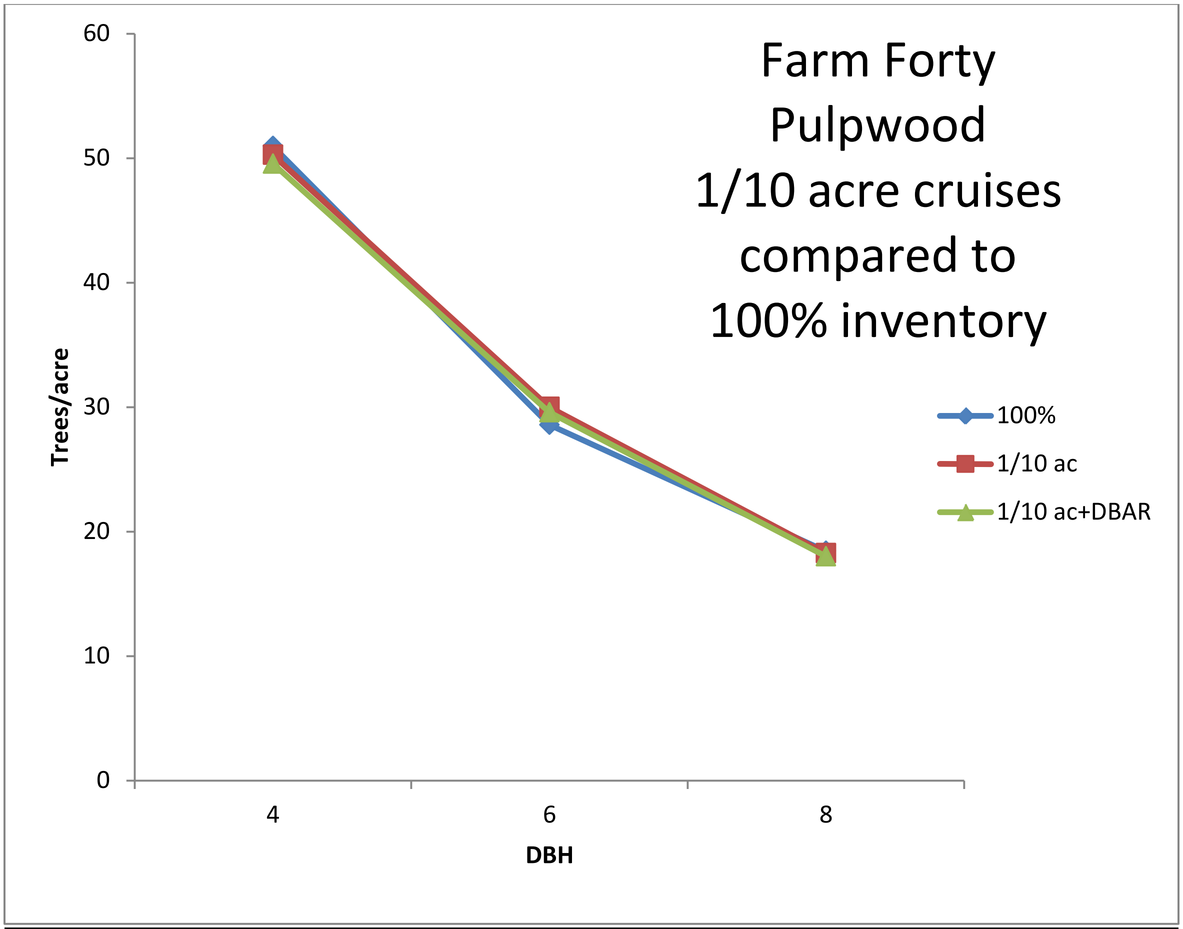


Figure 7.1.11: Farm Forty estimate of current stocking. Detail of results in pole category using 1/10 acre and 1/10 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

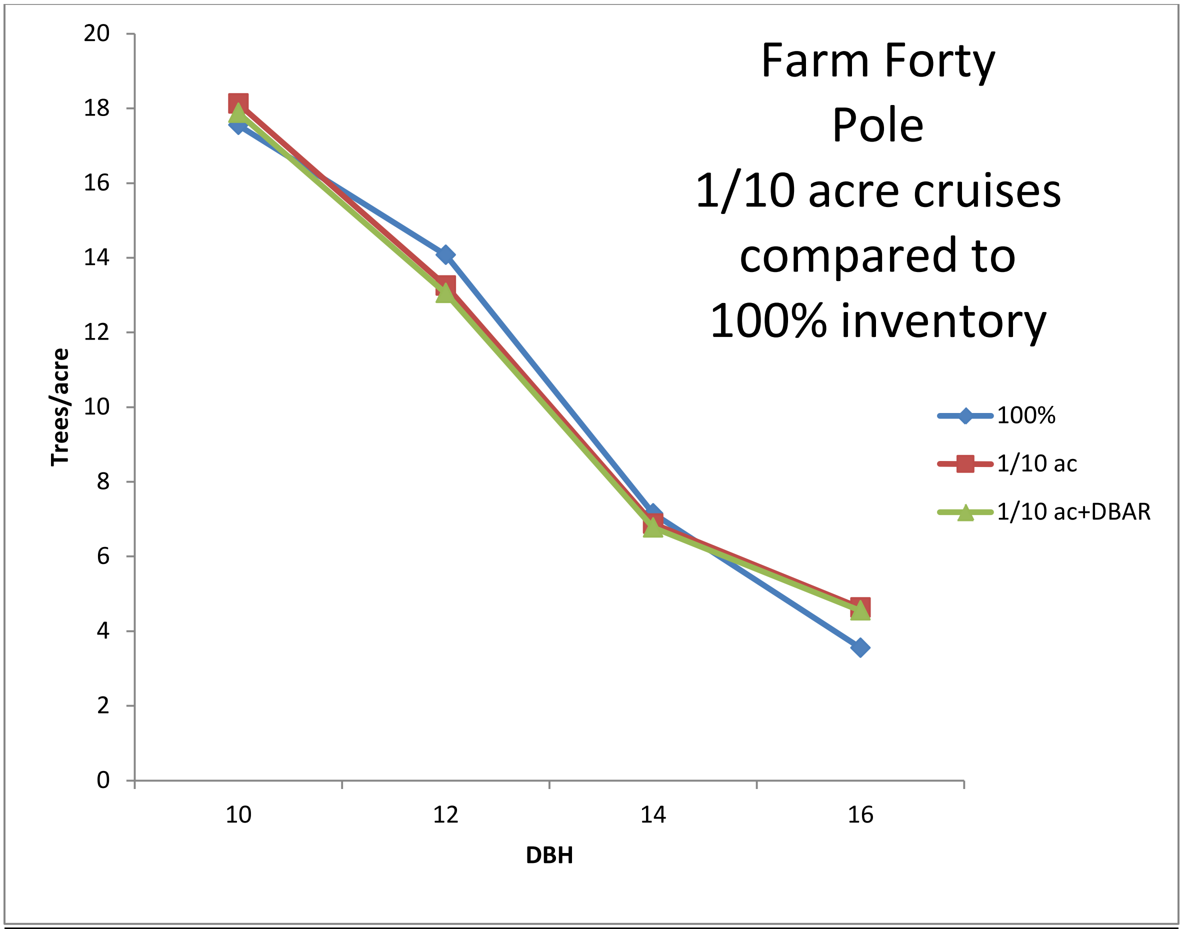


Figure 7.1.12: Farm Forty estimate of current stocking. Detail of results in sawtimber category using 1/10 acre and 1/10 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

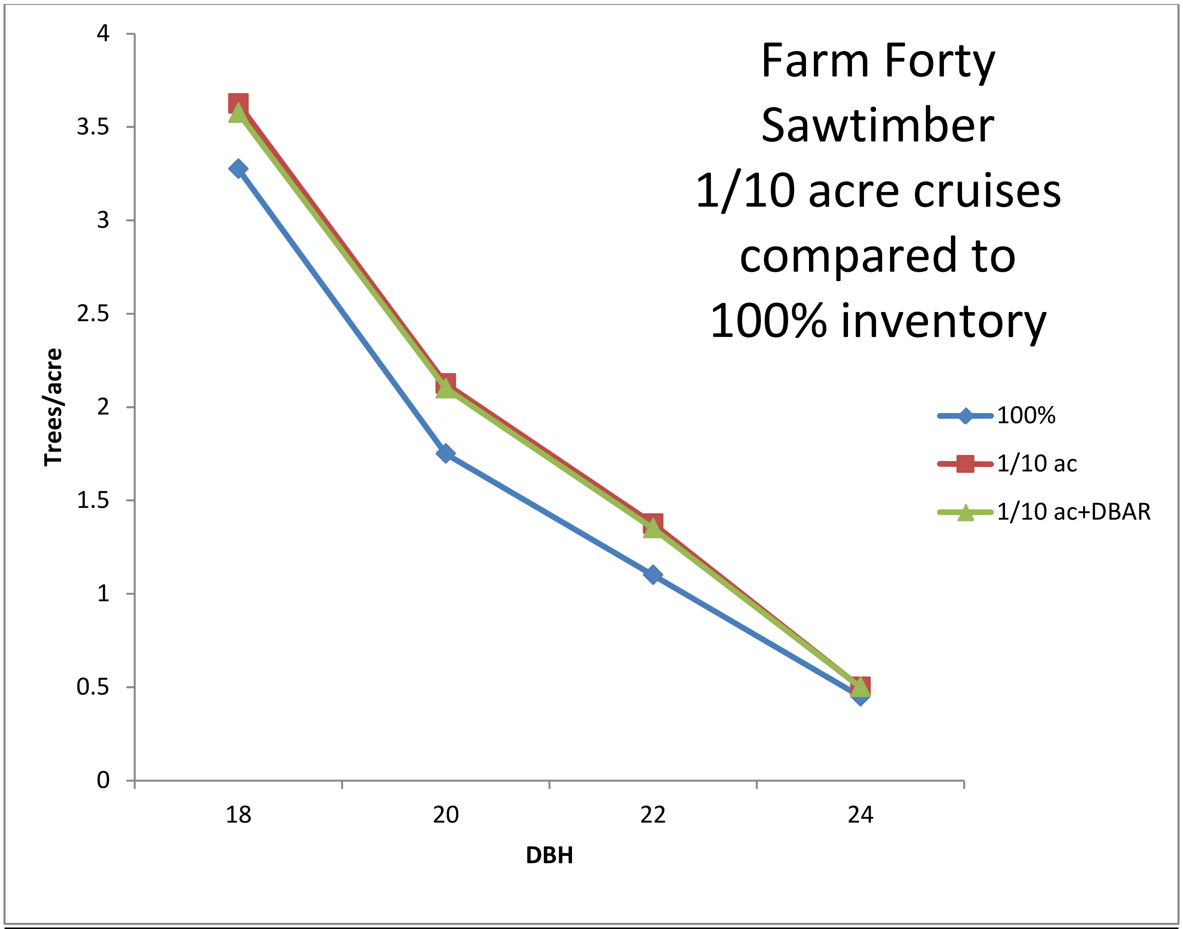


Table 7.1.6: Farm Forty. 33 ft. strip (20%) Cruise, 2.5 chain centers running east/west, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	2330	203.331	2038	177.849	+14.33	
6	1330	261.145	1143	224.428	+16.36	
8	830	289.724	737	257.262	+12.62	
PW:	**4490**	**754.200 ft^2**	**3918**	**659.539 ft^2**	**+14.60%**	**+14.35%**
10	740	403.607	702	382.882	+ 5.41	
12	550	431.969	563	442.179	- 2.31	
14	295	315.359	286	305.738	+ 3.15	
16	185	285.309	142	198.269	+30.28	
PO:	**1770**	**1436.244 ft^2**	**1693**	**1329.068 ft^2**	**+ 4.55%**	**+ 8.06%**
18	125	220.893	131	231.496	- 4.58	
20	55	119.991	70	152.716	- 21.43	
22	40	105.592	44	116.152	- 9.09	
24+	20	68.504	18	62.221	+11.11	+10.10
ST:	**240**	**514.980 ft^2**	**263**	**562.585 ft^2**	**- 8.74%**	**- 8.46%**
All:	**6500**	**2705.424 ft^2**	**5874**	**2551.192 ft^2**	**+10.66%**	**+ 6.04%**

Table 7.1.7: Farm Forty. 33 ft. strip (20%) Cruise + DBAR, 2.5 chain centers running east/west, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	2282	199.142	2038	177.849	+11.97	
6	1303	255.843	1143	224.428	+14.00	
8	813	283.790	737	257.262	+10.31	
PW:	**4398**	**738.775 ft^2**	**3918**	**659.539 ft^2**	**+12.25%**	**+12.01%**
10	725	395.426	702	382.882	+ 3.28	
12	539	423.330	563	442.179	- 4.26	
14	289	308.945	286	305.738	+ 1.05	
16	181	252.724	142	198.269	+27.46	
PO:	**1734**	**1380.425 ft^2**	**1693**	**1329.068 ft^2**	**+ 2.42%**	**+ 3.86%**
18	122	215.592	131	231.496	- 6.87	
20	54	117.810	70	152.716	- 22.86	
22	39	102.593	44	116.152	- 11.36	
24+	20	68.504	18	62.221	+11.11	+10.10
ST:	**235**	**504.499 ft^2**	**263**	**562.585 ft^2**	**- 10.65%**	**- 10.32%**
All:	**6367**	**2623.699 ft^2**	**5874**	**2551.192 ft^2**	**+ 8.39%**	**+ 2.84%**

Table 7.1.8: Farm Forty – 2x2.5 chain cruise. Error by category compared to 100% inventory, expressed as percentage. Highlighted cells are <6% error in number of trees.

Cruise Method	Pulpwood		Poles		Sawtimber		Overall	
Cruise	**No.**	**BA**	**No.**	**BA**	**No.**	**BA**	**No.**	**BA**
10 BAF	+10.21	+15.99	- 2.60	- 2.15	- 0.38	- 0.19	+ 6.04	+ 2.97
1/20 ac. (10%)	+ 3.37	+ 6.68	+ 6.32	+10.78	+14.07	+10.40	+ 4.70	+ 9.64
1/20 ac. + DBAR	- 2.07	+ 1.07	+ 0.71	+ 4.91	+ 8.36	+ 5.01	- 0.65	+ 3.97
1/10 ac. (20%)	+ 0.56	+ 0.96	+ 1.30	+ 2.63	+15.97	+16.98	+ 1.46	+ 5.36
1/10 ac. + DBAR	- 0.84	- 0.45	- 0.18	- 1.11	+14.45	+15.49	+ 0.03	+ 3.88
33' strip (20%)	+14.60	+14.35	+ 4.55	+ 8.06	- 8.74	- 8.46	+10.66	+ 6.04
33' strip + DBAR	+12.25	+12.01	+ 2.42	+ 3.86	- 10.65	- 10.32	+ 8.39	+ 2.84

Figure 7.1.13: Farm Forty estimate of current stocking. Graphic comparison of data from Table 7.1.6 and Table 7.1.7. 33 ft. strip and 33 ft. strip + DBAR cruise on 2.5 chain centers running east/west, compared to 100% inventory.

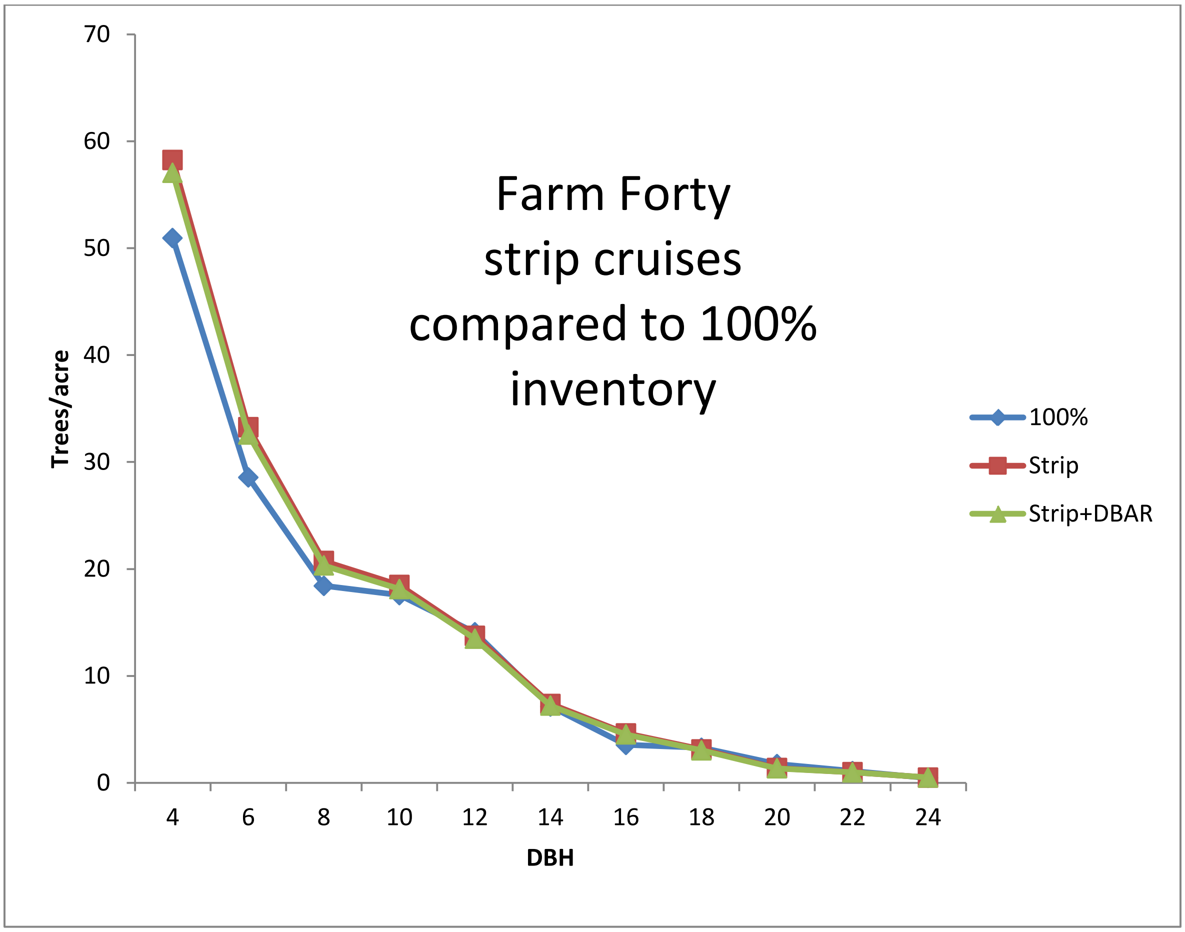


Figure 7.1.14: Farm Forty estimate of current stocking. Detail of results in pulpwood category using 33 ft. strip and 33 ft. strip + DBAR cruise on 2.5 chain centers, compared to 100% inventory.

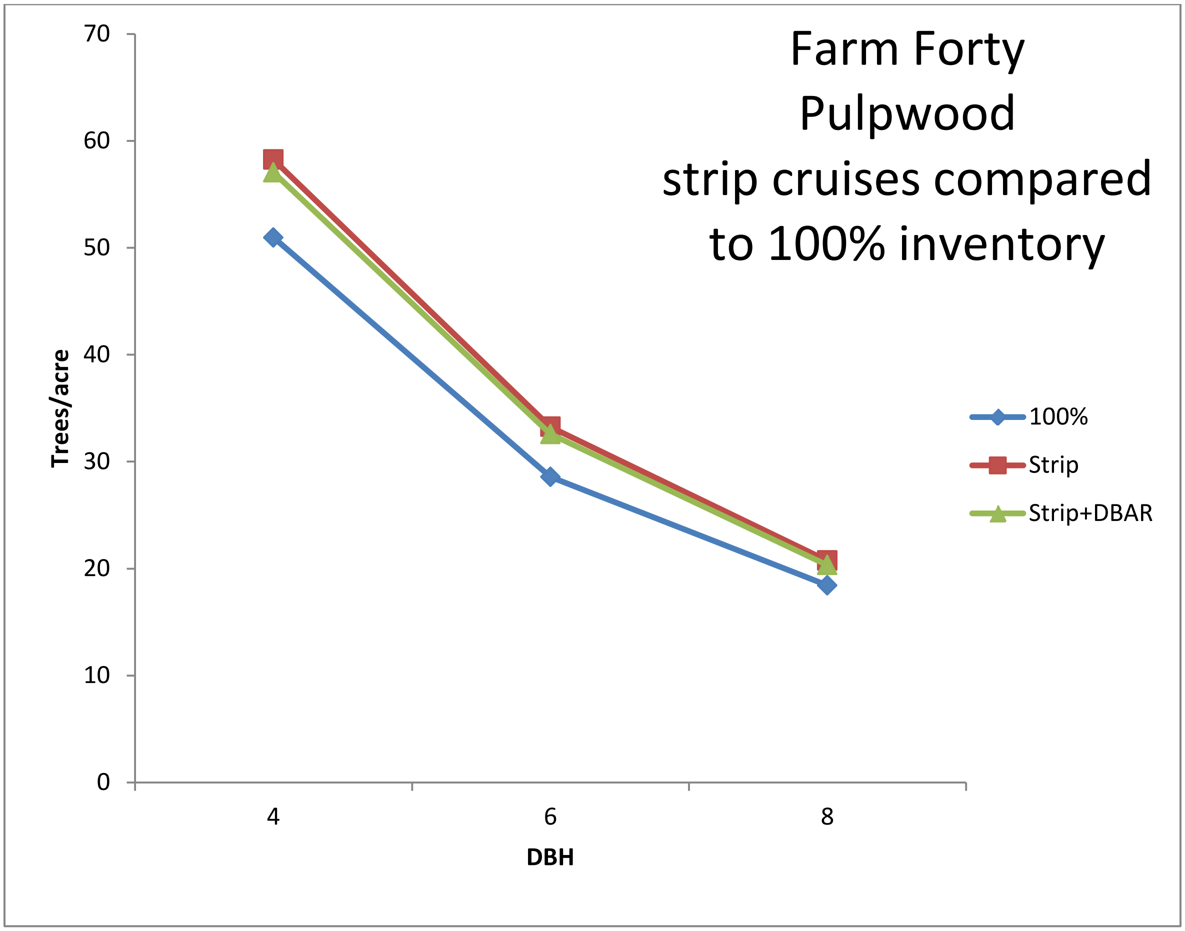


Figure 7.1.15: Farm Forty estimate of current stocking. Detail of results in pole category using 33 ft. strip and 33 ft. strip + DBAR cruise on 2.5 chain centers, compared to 100% inventory.

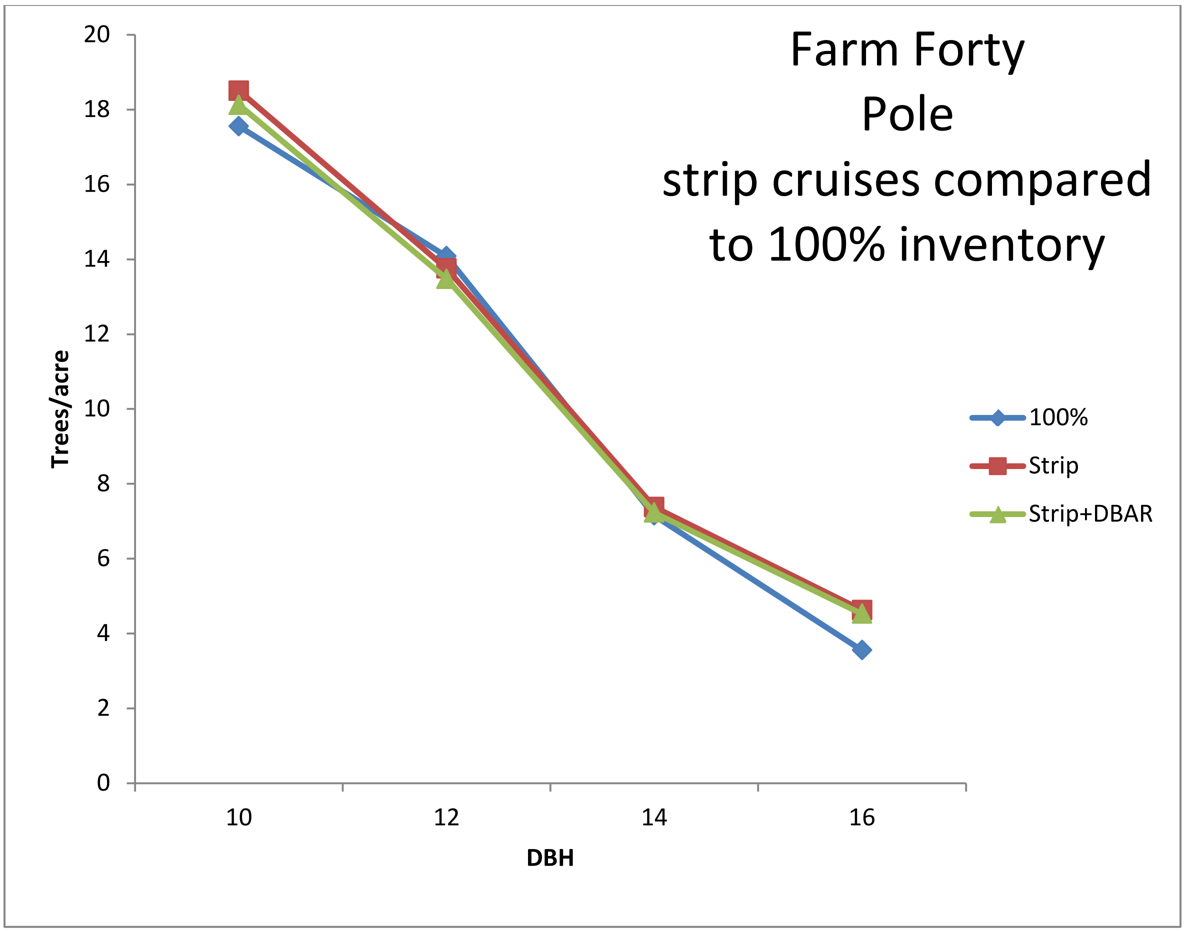
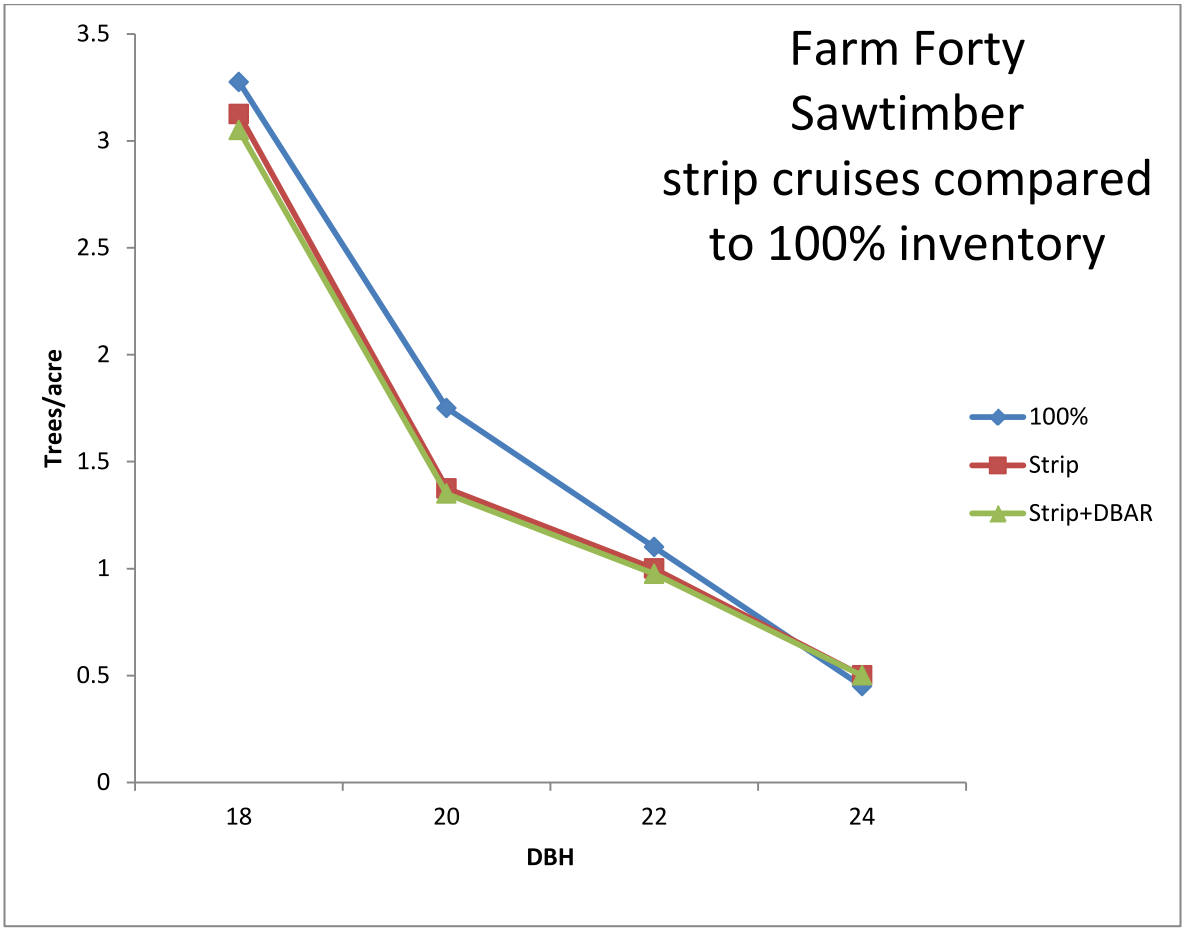


Figure 7.1.16: Farm Forty estimate of current stocking. Detail of results in sawtimber category using 33 ft. strip and 33 ft. strip + DBAR cruise on 2.5 chain centers, compared to 100% inventory.



Appendix 7.2: Comp 102, Comparison of Cruise Methods

Table 7.2.1: Comp. 102. 10BAF Cruise, 2x2.5 chain grid, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1146	100.007	1341	117.024	- 14.54	
6	713	139.997	818	160.614	- 12.84	
8	859	299.848	639	223.053	+34.43	
PW:	**2718**	**539.582 ft^2**	**2798**	**500.691 ft^2**	**+ 2.86%**	**+ 7.82%**
10	596	325.068	495	269.981	+20.40	
12	325	255.254	398	312.588	- 18.34	
14	337	360.258	381	407.294	- 11.55	
16	272	379.784	259	361.632	+ 5.02	
PO:	**1530**	**1320.364 ft^2**	**1533**	**1351.495 ft^2**	**- 0.20%**	**- 2.30%**
18	113	252.237	106	187.317	+ 6.60	
20	28	61.086	28	61.086	0.00	
22	4	10.559	3	7.919	+33.33	
ST:	**145**	**323.882 ft^2**	**137**	**256.322 ft^2**	**+ 5.84%**	**+26.33%**
All:	**4393**	**2184.098 ft^2**	**4468**	**2108.508 ft^2**	**- 1.68%**	**+ 3.58%**

Figure 7.2.1: Comp. 102. Graphic comparison of data from Table 7.2.1. 10BAF cruise on 2x2.5 chain grid, compared to 100% inventory.

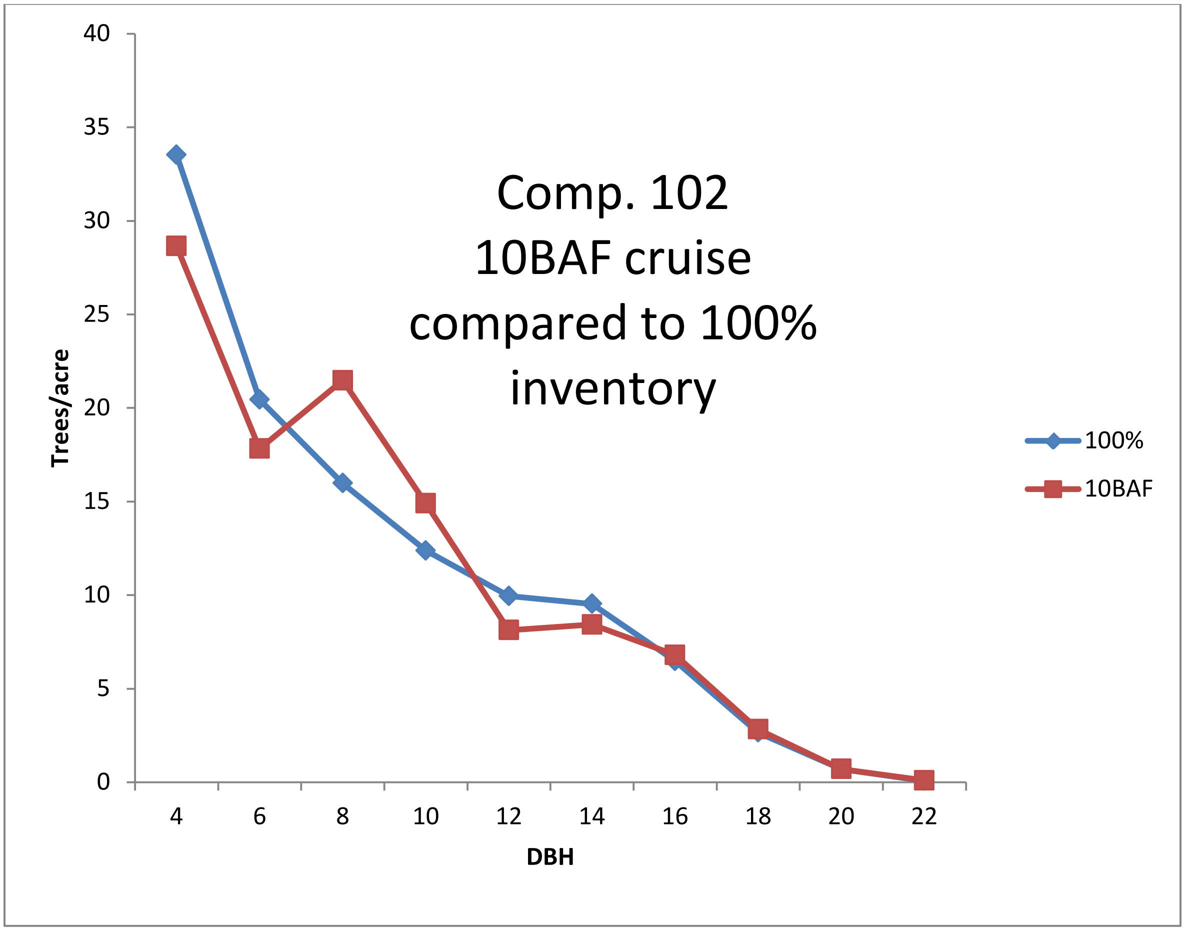


Figure 7.2.2: Comp. 102 estimate of current stocking. Detail of results in pulpwood category using 10BAF cruise on 2x2.5 chain grid, compared to 100% inventory.

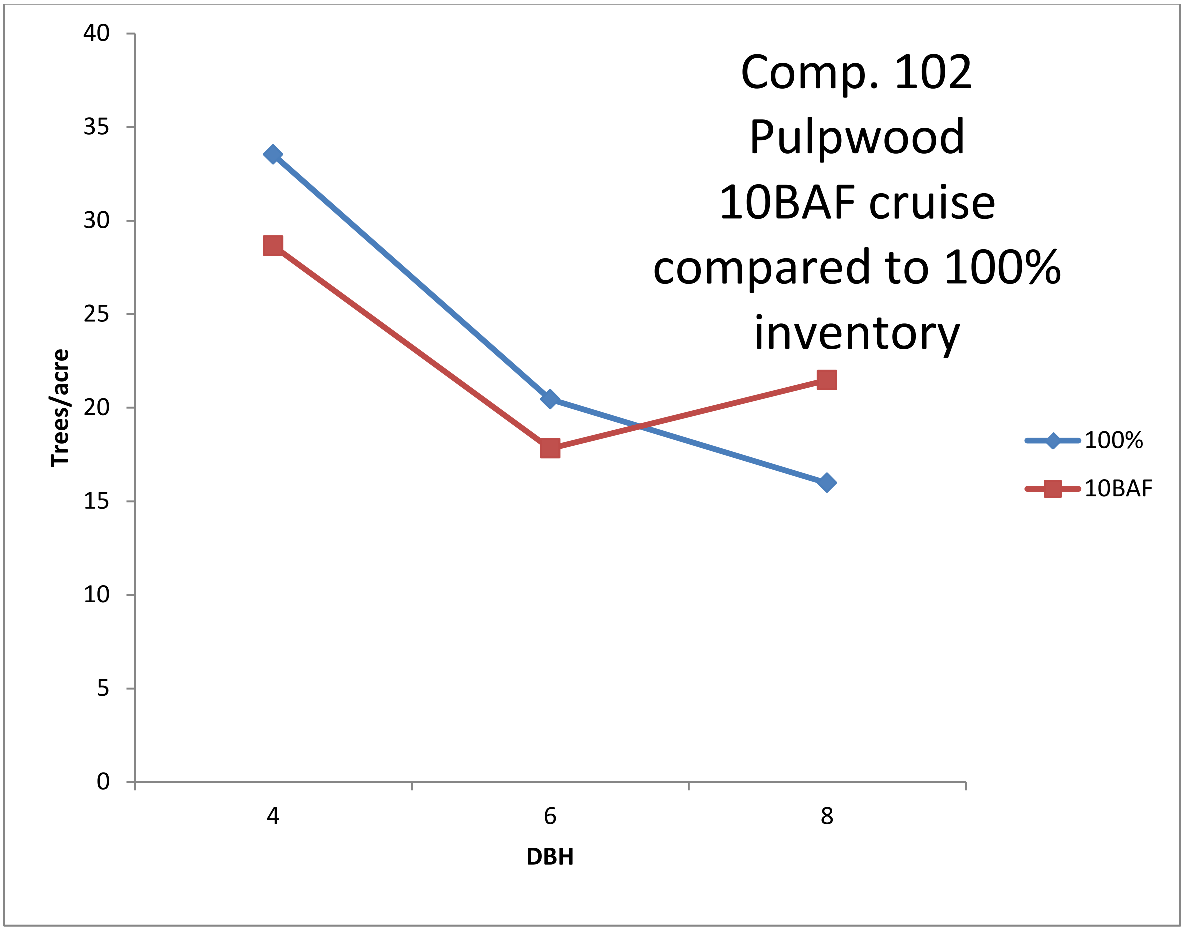


Figure 7.2.3: Comp. 102 estimate of current stocking. Detail of results in pole category using 10BAF cruise on 2x2.5 chain grid, compared to 100% inventory.

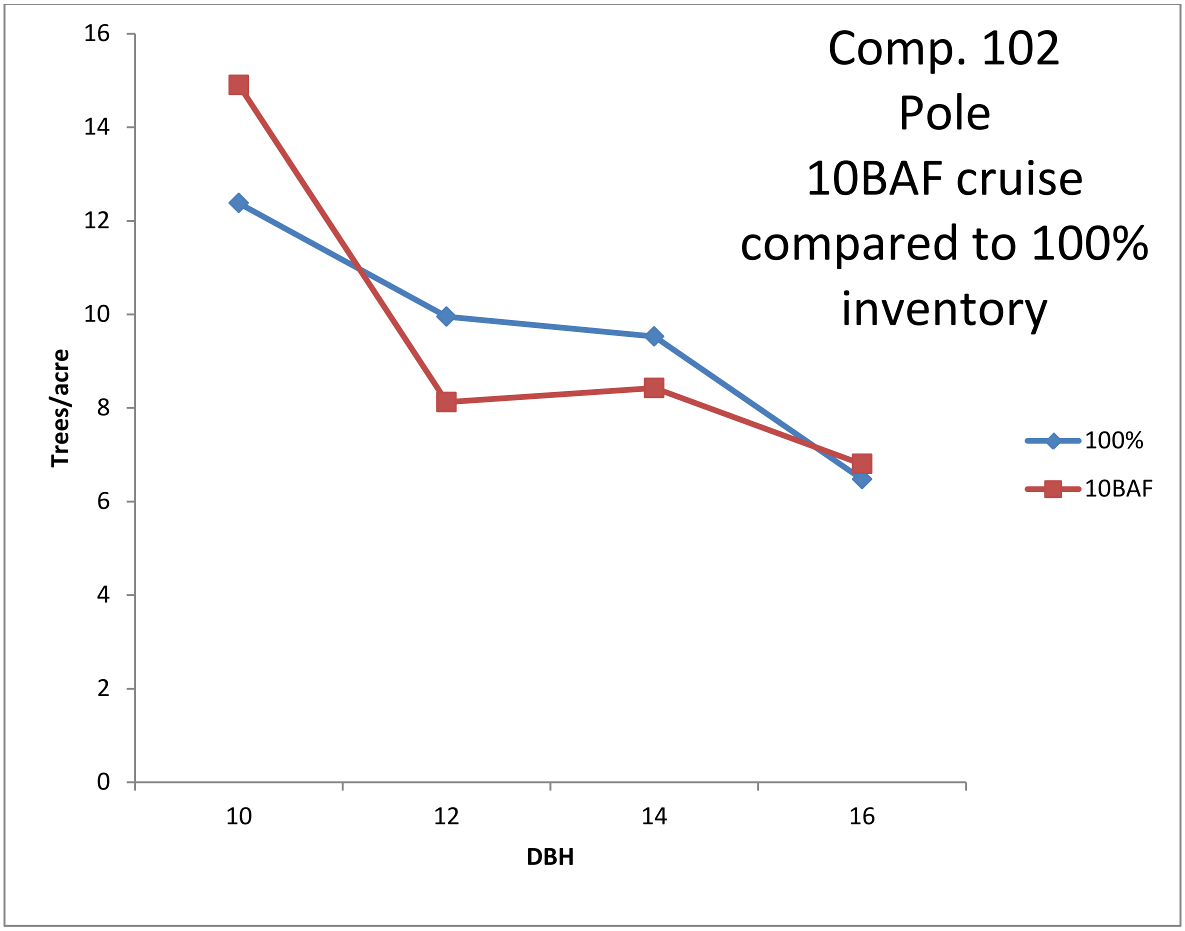


Figure 7.2.4: Comp. 102 estimate of current stocking. Detail of results in sawtimber category using 10BAF cruise on 2x2.5 chain grid, compared to 100% inventory.

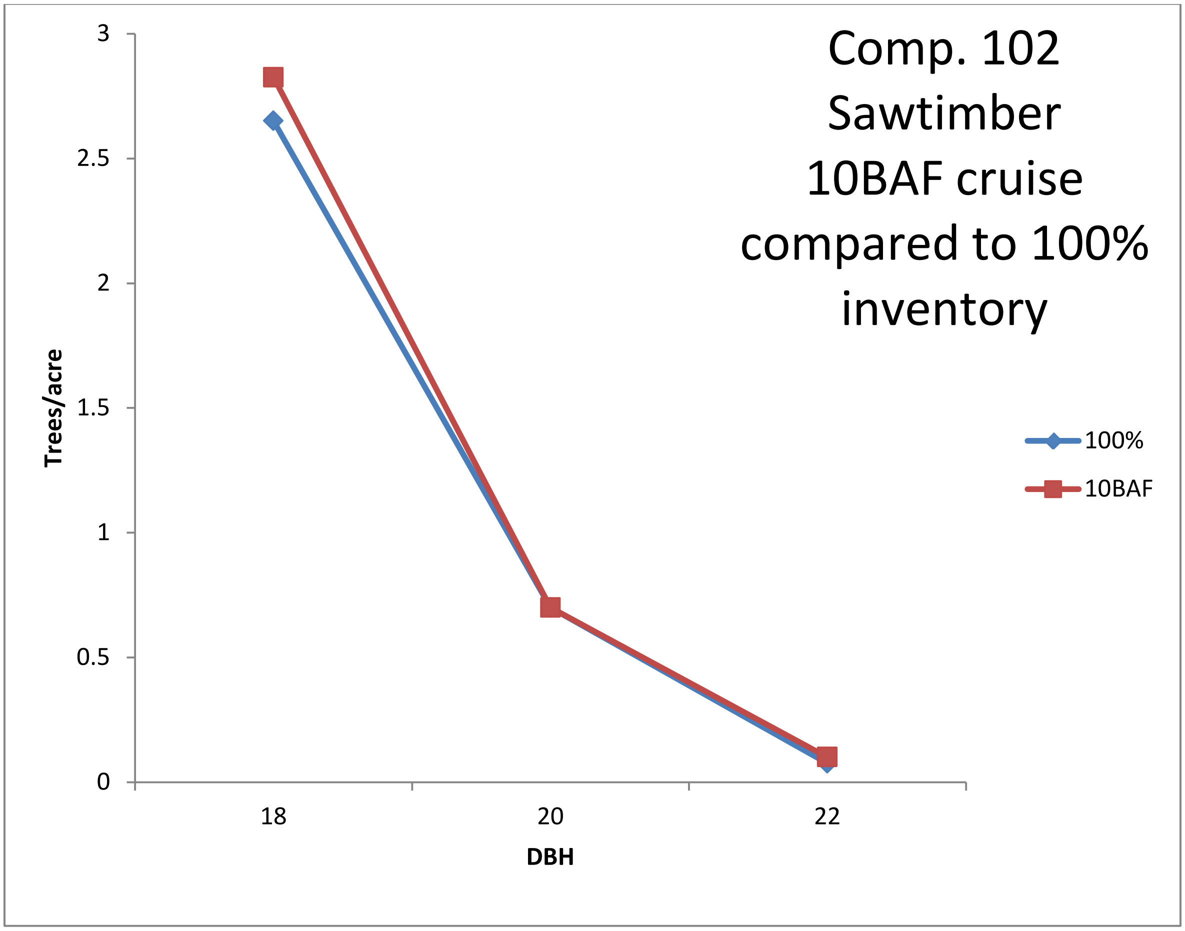


Table 7.2.2: Comp. 102. 1/20 acre (10%) Cruise, 2x2.5 chain grid, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1360	118.862	1341	117.024	+ 1.42	
6	740	145.299	818	160.614	- 9.54	
8	890	310.669	639	223.053	+39.28	
PW:	**2990**	**574.650 ft^2**	**2798**	**500.691 ft^2**	**+ 6.86%**	**+14.77%**
10	630	343.612	495	269.981	+27.27	
12	310	243.473	398	312.588	- 22.11	
14	360	384.845	381	407.294	- 5.51	
16	270	376.991	259	361.632	+ 4.25	
PO:	**1570**	**1348.921 ft^2**	**1533**	**1351.495 ft^2**	**+ 2.41%**	**- 1.90%**
18	130	229.729	106	187.317	+22.64	
20	50	109.083	28	61.086	+78.57	
22	10	26.398	3	7.919	+233.33	
ST:	**190**	**365.210 ft^2**	**137**	**256.322 ft^2**	**+38.69%**	**+42.48%**
All:	**4750**	**2288.781 ft^2**	**4468**	**2108.508 ft^2**	**+ 6.31%**	**+ 8.55%**

Table 7.2.3: Comp. 102. 1/20 acre (10%) Cruise + DBAR, 2x2.5 chain grid, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1218	106.290	1341	117.024	- 9.17	
6	663	130.180	818	160.614	- 18.95	
8	797	278.205	639	223.053	+24.73	
PW:	**2678**	**514.675 ft^2**	**2798**	**500.691 ft^2**	**- 4.29%**	**+ 2.79%**
10	564	307.614	495	269.981	+13.94	
12	278	218.341	398	312.588	- 30.15	
14	322	344.222	381	407.294	- 15.48	
16	242	337.896	259	361.632	- 6.56	
PO:	**1406**	**1208.073 ft^2**	**1533**	**1351.495 ft^2**	**- 8.28%**	**- 10.61%**
18	116	204.989	106	187.317	+ 9.43	
20	45	98.175	28	61.086	+60.71	
22	9	23.758	3	7.919	+200.00	
ST:	**170**	**326.922 ft^2**	**137**	**256.322 ft^2**	**+24.09%**	**+27.54%**
All:	**4254**	**2049.670 ft^2**	**4468**	**2108.508 ft^2**	**- 4.79%**	**- 2.79%**

Figure 7.2.5: Comp. 102 estimate of current stocking. Graphic comparison of data from Table 7.2.2 and Table 7.2.3. 1/20 acre and 1/20 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

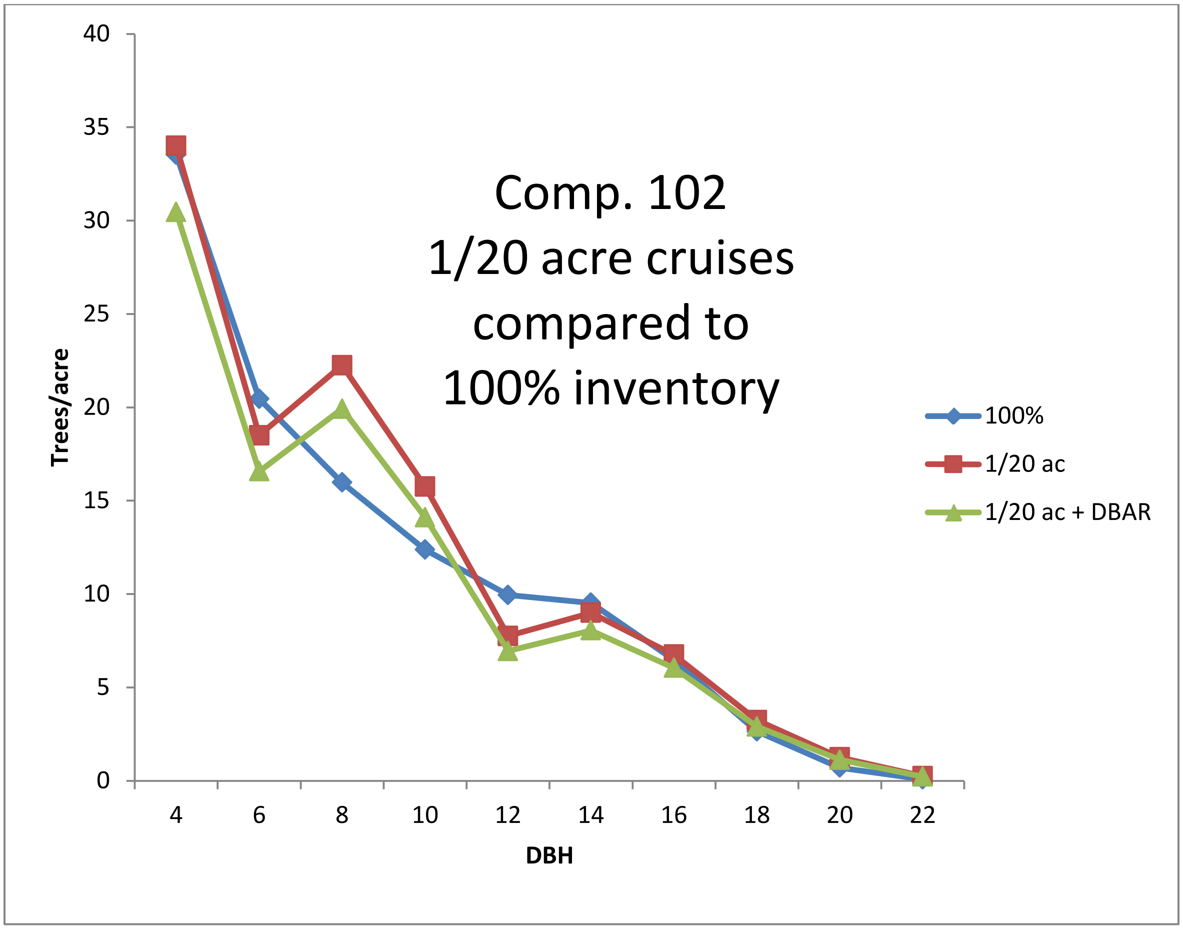


Figure 7.2.6: Comp. 102 estimate of current stocking. Detail of results in pulpwood category using 1/20 acre and 1/20 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

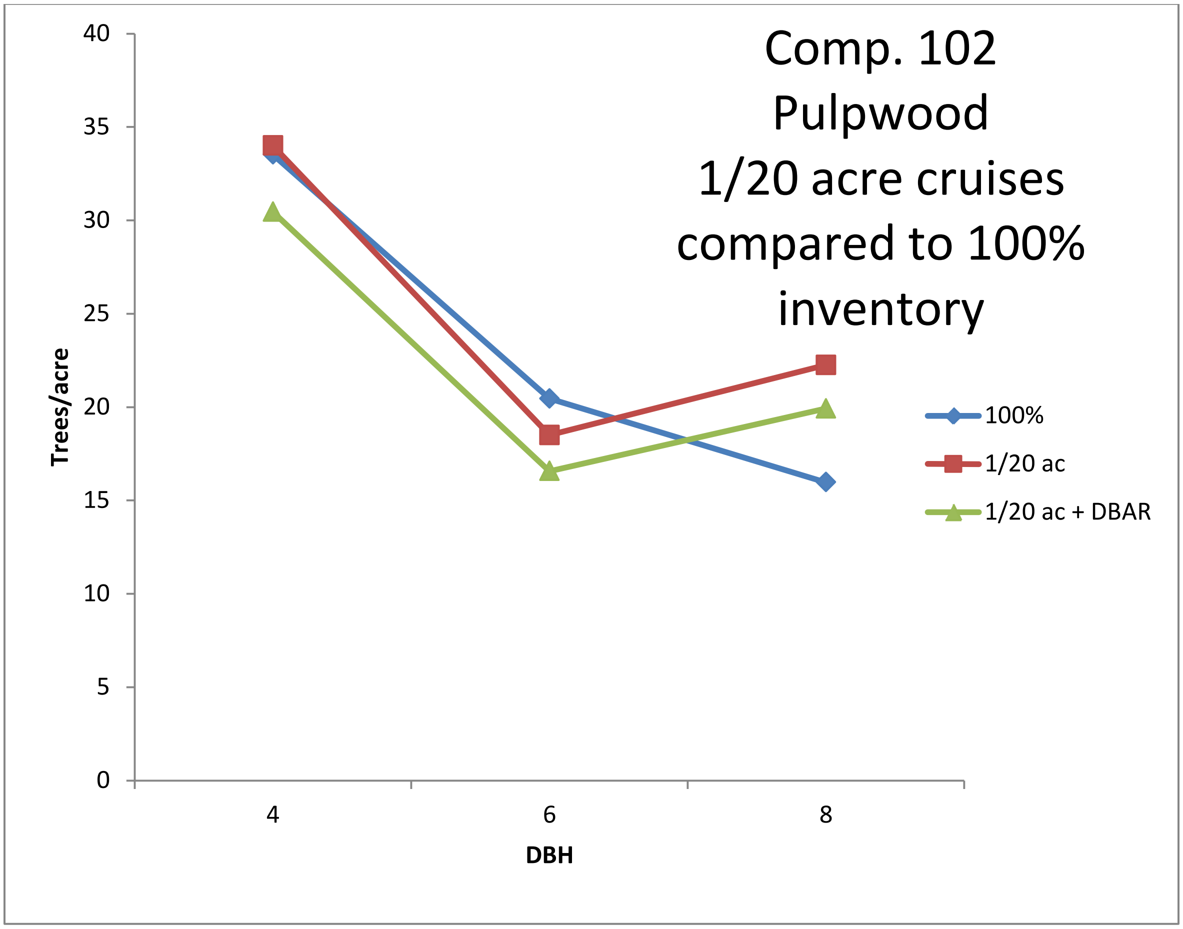


Figure 7.2.7: Comp. 102 estimate of current stocking. Detail of results in pole category using 1/20 acre and 1/20 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

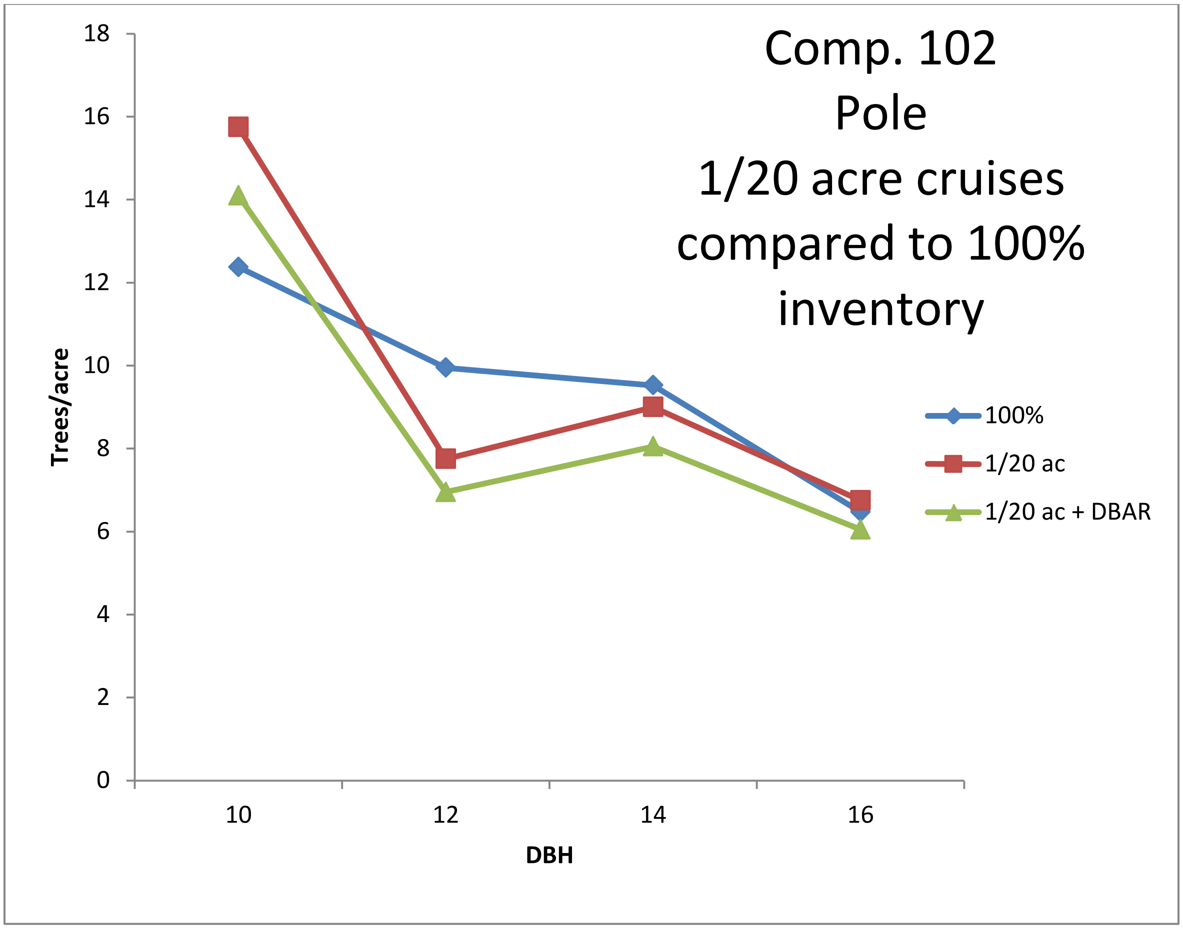


Figure 7.2.8: Comp. 102 estimate of current stocking. Detail of results in sawtimber category using 1/20 acre and 1/20 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

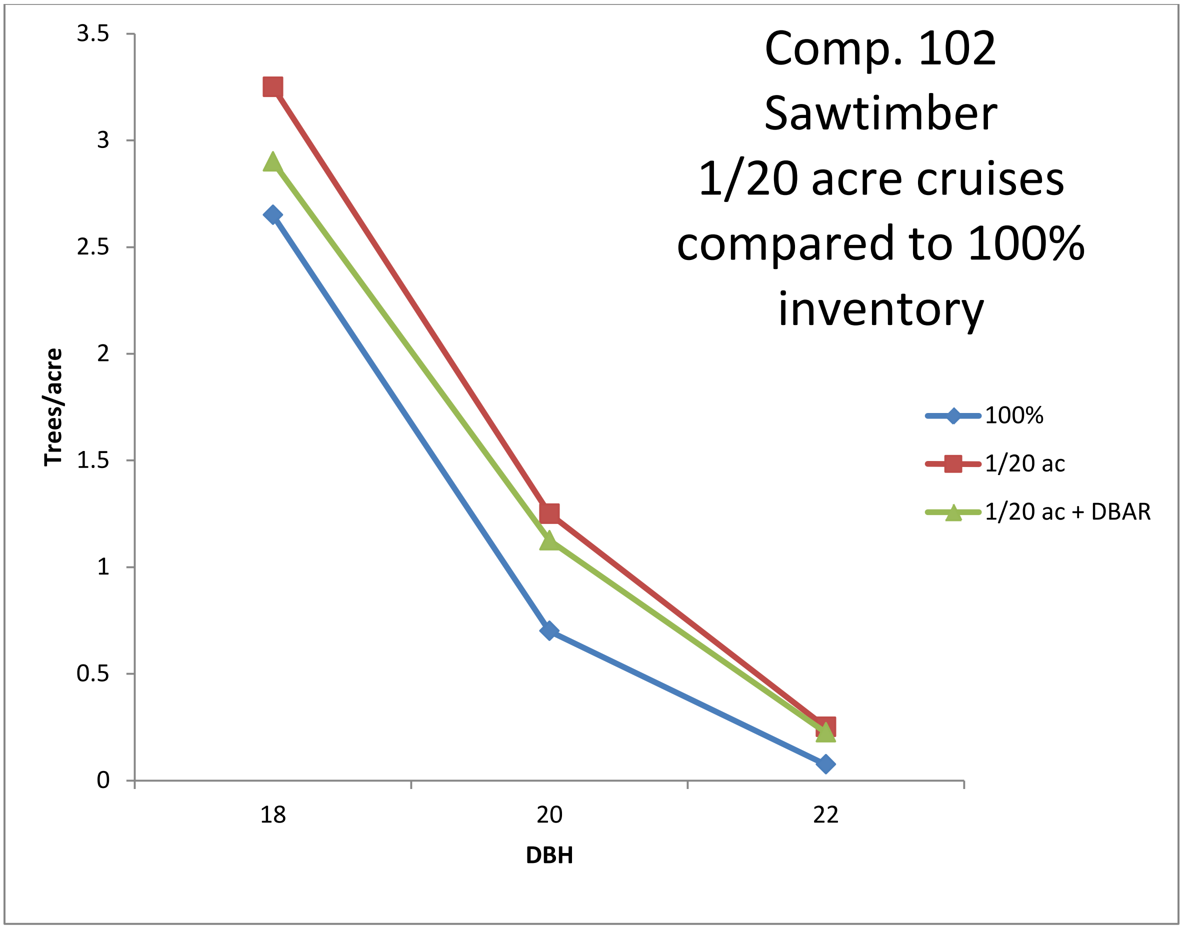


Table 7.2.4: Comp. 102. 1/10 acre (20%) Cruise, 2x2.5 chain grid, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1260	109.956	1341	117.024	- 6.04	
6	785	154.134	818	160.614	- 4.03	
8	850	296.706	639	223.053	+33.02	
PW:	**2895**	**560.796 ft^2**	**2798**	**500.691 ft^2**	**+ 3.47%**	**+12.00%**
10	550	299.978	495	269.981	+11.11	
12	345	270.962	398	312.588	- 13.32	
14	335	358.120	381	407.294	- 12.07	
16	290	404.916	259	361.632	+11.97	
PO:	**1520**	**1333.976 ft^2**	**1533**	**1351.495 ft^2**	**- 0.85%**	**- 1.30%**
18	145	256.236	106	187.317	+36.79	
20	30	65.450	28	61.086	+ 7.14	
22	5	13.199	3	7.919	+66.67	
ST:	**180**	**334.885 ft^2**	**137**	**256.322 ft^2**	**+31.39%**	**+30.65%**
All:	**4595**	**2229.657 ft^2**	**4468**	**2108.508 ft^2**	**+ 2.84%**	**+ 5.74%**

Table 7.2.5: Comp. 102. 1/10 acre (20%) Cruise + DBAR, 2x2.5 chain grid, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1204	105.069	1341	117.024	- 10.22	
6	750	147.262	818	160.614	- 8.31	
8	812	283.441	639	223.053	+27.07	
PW:	**2766**	**535.772 ft^2**	**2798**	**500.691 ft^2**	**- 1.14%**	**+ 7.01%**
10	525	286.343	495	269.981	+ 6.06	
12	330	259.181	398	312.588	- 17.08	
14	320	342.084	381	407.294	- 16.01	
16	277	386.765	259	361.632	+ 6.95	
PO:	**1452**	**1274.373 ft^2**	**1533**	**1351.495 ft^2**	**- 5.28%**	**- 5.71%**
18	138	243.866	106	187.317	+30.19	
20	28	61.086	28	61.086	0.00	
22	5	13.199	3	7.919	+66.67	
ST:	**171**	**318.151 ft^2**	**137**	**256.322 ft^2**	**+24.82%**	**+24.12%**
All:	**4389**	**2128.296 ft^2**	**4468**	**2108.508 ft^2**	**- 1.77%**	**+ 0.94%**

Figure 7.2.9: Comp. 102 estimate of current stocking. Graphic comparison of data from Table 7.2.4 and Table 7.2.5. 1/10 acre and 1/10 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

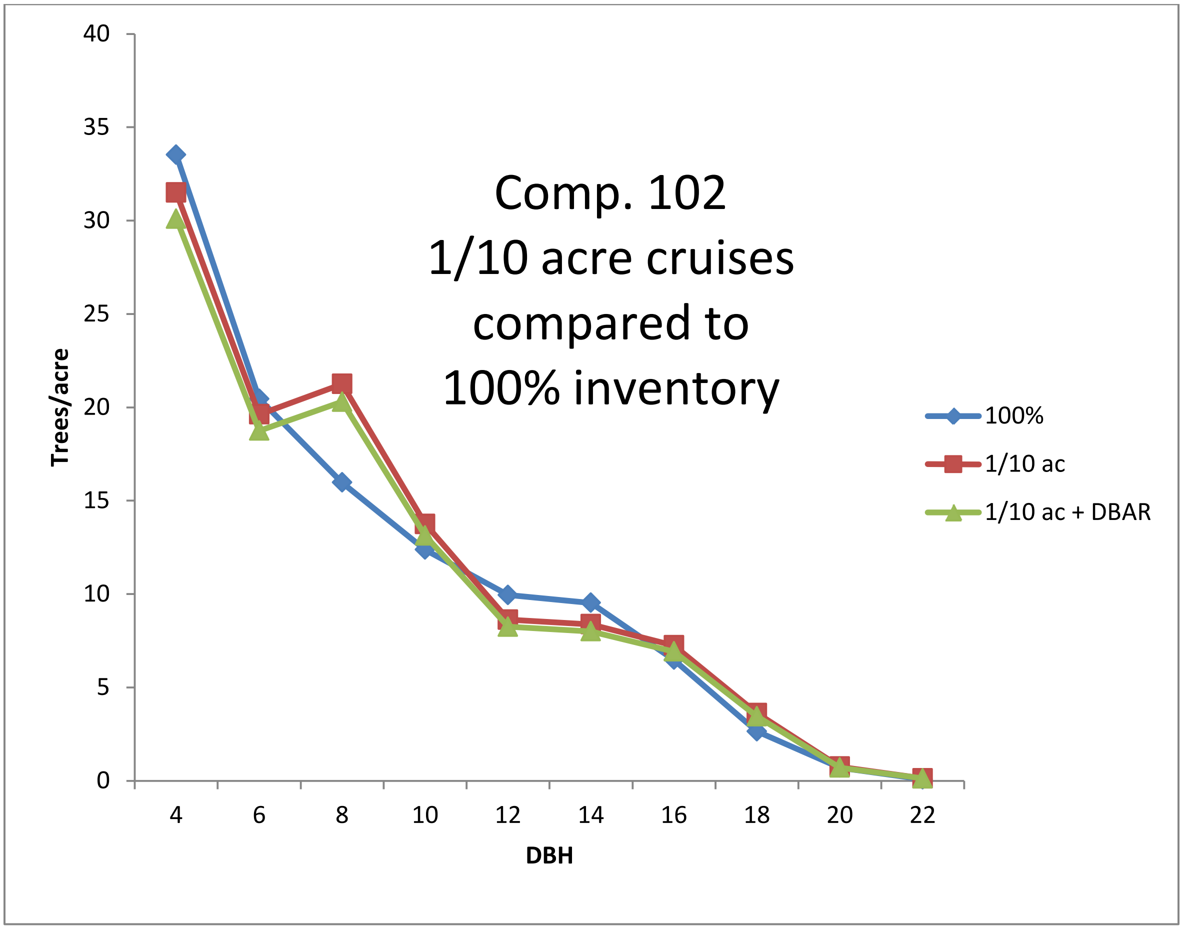


Figure 7.2.10: Comp. 102 estimate of current stocking. Detail of results in pulpwood category using 1/10 acre and 1/10 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

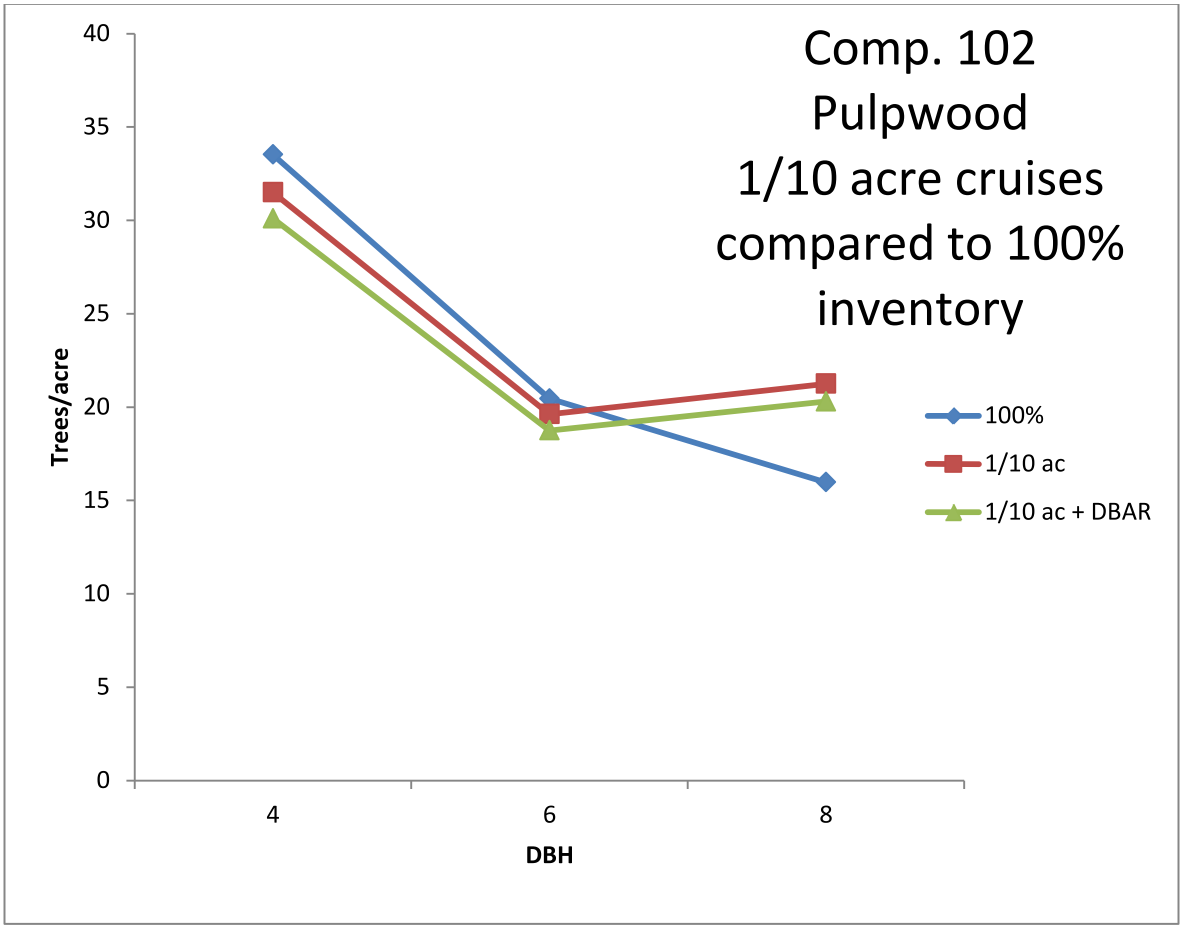


Figure 7.2.11: Comp. 102 estimate of current stocking. Detail of results in pole category using 1/10 acre and 1/10 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

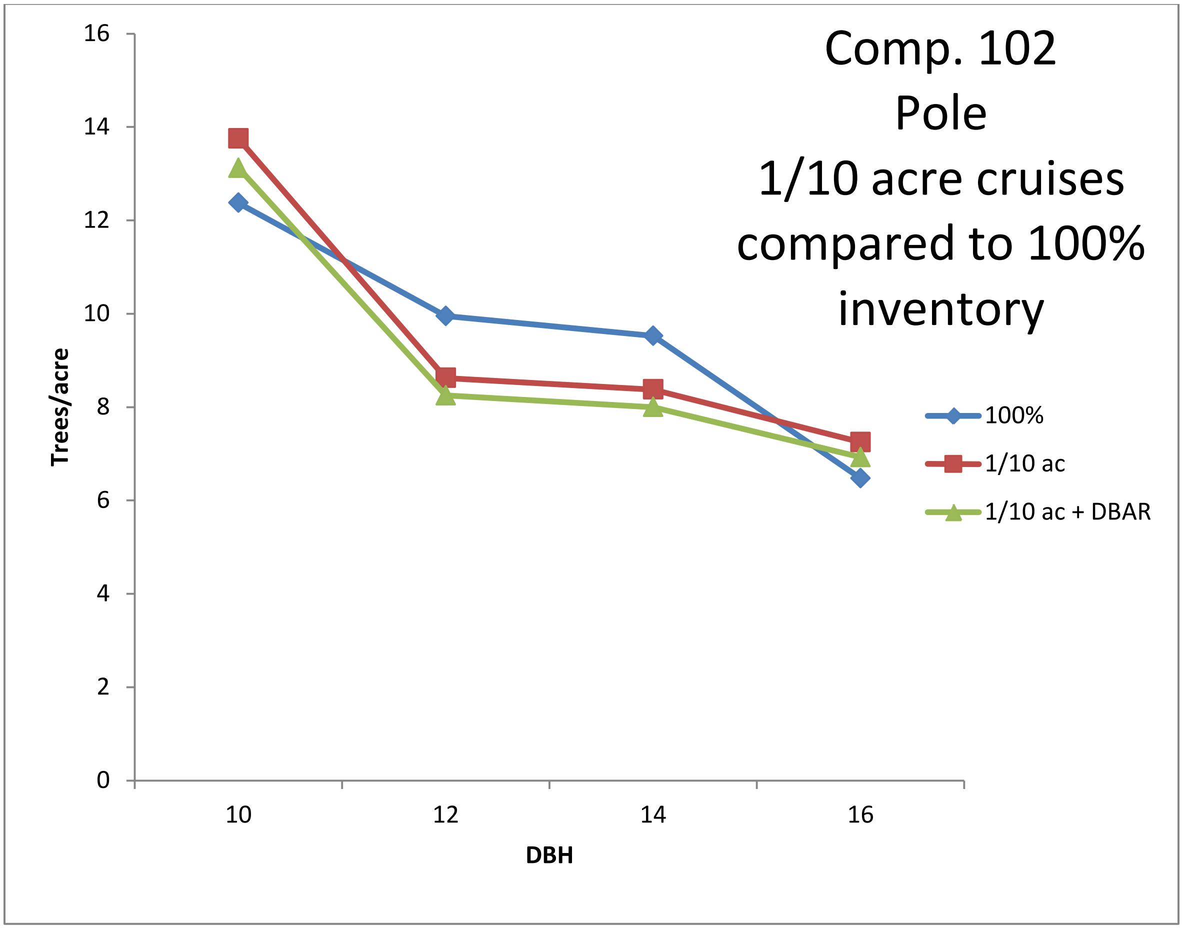


Figure 7.2.12: Comp. 102 estimate of current stocking. Detail of results in sawtimber category using 1/10 acre and 1/10 acre + DBAR cruise on 2x2.5 chain grid, compared to 100% inventory.

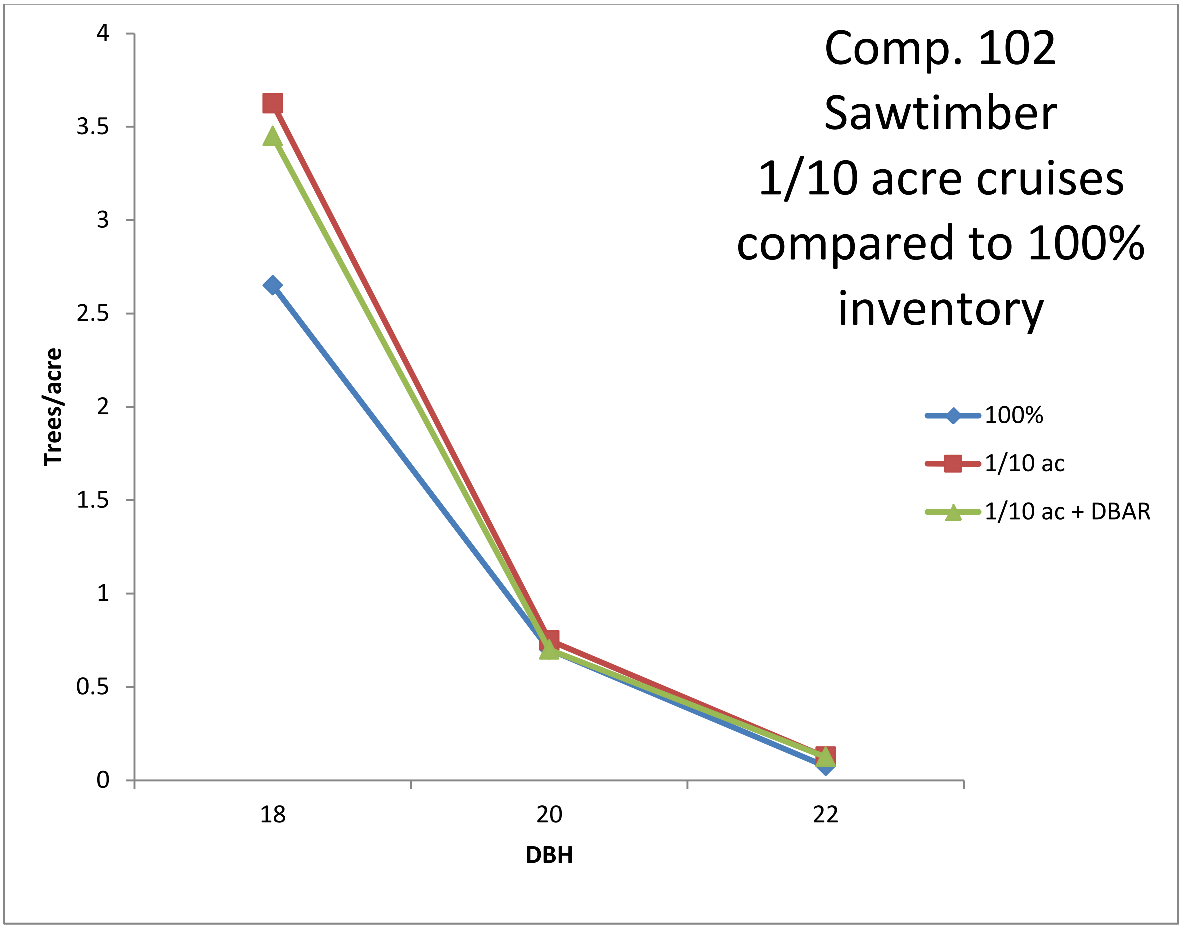


Table 7.2.6: Comp. 102. 33 ft. strip (20%) Cruise, 2.5 chain centers running east/west, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1140	99.484	1341	117.024	- 14.99	
6	795	156.098	818	160.614	- 2.81	
8	780	272.271	639	223.053	+22.06	
PW:	**2715**	**527.853 ft^2**	**2798**	**500.691 ft^2**	**- 2.97%**	**+ 5.42%**
10	565	308.160	495	269.981	+14.14	
12	345	270.962	398	312.588	- 13.32	
14	385	411.570	381	407.294	+ 1.05	
16	315	439.823	259	361.632	+21.62	
PO:	**1610**	**1430.515 ft^2**	**1533**	**1351.495 ft^2**	**+ 5.02%**	**+ 5.81%**
18	160	282.743	106	187.317	+50.94	
20	35	76.358	28	61.086	+25.00	
22	5	13.199	3	7.919	+66.67	
ST:	**200**	**372.300 ft^2**	**137**	**256.322 ft^2**	**+45.98%**	**+45.25%**
All:	**4525**	**2330.668 ft^2**	**4468**	**2108.508 ft^2**	**+ 1.28%**	**+10.54%**

Table 7.2.7: Comp. 102. 33 ft. strip (20%) Cruise + DBAR, 2.5 chain centers running east/west, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1042	90.932	1341	117.024	- 22.30	
6	726	142.550	818	160.614	- 11.25	
8	713	248.884	639	223.053	+11.58	
PW:	**2481**	**482.366 ft^2**	**2798**	**500.691 ft^2**	**- 11.33%**	**- 3.66%**
10	516	281.434	495	269.981	+ 4.24	
12	315	247.400	398	312.588	- 20.85	
14	351	375.224	381	407.294	- 7.87	
16	288	402.124	259	361.632	+11.20	
PO:	**1470**	**1306.182 ft^2**	**1533**	**1351.495 ft^2**	**- 4.11%**	**- 3.35%**
18	146	258.003	106	187.317	+37.74	
20	32	69.813	28	61.086	+14.28	
22	5	13.199	3	7.919	+66.67	
ST:	**183**	**341.015 ft^2**	**137**	**256.322 ft^2**	**+33.58%**	**+33.04%**
All:	**4134**	**2129.563 ft^2**	**4468**	**2108.508 ft^2**	**- 7.48%**	**+ 1.00%**

Table 7.2.8: Comp. 102 – 2x2.5 chain cruise. Error by category compared to 100% inventory, expressed as percentage. Highlighted cells are <6% error in number of trees.

Cruise Method	Pulpwood		Poles		Sawtimber		Overall	
Cruise	**No.**	**BA**	**No.**	**BA**	**No.**	**BA**	**No.**	**BA**
10 BAF	+ 2.86	+ 7.82	- 0.20	- 2.30	+ 5.84	+26.33	- 1.68	+ 3.58
1/20 ac. (10%)	+ 6.86	+14.77	+ 2.41	- 1.90	+38.69	+42.48	+ 6.31	+ 8.55
1/20 ac. + DBAR	- 4.29	+ 2.79	- 8.28	- 10.61	+24.09	+27.54	- 4.79	- 2.79
1/10 ac. (20%)	+ 3.47	+12.00	- 0.85	- 1.30	+31.39	+30.65	+ 2.84	+ 5.74
1/10 ac. + DBAR	- 1.14	+ 7.01	- 5.28	- 5.71	+24.82	+24.12	- 1.77	+ 0.94
33' strip (20%)	- 2.97	+ 5.42	+ 5.02	+ 5.81	+45.98	+45.25	+ 1.28	+10.54
33' strip + DBAR	-11.33	- 3.66	- 4.11	- 3.35	+33.58	+33.04	- 7.48	+ 1.00

Figure 7.2.13: Comp. 102 estimate of current stocking. Graphic comparison of data from Table 7.2.6 and Table 7.2.7. 33 ft. strip and 33 ft. strip + DBAR cruise on 2.5 chain centers running east/west, compared to 100% inventory.

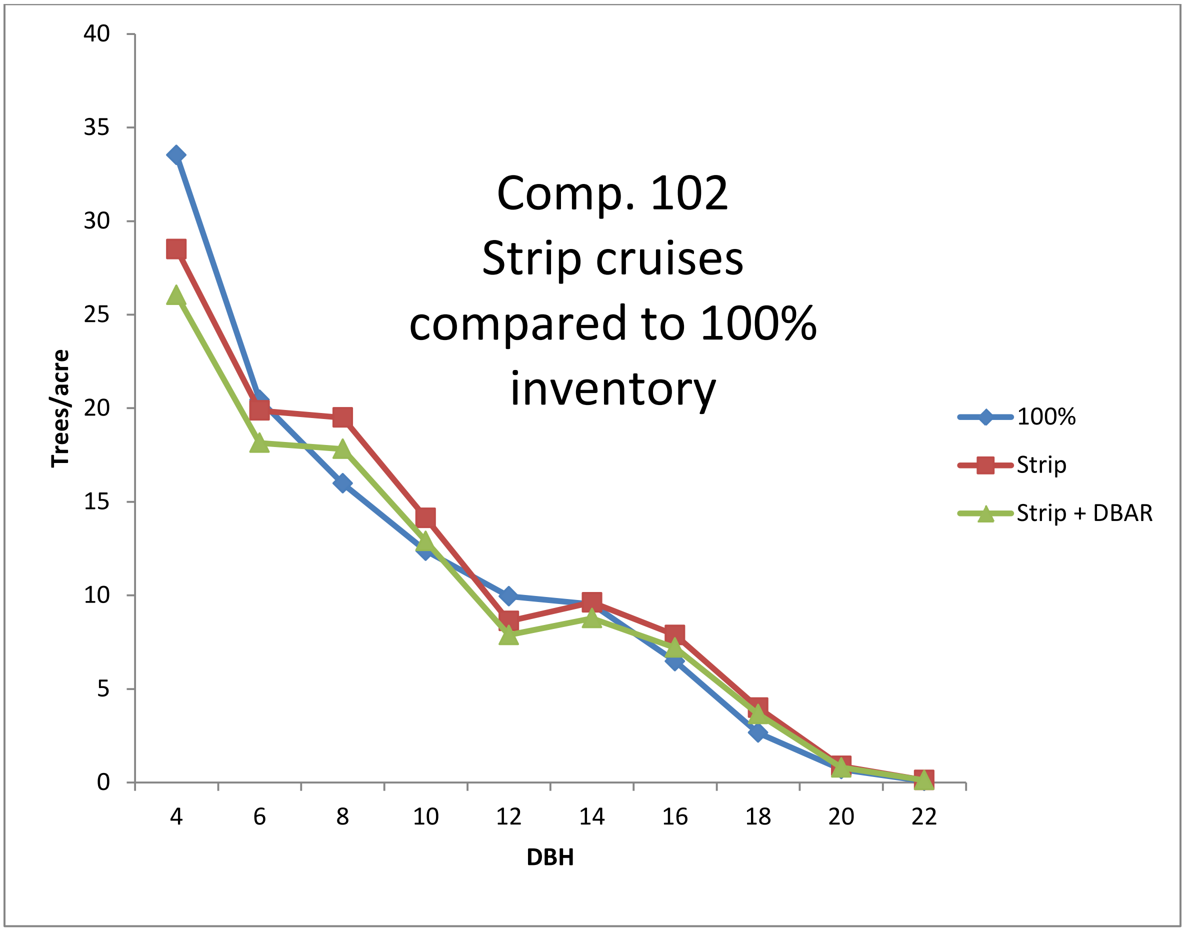


Figure 7.2.14: Comp. 102 estimate of current stocking. Detail of results in pulpwood category using 33 ft. strip and 33 ft. strip + DBAR cruise on 2.5 chain centers, compared to 100% inventory.

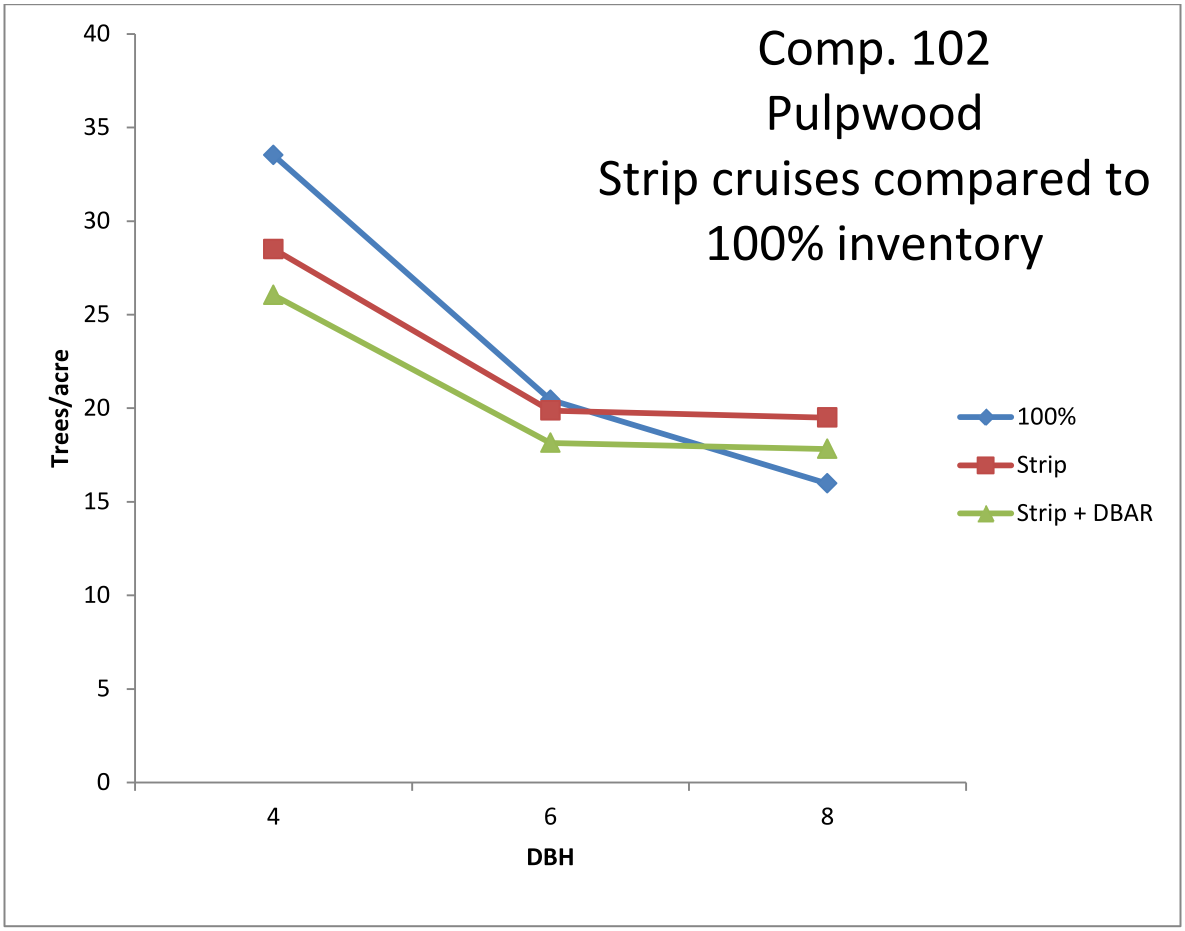


Figure 7.2.15: Comp. 102 estimate of current stocking. Detail of results in pole category using 33 ft. strip and 33 ft. strip + DBAR cruise on 2.5 chain centers, compared to 100% inventory.

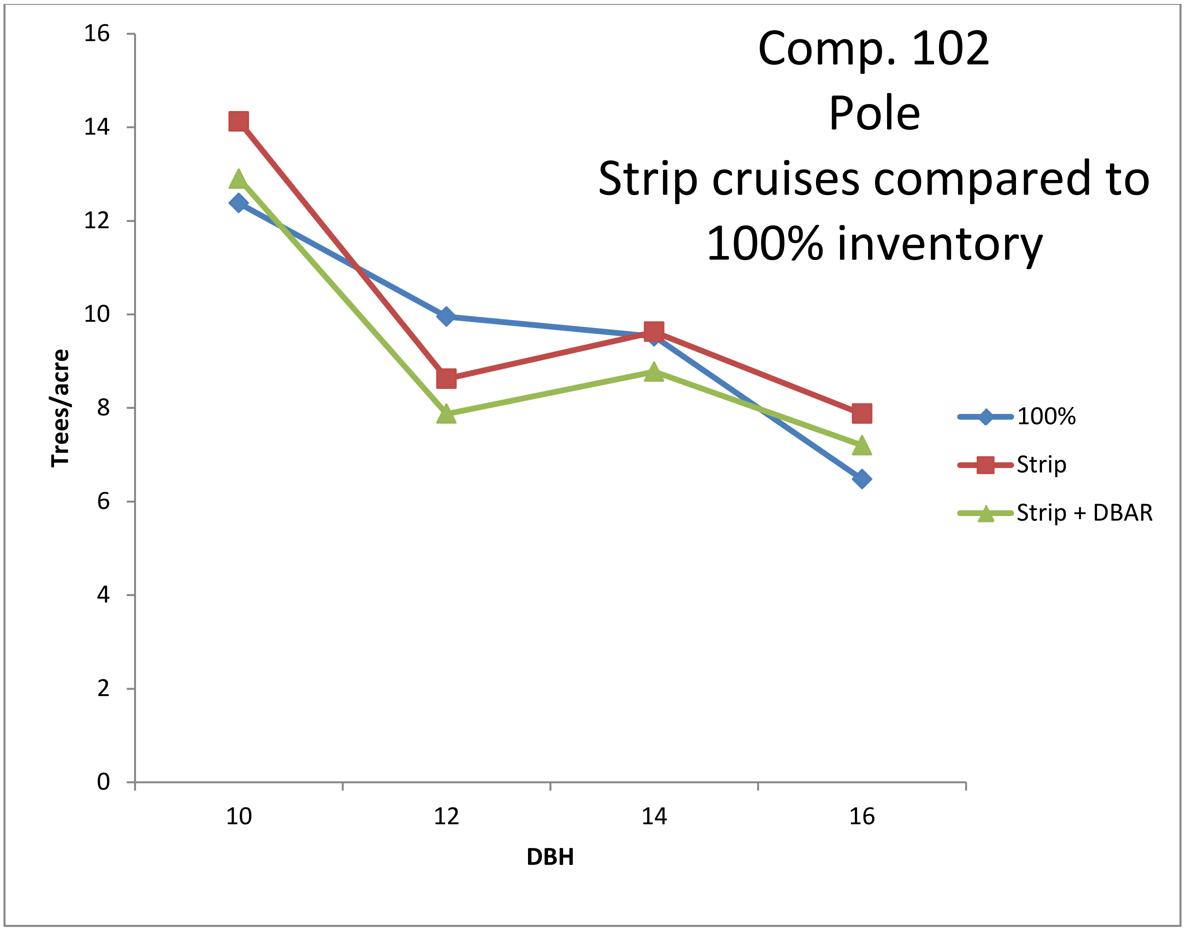
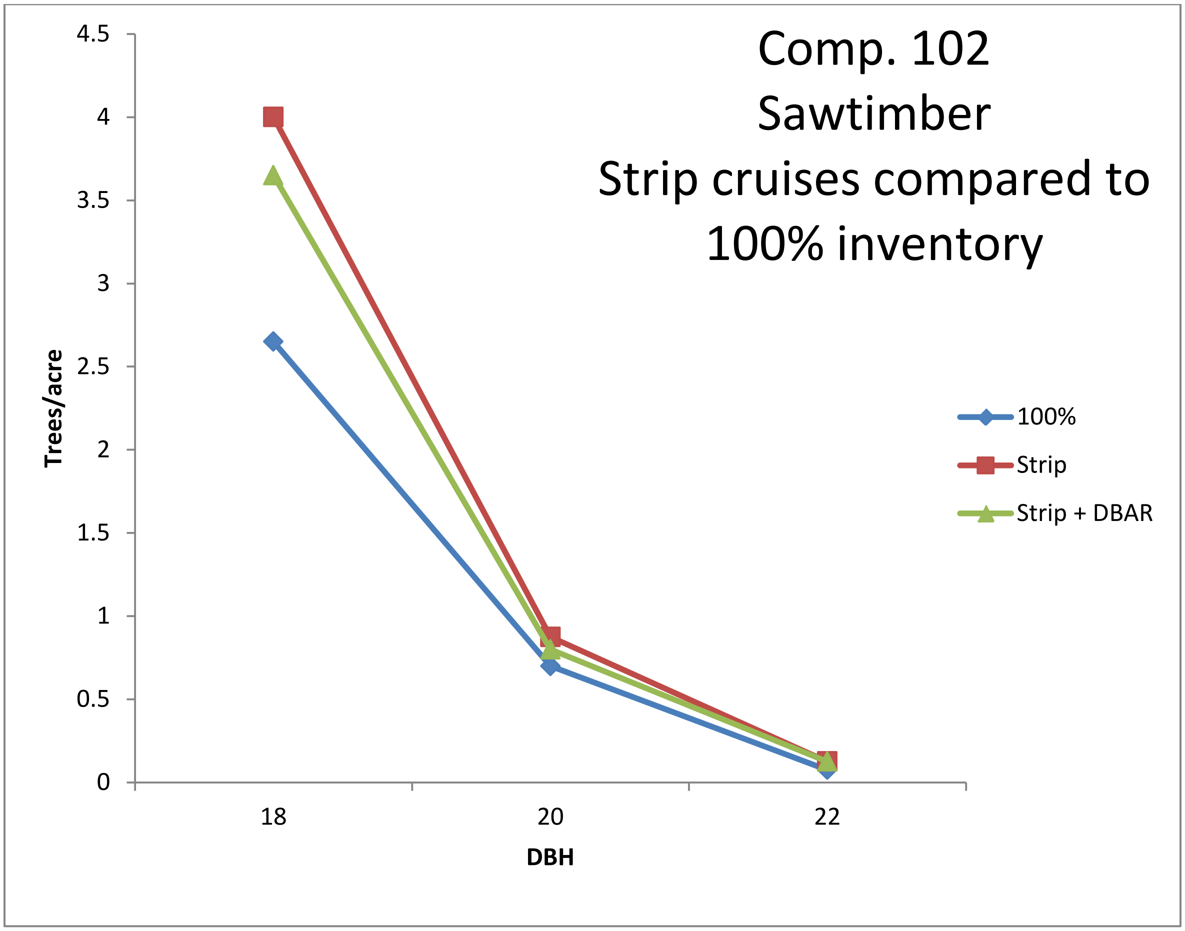


Figure 7.2.16: Comp. 102 estimate of current stocking. Detail of results in sawtimber category using 33 ft. strip and 33 ft. strip + DBAR cruise on 2.5 chain centers, compared to 100% inventory.



Appendix 7.3: Farm Forty, Combination Cruise + DBAR & 10BAF

Table 7.3.1: Farm Forty. Pulpwood: 1/10 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/10 DBAR + 10BAF + 10BAF)

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1982	172.962	2038	177.849	- 2.75	
6	1183	232.282	1143	224.428	+ 3.50	
8	720	251.327	737	257.262	- 2.31	
PW:	**3885**	**656.571 ft^2**	**3918**	**659.539 ft^2**	**- 0.84%**	**- 0.45%**
10	706	385.063	702	382.882	+ 0.57	
12	509	399.768	563	442.179	- 9.59	
14	276	295.048	286	305.738	- 3.50	
16	158	220.610	142	198.269	+11.27	
PO:	**1649**	**1300.489 ft^2**	**1693**	**1329.068 ft^2**	**- 2.60%**	**- 2.15%**
18	124	219.126	131	231.496	- 5.34	
20	76	165.806	70	152.716	+ 8.57	
22	44	116.152	44	116.152	0.00	
24+	18	60.454	18	62.221	0.00	- 2.84
ST:	**262**	**561.538 ft^2**	**263**	**562.585 ft^2**	**- 0.38%**	**- 0.19%**
All:	**5796**	**2518.598 ft^2**	**5874**	**2551.192 ft^2**	**- 1.33%**	**- 1.28%**

Table 7.3.2: Farm Forty. Pulpwood: 1/10 acre + DBAR; Poles: 1/10 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/10 DBAR + 1/10 DBAR + 10BAF)

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1982	172.962	2038	177.849	- 2.75	
6	1183	232.282	1143	224.428	+ 3.50	
8	720	251.327	737	257.262	- 2.31	
PW:	**3885**	**656.571 ft^2**	**3918**	**659.539 ft^2**	**- 0.84%**	**- 0.45%**
10	715	389.972	702	382.882	+ 1.85	
12	522	409.978	563	442.179	- 7.28	
14	271	289.703	286	305.738	- 5.24	
16	182	254.120	142	198.269	+28.17	
PO:	**1690**	**1343.773 ft^2**	**1693**	**1329.068 ft^2**	**- 0.18%**	**- 1.11%**
18	124	219.126	131	231.496	- 5.34	
20	76	165.806	70	152.716	+ 8.57	
22	44	116.152	44	116.152	0.00	
24+	18	60.454	18	62.221	0.00	- 2.84
ST:	**262**	**561.538 ft^2**	**263**	**562.585 ft^2**	**- 0.38%**	**- 0.19%**
All:	**5837**	**2561.882 ft^2**	**5874**	**2551.192 ft^2**	**- 0.63%**	**- 0.42%**

Table 7.3.3: Farm Forty. Pulpwood: 1/20 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/20 DBAR + 10BAF + 10BAF)

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1857	162.053	2038	177.849	- 8.88	
6	1222	239.939	1143	224.428	+ 6.91	
8	758	264.592	737	257.262	+ 2.85	
PW:	**3837**	**666.584 ft^2**	**3918**	**659.539 ft^2**	**- 2.07%**	**+ 1.07%**
10	706	385.063	702	382.882	+ 0.57	
12	509	399.768	563	442.179	- 9.59	
14	276	295.048	286	305.738	- 3.50	
16	158	220.610	142	198.269	+11.27	
PO:	**1649**	**1300.489 ft^2**	**1693**	**1329.068 ft^2**	**- 2.60%**	**- 2.15%**
18	124	219.126	131	231.496	- 5.34	
20	76	165.806	70	152.716	+ 8.57	
22	44	116.152	44	116.152	0.00	
24+	18	60.454	18	62.221	0.00	- 2.84
ST:	**262**	**561.538 ft^2**	**263**	**562.585 ft^2**	**- 0.38%**	**- 0.19%**
All:	**5748**	**2528.611 ft^2**	**5874**	**2551.192 ft^2**	**- 2.14%**	**- 0.88%**

Table 7.3.4: Farm Forty. Pulpwood: 1/20 acre + DBAR; Poles: 1/20 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/20 DBAR + 1/20 DBAR + 10BAF)

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1857	162.053	2038	177.849	- 8.88	
6	1222	239.939	1143	224.428	+ 6.91	
8	758	264.592	737	257.262	+ 2.85	
PW:	**3837**	**666.584 ft^2**	**3918**	**659.539 ft^2**	**- 2.07%**	**+ 1.07%**
10	654	356.702	702	382.882	- 6.84	
12	521	409.192	563	442.179	- 7.46	
14	341	364.534	286	305.738	+19.23	
16	189	263.894	142	198.269	+33.10	
PO:	**1705**	**1394.322 ft^2**	**1693**	**1329.068 ft^2**	**+ 0.71%**	**+ 4.91%**
18	124	219.126	131	231.496	- 5.34	
20	76	165.806	70	152.716	+ 8.57	
22	44	116.152	44	116.152	0.00	
24+	18	60.454	18	62.221	0.00	- 2.84
ST:	**262**	**561.538 ft^2**	**263**	**562.585 ft^2**	**- 0.38%**	**- 0.19%**
All:	**5804**	**2622.444 ft^2**	**5874**	**2551.192 ft^2**	**- 1.19%**	**+ 2.79%**

Appendix 7.4: Comp. 102, Combination Cruise + DBAR & 10BAF

Table 7.4.1: Comp. 102. Pulpwood: 1/10 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/10 DBAR + 10BAF + 10BAF)

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1204	105.069	1341	117.024	- 10.22	
6	750	147.262	818	160.614	- 8.31	
8	812	283.441	639	223.053	+27.07	
PW:	**2766**	**535.772 ft^2**	**2798**	**500.691 ft^2**	**- 1.14%**	**+ 7.01%**
10	596	325.068	495	269.981	+20.40	
12	325	255.254	398	312.588	- 18.34	
14	337	360.258	381	407.294	- 11.55	
16	272	379.784	259	361.632	+ 5.02	
PO:	**1530**	**1320.364 ft^2**	**1533**	**1351.495 ft^2**	**- 0.20%**	**- 2.30%**
18	113	252.237	106	187.317	+ 6.60	
20	28	61.086	28	61.086	0.00	
22	4	10.559	3	7.919	+33.33	
ST:	**145**	**323.882 ft^2**	**137**	**256.322 ft^2**	**+ 5.84%**	**+26.33%**
All:	**4441**	**2180.018 ft^2**	**4468**	**2108.508 ft^2**	**- 0.60%**	**+ 3.39%**

Table 7.4.2: Comp. 102. Pulpwood: 1/10 acre + DBAR; Poles: 1/10 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/10 DBAR + 1/10 DBAR + 10BAF)

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1204	105.069	1341	117.024	- 10.22	
6	750	147.262	818	160.614	- 8.31	
8	812	283.441	639	223.053	+27.07	
PW:	**2766**	**535.772 ft^2**	**2798**	**500.691 ft^2**	**- 1.14%**	**+ 7.01%**
10	525	286.343	495	269.981	+ 6.06	
12	330	259.181	398	312.588	- 17.08	
14	320	342.084	381	407.294	- 16.01	
16	277	386.765	259	361.632	+ 6.95	
PO:	**1452**	**1274.373 ft^2**	**1533**	**1351.495 ft^2**	**- 5.28%**	**- 5.71%**
18	113	252.237	106	187.317	+ 6.60	
20	28	61.086	28	61.086	0.00	
22	4	10.559	3	7.919	+33.33	
ST:	**145**	**323.882 ft^2**	**137**	**256.322 ft^2**	**+ 5.84%**	**+26.33%**
All:	**4363**	**2134.027 ft^2**	**4468**	**2108.508 ft^2**	**- 2.35%**	**+ 1.21%**

Table 7.4.3: Comp. 102. Pulpwood: 1/20 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/20 DBAR + 10BAF + 10BAF)

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1218	106.290	1341	117.024	- 9.17	
6	663	130.180	818	160.614	- 18.95	
8	797	278.205	639	223.053	+24.73	
PW:	**2678**	**514.675 ft^2**	**2798**	**500.691 ft^2**	**- 4.29%**	**+ 2.79%**
10	596	325.068	495	269.981	+20.40	
12	325	255.254	398	312.588	- 18.34	
14	337	360.258	381	407.294	- 11.55	
16	272	379.784	259	361.632	+ 5.02	
PO:	**1530**	**1320.364 ft^2**	**1533**	**1351.495 ft^2**	**- 0.20%**	**- 2.30%**
18	113	252.237	106	187.317	+ 6.60	
20	28	61.086	28	61.086	0.00	
22	4	10.559	3	7.919	+33.33	
ST:	**145**	**323.882 ft^2**	**137**	**256.322 ft^2**	**+ 5.84%**	**+26.33%**
All:	**4353**	**2158.921 ft^2**	**4468**	**2108.508 ft^2**	**- 2.57%**	**+ 2.39%**

Table 7.4.4: Comp. 102. Pulpwood: 1/20 acre + DBAR; Poles: 1/20 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/20 DBAR + 1/20 DBAR + 10BAF)

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1218	106.290	1341	117.024	- 9.17	
6	663	130.180	818	160.614	- 18.95	
8	797	278.205	639	223.053	+24.73	
PW:	**2678**	**514.675 ft^2**	**2798**	**500.691 ft^2**	**- 4.29%**	**+ 2.79%**
10	564	307.614	495	269.981	+13.94	
12	278	218.341	398	312.588	- 30.15	
14	322	344.222	381	407.294	- 15.48	
16	242	337.896	259	361.632	- 6.56	
PO:	**1406**	**1208.073 ft^2**	**1533**	**1351.495 ft^2**	**- 8.28%**	**- 10.61%**
18	113	252.237	106	187.317	+ 6.60	
20	28	61.086	28	61.086	0.00	
22	4	10.559	3	7.919	+33.33	
ST:	**145**	**323.882 ft^2**	**137**	**256.322 ft^2**	**+ 5.84%**	**+26.33%**
All:	**4229**	**2046.630 ft^2**	**4468**	**2108.508 ft^2**	**- 5.35%**	**- 2.93%**

Appendix 7.5: Farm Forty + Comp. 102, Comparison of Cruise Methods

Table 7.5.1: Comp. 102 + Farm Forty. 10 BAF cruise 2x5 chain grid, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	4125	359.974	3379	294.873	+22.08	
6	1833	359.909	1961	385.042	- 6.53	
8	1346	469.843	1376	480.315	- 2.18	
PW:	**7304**	**1189.726 ft^2**	**6716**	**1160.230 ft^2**	**+ 8.76%**	**+2.54%**
10	1320	719.948	1197	652.863	+10.28	
12	980	769.690	961	754.767	+ 1.98	
14	758	810.313	667	713.032	+13.64	
16	358	499.862	401	559.901	- 10.72	
PO:	**3416**	**2799.813 ft^2**	**3226**	**2680.563 ft^2**	**+ 5.89%**	**+ 4.45%**
18	226	399.375	237	418.813	- 4.64	
20	96	209.440	98	213.802	- 2.04	
22	49	129.351	47	124.071	+ 4.26	
24+	28	98.938	18	62.221	+55.56	
ST:	**399**	**837.104 ft^2**	**400**	**818.907 ft^2**	**- 0.25%**	**+ 2.22%**
All:	**11119**	**4826.643 ft^2**	**10342**	**4659.700 ft^2**	**+ 7.51%**	**+ 3.58%**

Table 7.5.2: Comp. 102 + Farm Forty. 1/20 acre cruise (5%) 2x5 chain grid, compared to 100% inventory.

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	3900	340.339	3379	294.873	+15.42	
6	1900	373.064	1961	385.042	- 3.11	
8	1200	418.879	1376	480.315	- 12.79	
PW:	**7000**	**1132.282 ft^2**	**6716**	**1160.230 ft^2**	**+ 4.23%**	**- 2.41%**
10	1280	698.132	1197	652.863	+ 6.93	
12	940	738.274	961	754.767	- 2.18	
14	640	684.169	667	713.032	- 4.05	
16	380	530.580	401	559.901	- 5.24	
PO:	**3240**	**2651.155 ft^2**	**3226**	**2680.563 ft^2**	**- 0.43%**	**- 1.10%**
18	280	494.801	237	418.813	+18.14	
20	100	218.166	98	213.802	+ 2.04	
22	80	211.185	47	124.071	+70.21	
24+	20	62.832	18	62.221	+11.11	
ST:	**480**	**986.984 ft^2**	**400**	**818.907 ft^2**	**+20.00%**	**+20.52%**
All:	**10720**	**4770.421 ft^2**	**10342**	**4659.700 ft^2**	**+ 3.65%**	**+ 2.38%**

Table 7.5.3: Comp. 102 + Farm Forty. 1/20 acre cruise (5%) 2x5 chain grid + DBAR, compared to 100% inventory. (No change because basal area is the same as 10 BAF estimate.)

	CRUISE		100%		% ERROR	
dbh	No. Trees	BA	No. Trees	BA	No. Trees	BA
4	3900	340.339	3379	294.873	+15.42	
6	1900	373.064	1961	385.042	- 3.11	
8	1200	418.879	1376	480.315	- 12.79	
PW:	**7000**	**1132.282 ft^2**	**6716**	**1160.230 ft^2**	**+ 4.23%**	**- 2.41%**
10	1280	698.132	1197	652.863	+ 6.93	
12	940	738.274	961	754.767	- 2.18	
14	640	684.169	667	713.032	- 4.05	
16	380	530.580	401	559.901	- 5.24	
PO:	**3240**	**2651.155 ft^2**	**3226**	**2680.563 ft^2**	**- 0.43%**	**- 1.10%**
18	280	494.801	237	418.813	+18.14	
20	100	218.166	98	213.802	+ 2.04	
22	80	211.185	47	124.071	+70.21	
24+	20	62.832	18	62.221	+11.11	
ST:	**480**	**986.984 ft^2**	**400**	**818.907 ft^2**	**+20.00%**	**+20.52%**
All:	**10720**	**4770.421 ft^2**	**10342**	**4659.700 ft^2**	**+ 3.65%**	**+ 2.38%**

Table 7.5.4: Comp. 102 + Farm Forty. 2x5 chain cruise. Error by category compared to 100% inventory, expressed as percentage. Highlighted cells are <6% error in number of trees.

Cruise Method	Pulpwood		Poles		Sawtimber		Overall	
Cruise	No.	BA	No.	BA	No.	BA	No.	BA
10 BAF	+ 8.76	+ 2.54	+ 5.89	+ 4.45	- 0.25	+ 2.22	+ 7.51	+ 3.58
1/20 ac. (5%)	+ 4.23	- 2.41	- 0.43	- 1.10	+20.00	+20.52	+ 3.65	+ 2.38
1/20 ac. + DBAR	+ 4.23	- 2.41	- 0.43	- 1.10	+20.00	+20.52	+ 3.65	+ 2.38

Note: 1/20 ac. + DBAR resulted in no change, because basal area estimated by plot cruise same as 10BAF prism.

Appendix 7.6: Farm Forty + Comp. 102, Combination Cruise + DBAR & 10BAF

Table 7.6.1: Comp. 102 + Farm Forty. Pulpwood: 1/20 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x5 chain grid, compared to 100% inventory.

(1/20 DBAR + 10BAF + 10BAF)

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	3900	340.339	3379	294.873	+15.42	
6	1900	373.064	1961	385.042	- 3.11	
8	1200	418.879	1376	480.315	- 12.79	
PW:	**7000**	**1132.282 ft^2**	**6716**	**1160.230 ft^2**	**+ 4.23%**	**- 2.41%**
10	1320	719.948	1197	652.863	+10.28	
12	980	769.690	961	754.767	+ 1.98	
14	758	810.313	667	713.032	+13.64	
16	358	499.862	401	559.901	- 10.72	
PO:	**3416**	**2799.813 ft^2**	**3226**	**2680.563 ft^2**	**+ 5.89%**	**+ 4.45%**
18	226	399.375	237	418.813	- 4.64	
20	96	209.440	98	213.802	- 2.04	
22	49	129.351	47	124.071	+ 4.26	
24+	28	98.938	18	62.221	+55.56	
ST:	**399**	**837.104 ft^2**	**400**	**818.907 ft^2**	**- 0.25%**	**+ 2.22%**
All:	**10815**	**4769.199 ft^2**	**10342**	**4659.700 ft^2**	**+ 4.57%**	**+ 2.35%**

Table 7.6.2: Comp. 102 + Farm Forty. Pulpwood: 1/20 acre + DBAR; Poles: 1/20 acre + DBAR; Sawtimber: 10BAF. 2x5 chain grid, compared to 100% inventory.

(1/20 DBAR + 1/20 DBAR + 10BAF)

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	3900	340.339	3379	294.873	+15.42	
6	1900	373.064	1961	385.042	- 3.11	
8	1200	418.879	1376	480.315	- 12.79	
PW:	**7000**	**1132.282 ft^2**	**6716**	**1160.230 ft^2**	**+ 4.23%**	**- 2.41%**
10	1280	698.132	1197	652.863	+ 6.93	
12	940	738.274	961	754.767	- 2.18	
14	640	684.169	667	713.032	- 4.05	
16	380	530.580	401	559.901	- 5.24	
PO:	**3240**	**2651.155 ft^2**	**3226**	**2680.563 ft^2**	**- 0.43%**	**- 1.10%**
18	226	399.375	237	418.813	- 4.64	
20	96	209.440	98	213.802	- 2.04	
22	49	129.351	47	124.071	+ 4.26	
24+	28	98.938	18	62.221	+55.56	
ST:	**399**	**837.104 ft^2**	**400**	**818.907 ft^2**	**- 0.25%**	**+ 2.22%**
All:	**10639**	**4620.541 ft^2**	**10342**	**4659.700 ft^2**	**+ 2.87%**	**- 0.84%**

Appendix 7.7: Residual Stand Estimates, Farm Forty

Table 7.7.1: Farm Forty Residual Stand. Pulpwood: 1/10 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/10 DBAR + 10BAF + 10BAF) X WSR B=40, D=20, N=9

RESIDUAL STAND

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	2038	177.849	2037	177.762	+ 0.05	
6	865	169.842	905	177.696	- 4.42	
8	526	183.609	509	177.674	+ 3.34	
PW:	**3429**	**531.300 ft^2**	**3451**	**533.132 ft^2**	**- 0.64%**	**- 0.34%**
10	322	175.623	326	177.805	- 1.23	
12	280	219.911	226	177.500	+23.89	
14	176	188.146	166	177.456	+ 6.02	
16	111	154.985	127	177.325	- 12.60	
PO:	**889**	**738.665 ft^2**	**845**	**710.086 ft^2**	**+ 5.21%**	**+ 4.02%**
18	108	190.852	101	178.482	+ 36.93	
20	70	152.716	70	152.716	0.00	
22	7	18.479	10	26.398		
24+	0	0.000	0	0.000	0.00	
ST:	**185**	**362.047 ft^2**	**181**	**357.596 ft^2**	**+ 2.21%**	**+ 1.24%**
All:	**4503**	**1632.012 ft^2**	**4477**	**1600.814 ft^2**	**+ 0.58%**	**+ 1.95%**

Overstocked 0.65 trees/acre; overstocked 0.78 ft^2/acre.

Figure 7.7.1.1: Graphic comparison of data from Table 7.7.1. Farm Forty Residual Stand. Pulpwood: 1/10 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

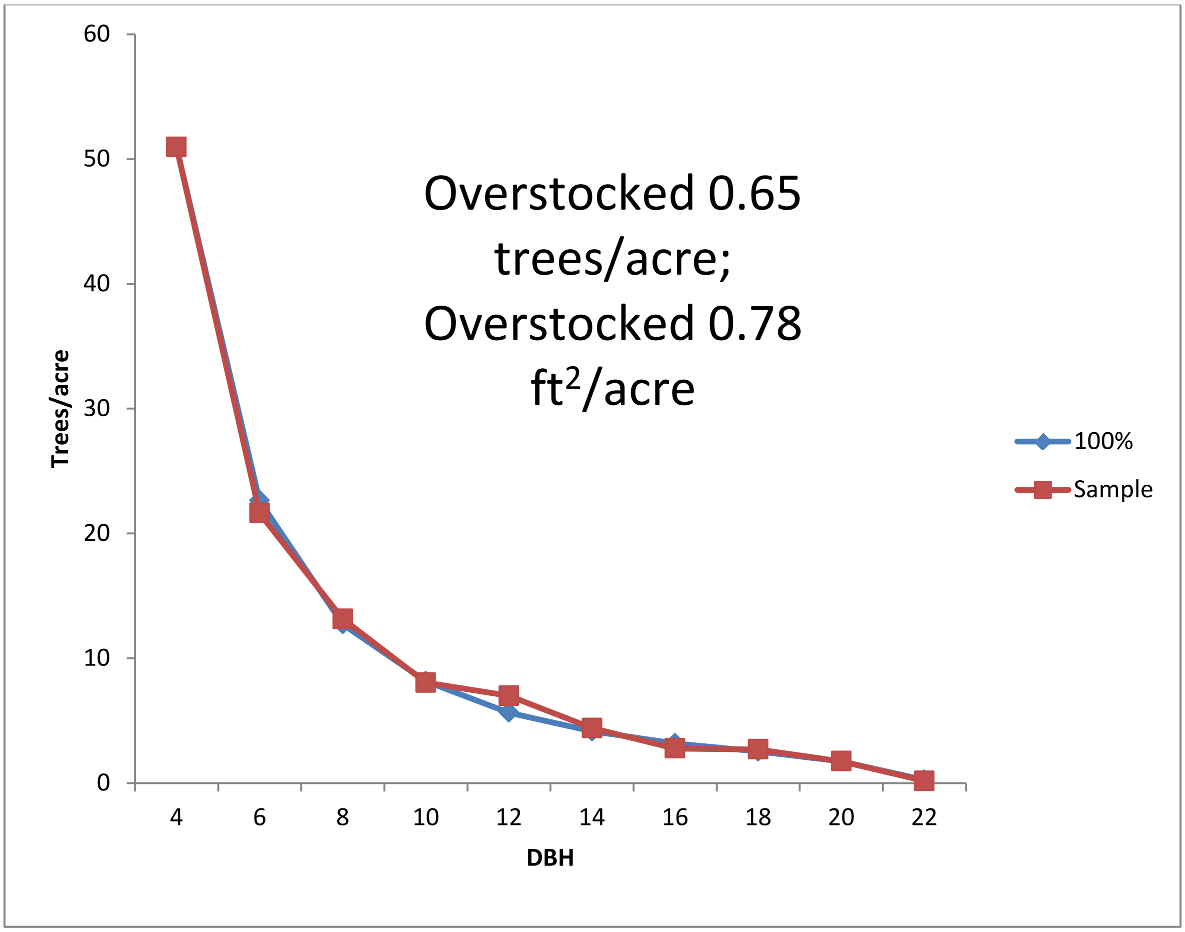


Figure 7.7.1.2: Graphic comparison of pulpwood category. Data from Table 7.7.1. Farm Forty Residual Stand. **Pulpwood: 1/10 acre + DBAR.** 2x2.5 chain grid, compared to 100% inventory.

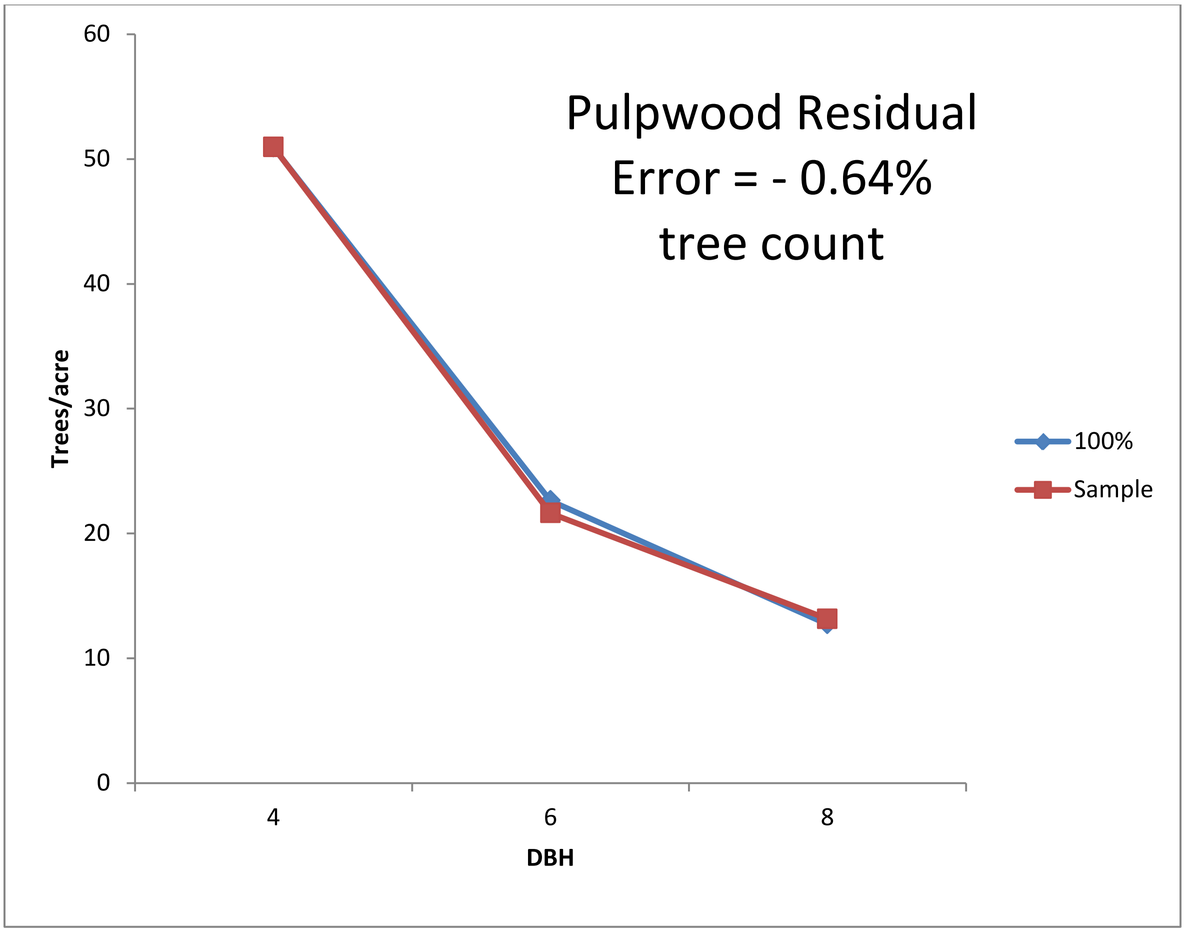


Figure 7.7.1.3: Graphic comparison of pole category. Data from Table 7.7.1. Farm Forty Residual Stand. **Poles: 10BAF.** 2x2.5 chain grid, compared to 100% inventory.

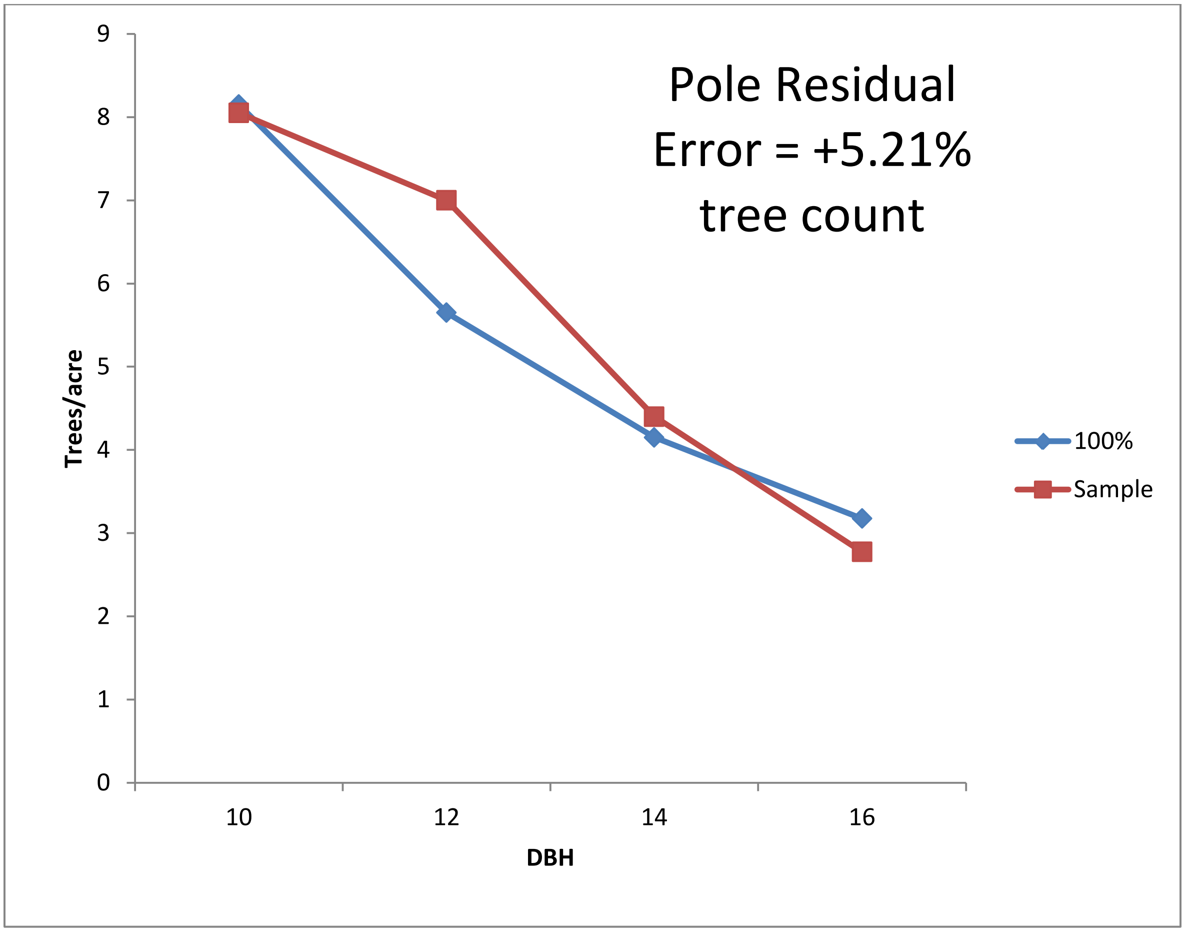


Figure 7.7.1.4: Graphic comparison of sawtimber category. Data from Table 7.7.1. Farm Forty Residual Stand. **Sawtimber: 10BAF**. 2x2.5 chain grid, compared to 100% inventory.

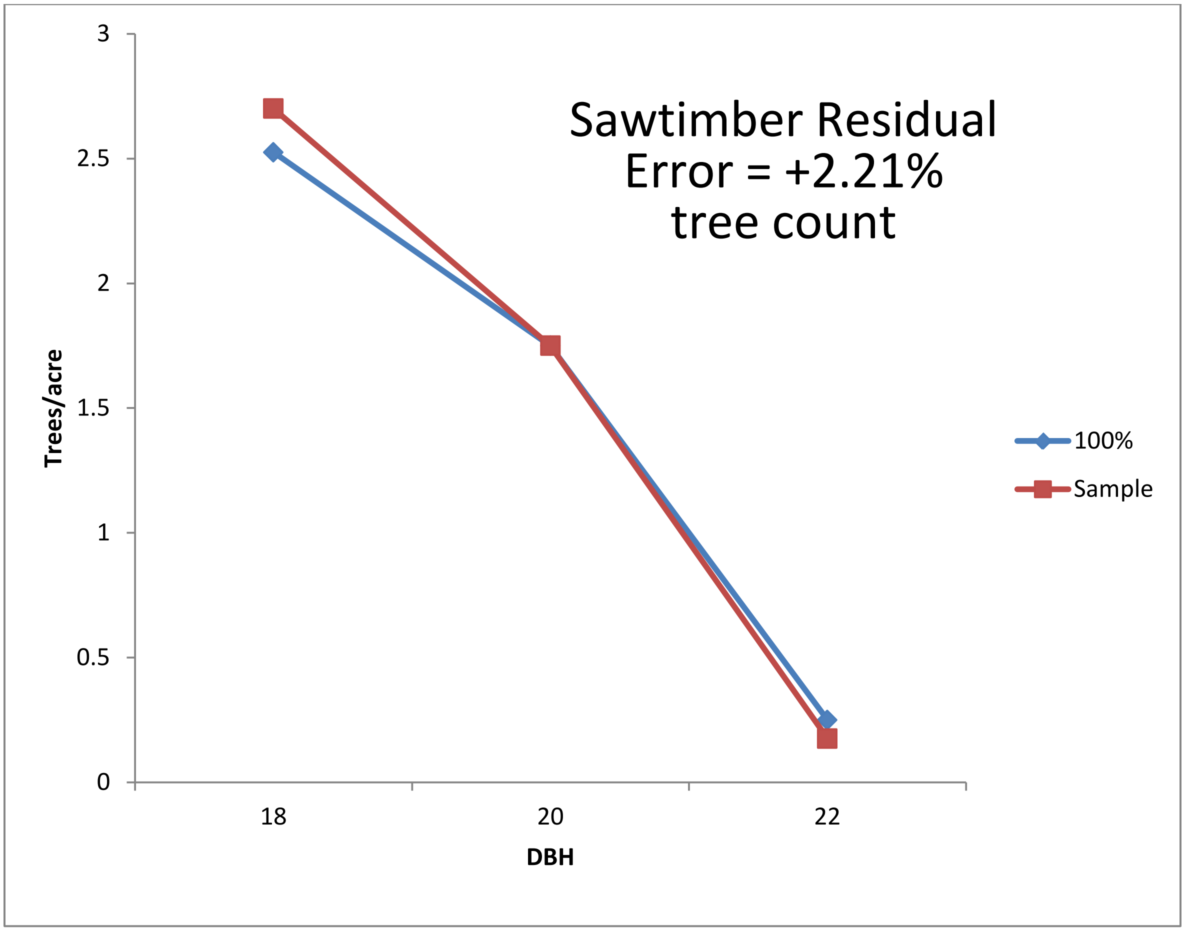


Table 7.7.2: Farm Forty Residual Stand. Pulpwood: 1/10 acre + DBAR; Poles: 1/10 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/10 DBAR + 1/10 DBAR + 10BAF) X WSR B=40, D=20, N=9

RESIDUAL STAND

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	2038	177.849	2037	177.762	+ 0.05	
6	865	169.842	905	177.696	- 4.42	
8	526	183.609	509	177.674	+ 3.34	
PW:	**3429**	**531.300 ft^2**	**3451**	**533.132 ft^2**	**- 0.64%**	**- 0.34%**
10	313	170.715	326	177.805	- 3.99	
12	267	209.701	226	177.500	+18.14	
14	181	193.492	166	177.456	+ 9.04	
16	87	121.475	127	177.325	- 31.50	
PO:	**848**	**695.383 ft^2**	**845**	**710.086 ft^2**	**+ 0.36%**	**- 2.07%**
18	108	190.852	101	178.482	+ 6.93	
20	70	152.716	70	152.716	0.00	
22	7	18.479	10	26.398	0.00	
24+	0	0.000	0	0.000	0.00	
ST:	**185**	**362.047 ft^2**	**181**	**357.596 ft^2**	**+ 2.21%**	**+ 1.24%**
All:	**4462**	**1588.730 ft^2**	**4477**	**1600.814 ft^2**	**- 0.34%**	**- 0.75%**

Under-stocked 0.38 trees/acre; under-stocked 0.30 ft^2/acre.

Figure 7.7.2.1: Graphic comparison of data from Table 7.7.2. Farm Forty Residual Stand. Pulpwood: 1/10 acre + DBAR; Poles: 1/10 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

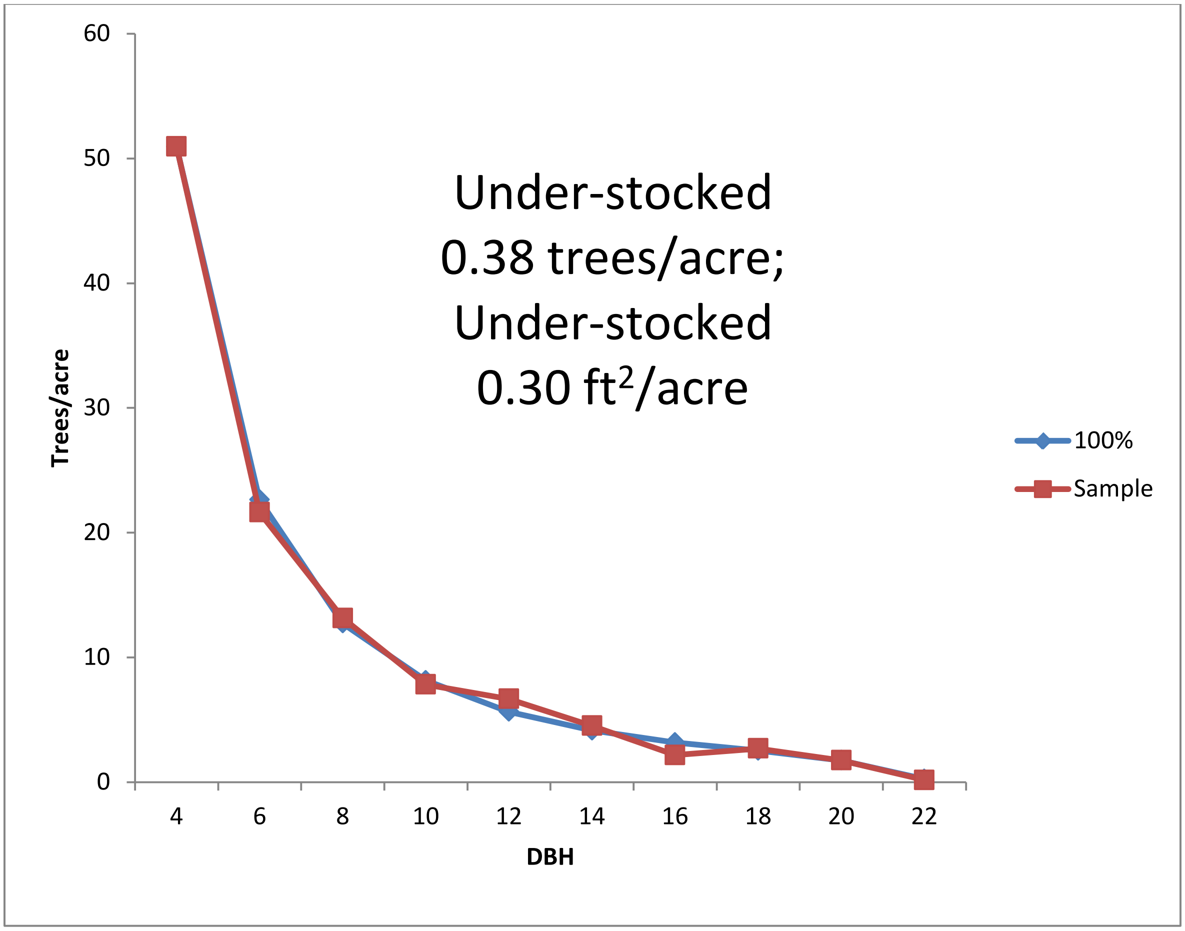


Figure 7.7.2.2: Graphic comparison of pole category. Data from Table 7.7.2. Farm Forty Residual Stand. **Poles: 1/10 acre + DBAR.** 2x2.5 chain grid, compared to 100% inventory.

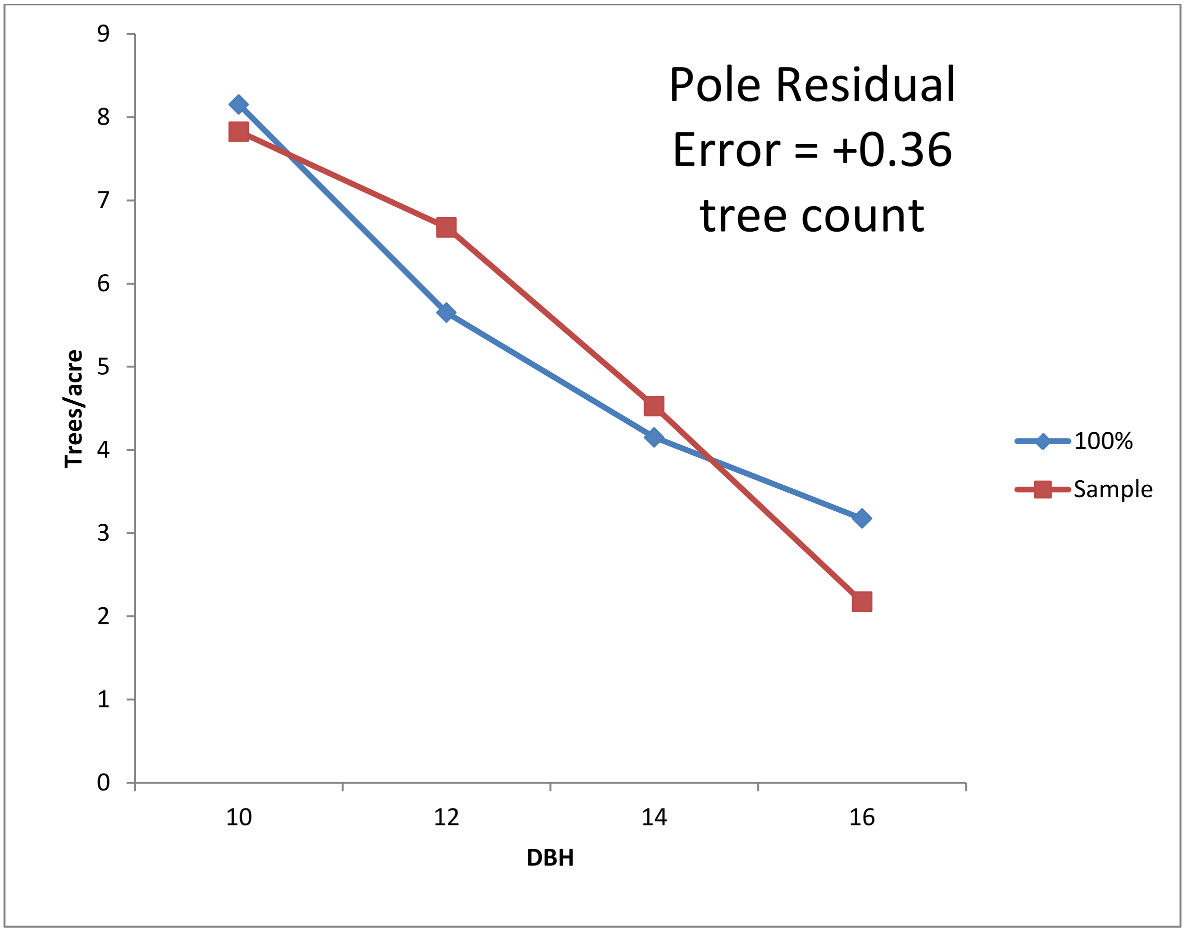


Table 7.7.3: Farm Forty Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/20 DBAR + 10BAF + 10BAF) X WSR B=40, D=20, N=9

RESIDUAL STAND

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	2038	177.849	2037	177.762	+ 0.05	
6	826	162.185	905	177.696	- 8.73	
8	488	170.344	509	177.674	- 4.12	
PW:	**3352**	**510.378 ft^2**	**3451**	**533.132 ft^2**	**- 2.87%**	**- 4.27%**
10	322	170.715	326	177.805	- 3.99	
12	280	209.701	226	177.500	+18.14	
14	176	193.492	166	177.456	+ 9.04	
16	111	121.475	127	177.325	- 31.50	
PO:	**889**	**695.383 ft^2**	**845**	**710.086 ft^2**	**+ 0.36%**	**- 2.07%**
18	108	190.852	101	178.482	+ 6.93	
20	70	152.716	70	152.716	0.00	
22	10	26.398	10	26.398	0.00	
24+	0	0.000	0	0.000	0.00	
ST:	**188**	**369.966 ft^2**	**181**	**357.596 ft^2**	**+ 3.87%**	**+ 1.24%**
All:	**4429**	**1575.727 ft^2**	**4477**	**1600.814 ft^2**	**- 1.07%**	**- 1.57%**

Under-stocked 1.2 trees/acre; under-stocked 0.63 ft^2/acre.

Figure 7.7.3.1: Graphic comparison of data from Table 7.7.3. Farm Forty Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

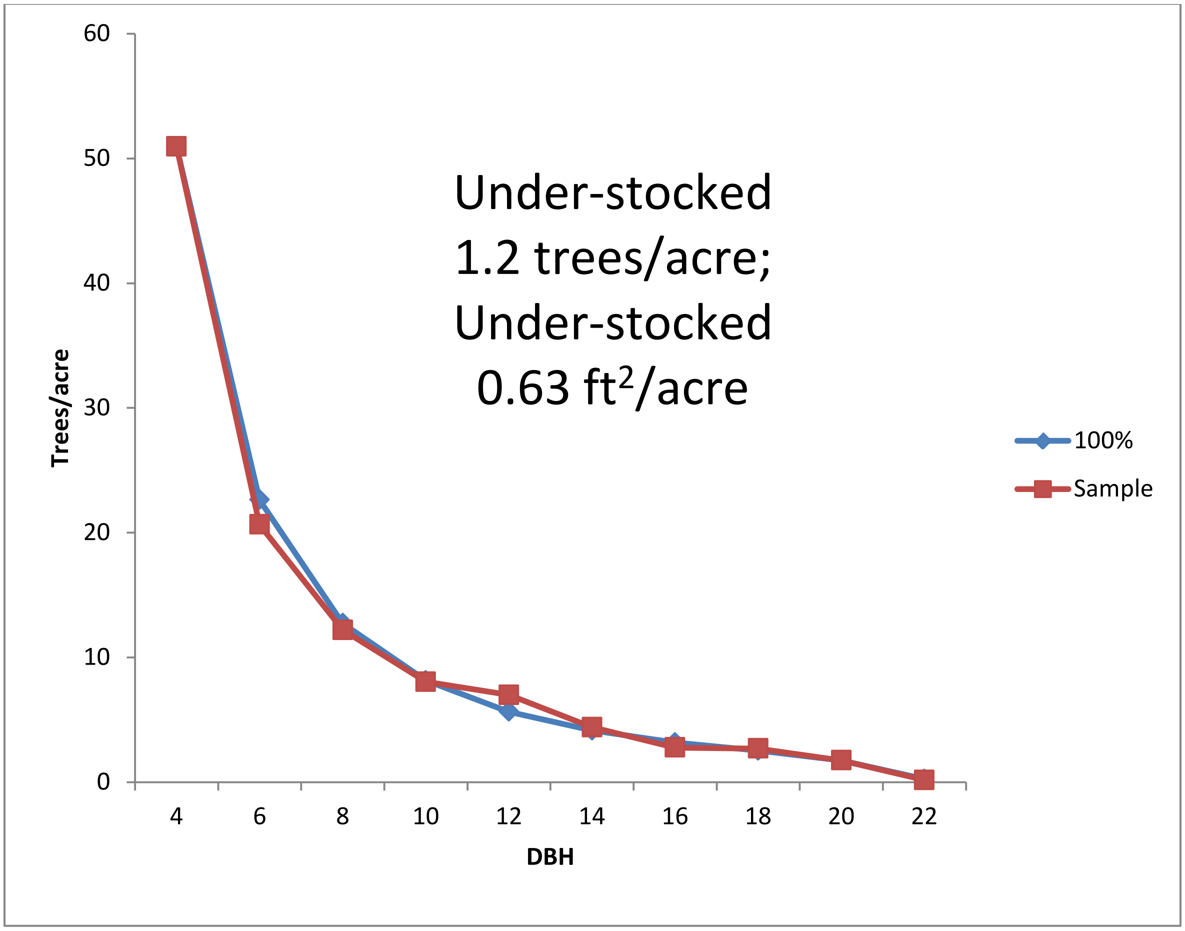


Figure 7.7.3.2: Graphic comparison of pulpwood category. Data from Table 7.7.3. Farm Forty Residual Stand. **Pulpwood: 1/20 acre + DBAR.** 2x2.5 chain grid, compared to 100% inventory.

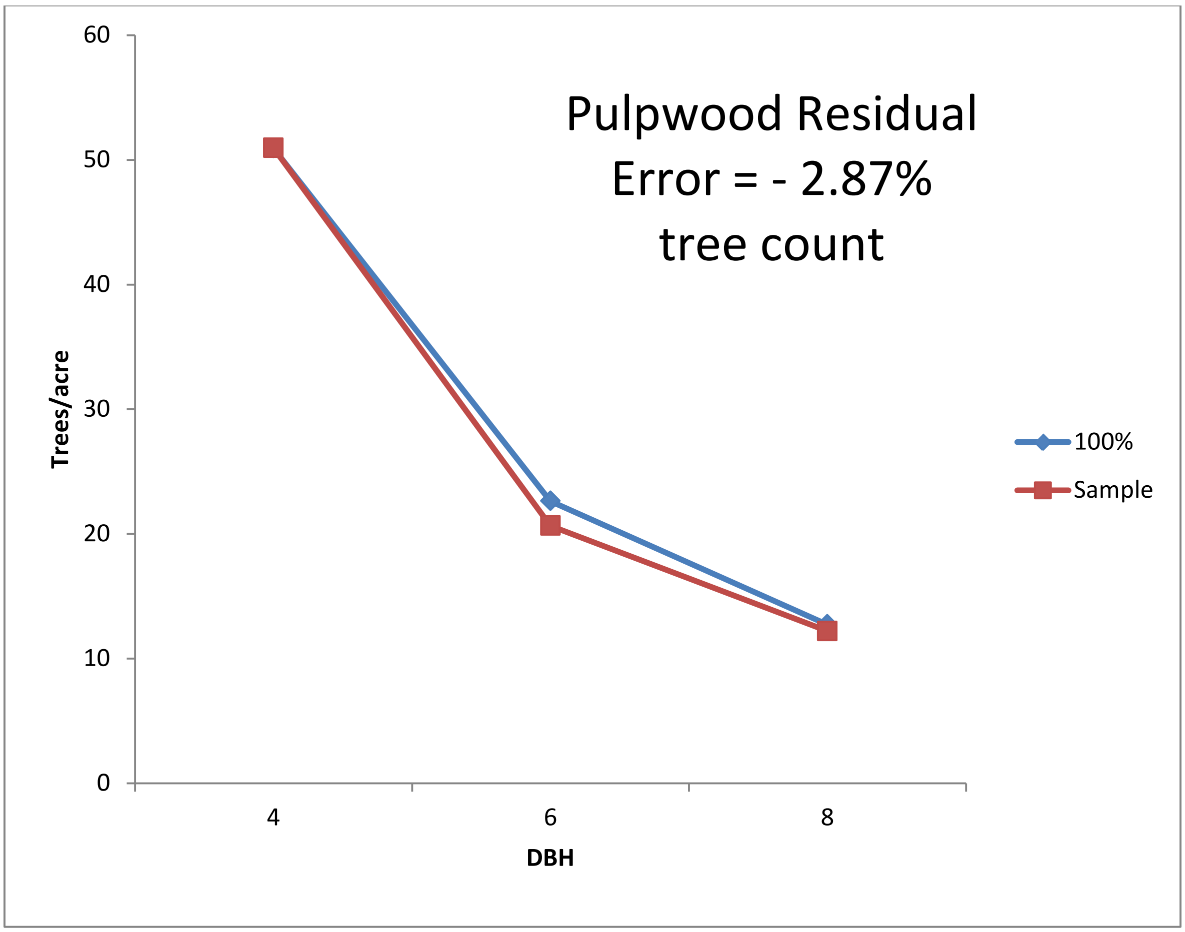


Table 7.7.4: Farm Forty Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 1/20 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/20 DBAR + 1/20 DBAR + 10BAF) X WSR B=40, D=20, N=9

RESIDUAL STAND

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	2038	177.849	2037	177.762	+ 0.05	
6	826	162.185	905	177.696	- 8.73	
8	488	170.344	509	177.674	- 4.12	
PW:	**3352**	**510.378 ft^2**	**3451**	**533.132 ft^2**	**- 2.87%**	**- 4.27%**
10	374	203.985	326	177.805	+14.72	
12	268	210.487	226	177.500	+18.58	
14	111	118.660	166	177.456	- 33.13	
16	80	111.701	127	177.325	- 37.01	
PO:	**833**	**644.833 ft^2**	**845**	**710.086 ft^2**	**- 1.42%**	**- 9.19%**
18	108	190.852	101	178.482	+ 6.93	
20	70	152.716	70	152.716	0.00	
22	10	26.398	10	26.398	0.00	
24+	0	0.000	0	0.000	0.00	
ST:	**188**	**369.966 ft^2**	**181**	**357.596 ft^2**	**+ 3.87%**	**+ 1.24%**
All:	**4373**	**1525.177 ft^2**	**4477**	**1600.814 ft^2**	**- 2.32%**	**- 4.72%**

Under-stocked 2.6 trees/acre; under-stocked 1.89 ft^2/acre.

Figure 7.7.4.1: Graphic comparison of data from Table 7.7.4. Farm Forty Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 1/20 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

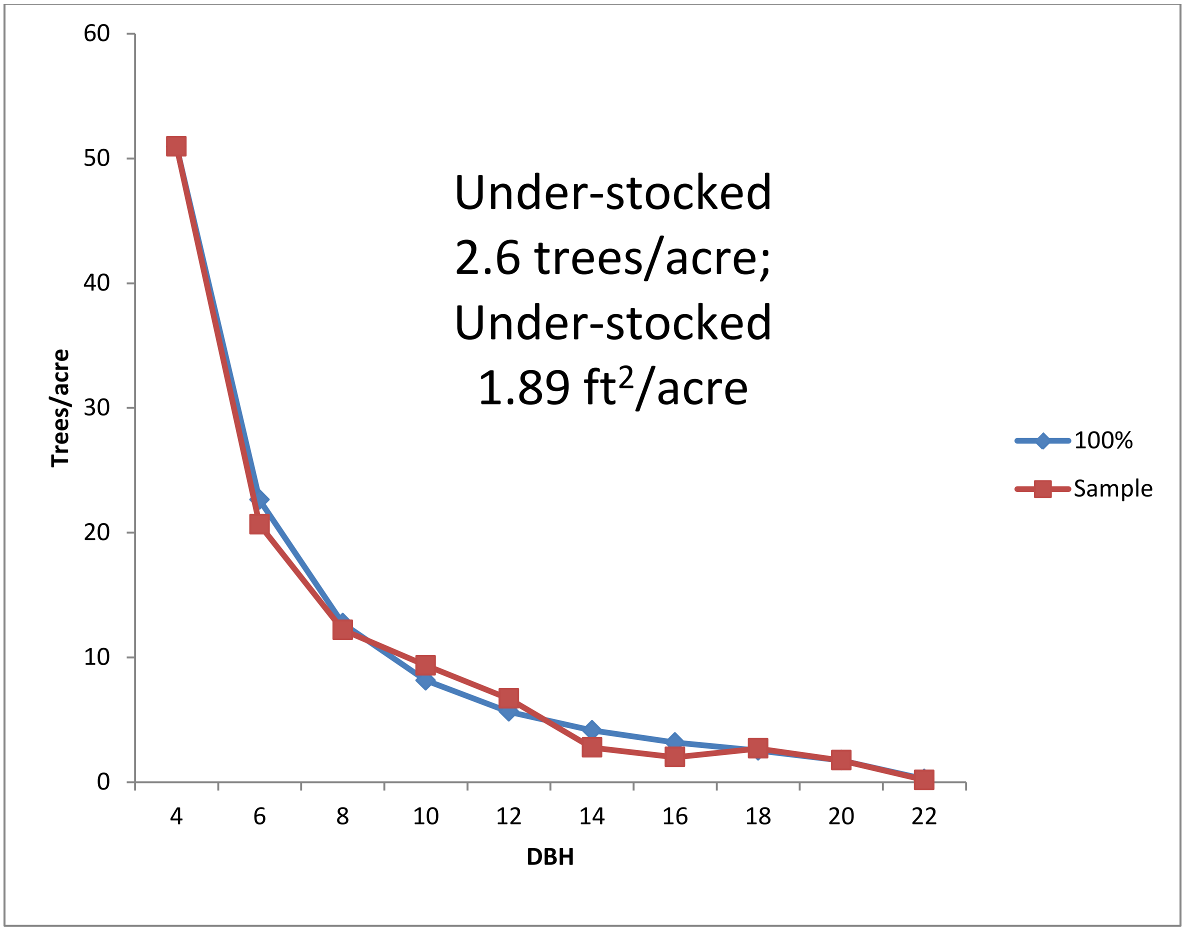
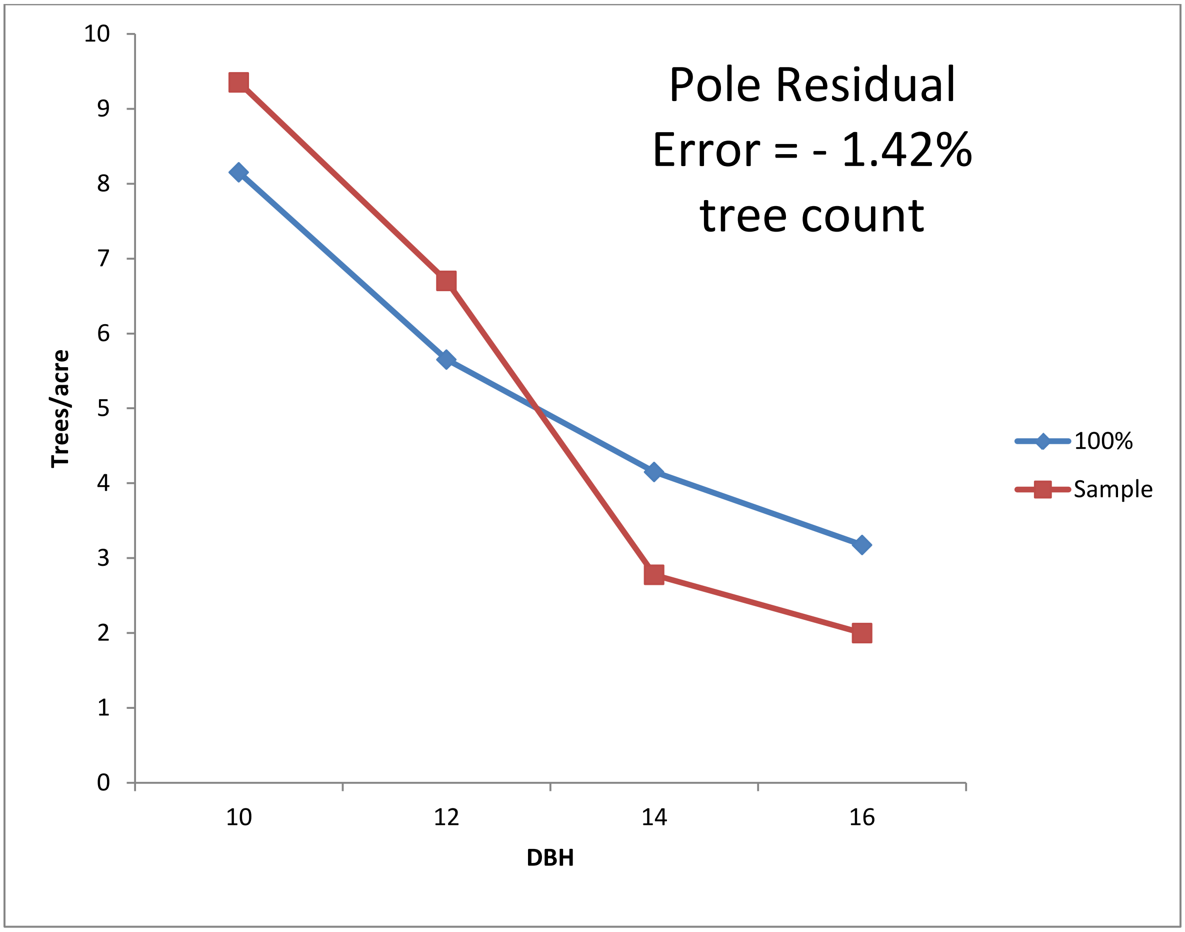


Figure 7.7.4.2: Graphic comparison of pole category. Data from Table 7.7.4. Farm Forty Residual Stand. **Poles: 1/20 acre + DBAR.** 2x2.5 chain grid, compared to 100% inventory.



Appendix 7.8: Residual Stand Estimates, Comp. 102

Table 7.8.1: Comp 102 Residual Stand. Pulpwood: 1/10 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/10 DBAR + 10BAF + 10BAF) X WSR B=40, D=20, N=9

RESIDUAL STAND

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1341	117.024	1341	117.024	0.00	
6	818	160.614	818	160.614	0.00	
8	336	117.286	509	177.674	-33.99	
PW:	**2495**	**394.924 ft^2**	**2668**	**455.312 ft^2**	**- 6.48%**	**- 13.26%**
10	288	157.080	406	221.439	- 29.06	
12	342	268.606	283	222.268	+20.85	
14	242	258.701	208	222.355	+16.35	
16	138	192.684	159	222.006	- 13.21	
PO:	**1010**	**877.071 ft^2**	**1056**	**888.068 ft^2**	**- 4.36%**	**- 1.24%**
18	106	187.317	106	187.317	0.00	
20	28	61.086	28	61.086	0.00	
22	3	7.919	3	7.919	0.00	
ST:	**137**	**256.322 ft^2**	**137**	**256.322 ft^2**	**0.00%**	**0.00%**
All:	**3642**	**1528.317 ft^2**	**3861**	**1599.702 ft^2**	**- 5.67%**	**- 4.46%**

Under-stocked 5.48 trees/acre; under-stocked 1.78 ft^2/acre.

Figure 7.8.1.1: Graphic comparison of data from Table 7.8.1. Comp 102 Residual Stand. Pulpwood: 1/10 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

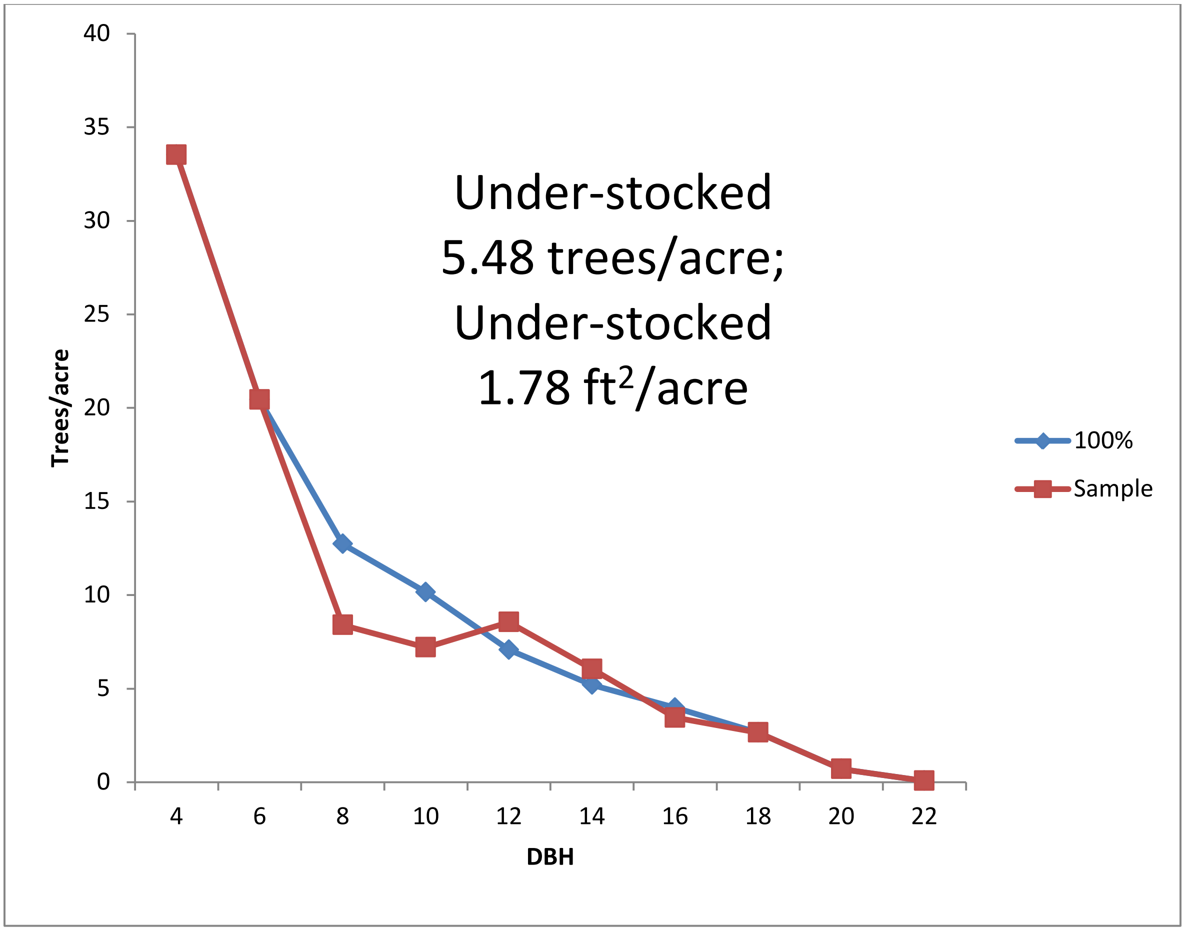


Figure 7.8.1.2: Graphic comparison of pulpwood category. Data from Table 7.8.1. Comp 102 Residual Stand. **Pulpwood: 1/10 acre + DBAR.** 2x2.5 chain grid, compared to 100% inventory.

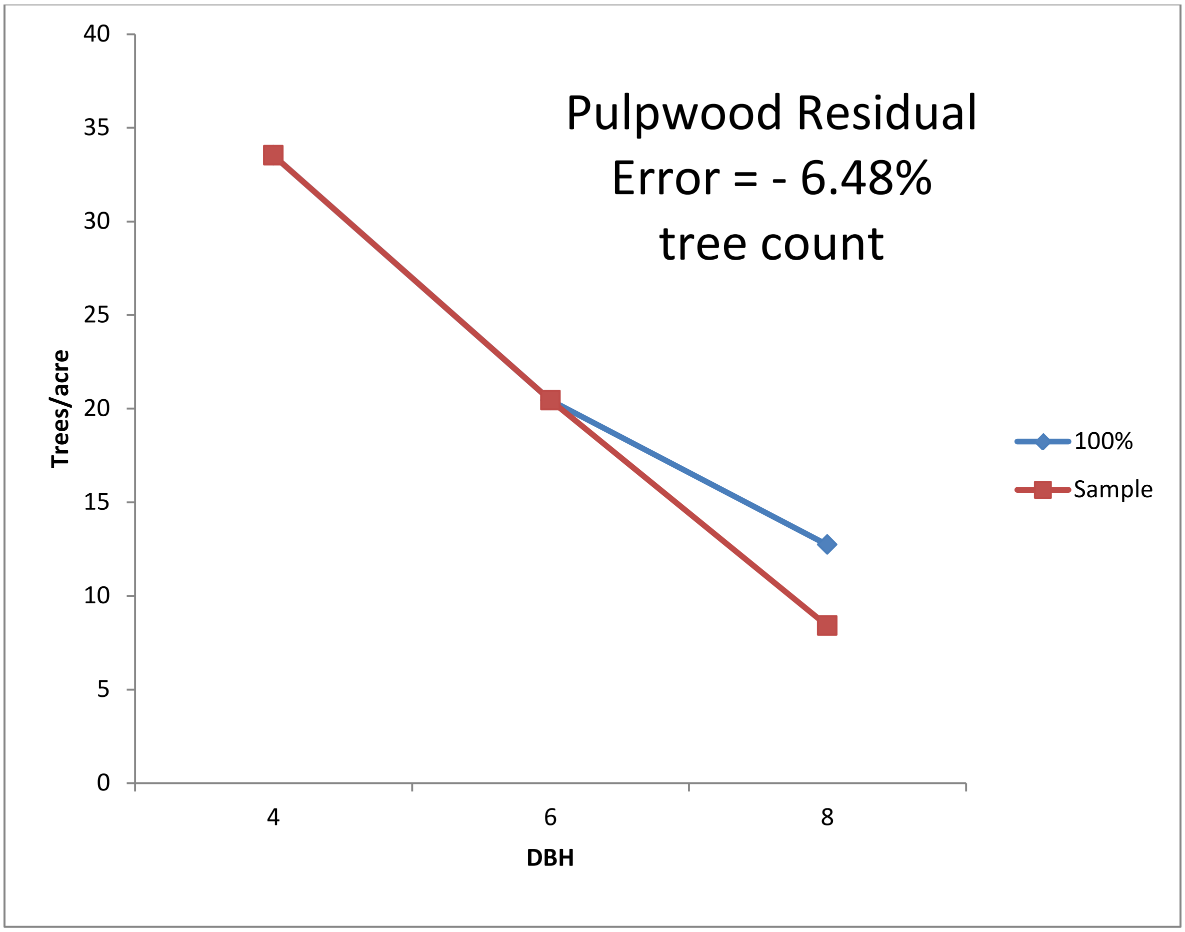


Figure 7.8.1.3: Graphic comparison of pole category. Data from Table 7.8.1. Comp 102 Residual Stand. **Poles: 10BAF.** 2x2.5 chain grid, compared to 100% inventory.

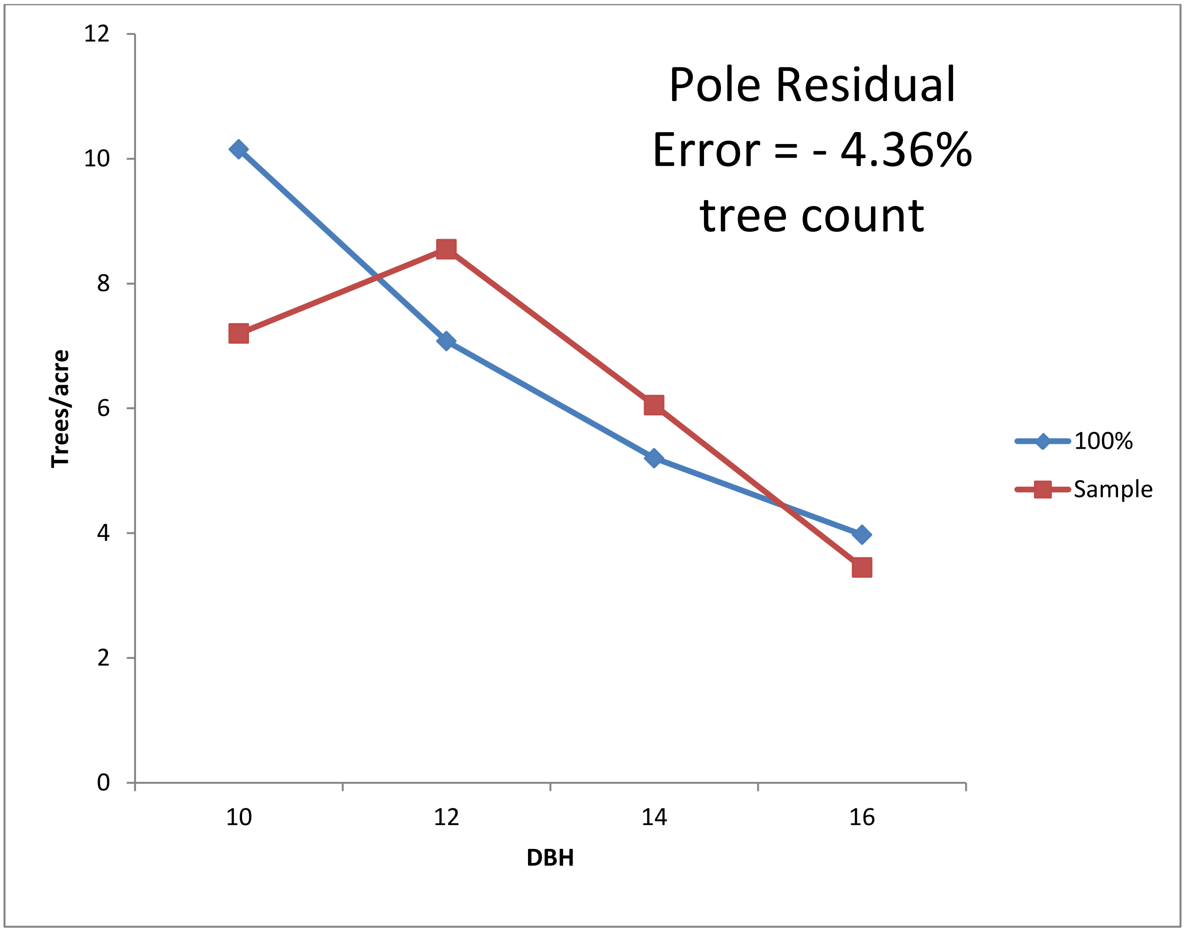


Figure 7.8.1.4: Graphic comparison of sawtimber category. Data from Table 7.8.1. Comp 102 Residual Stand. **Sawtimber: 10BAF**. 2x2.5 chain grid, compared to 100% inventory.

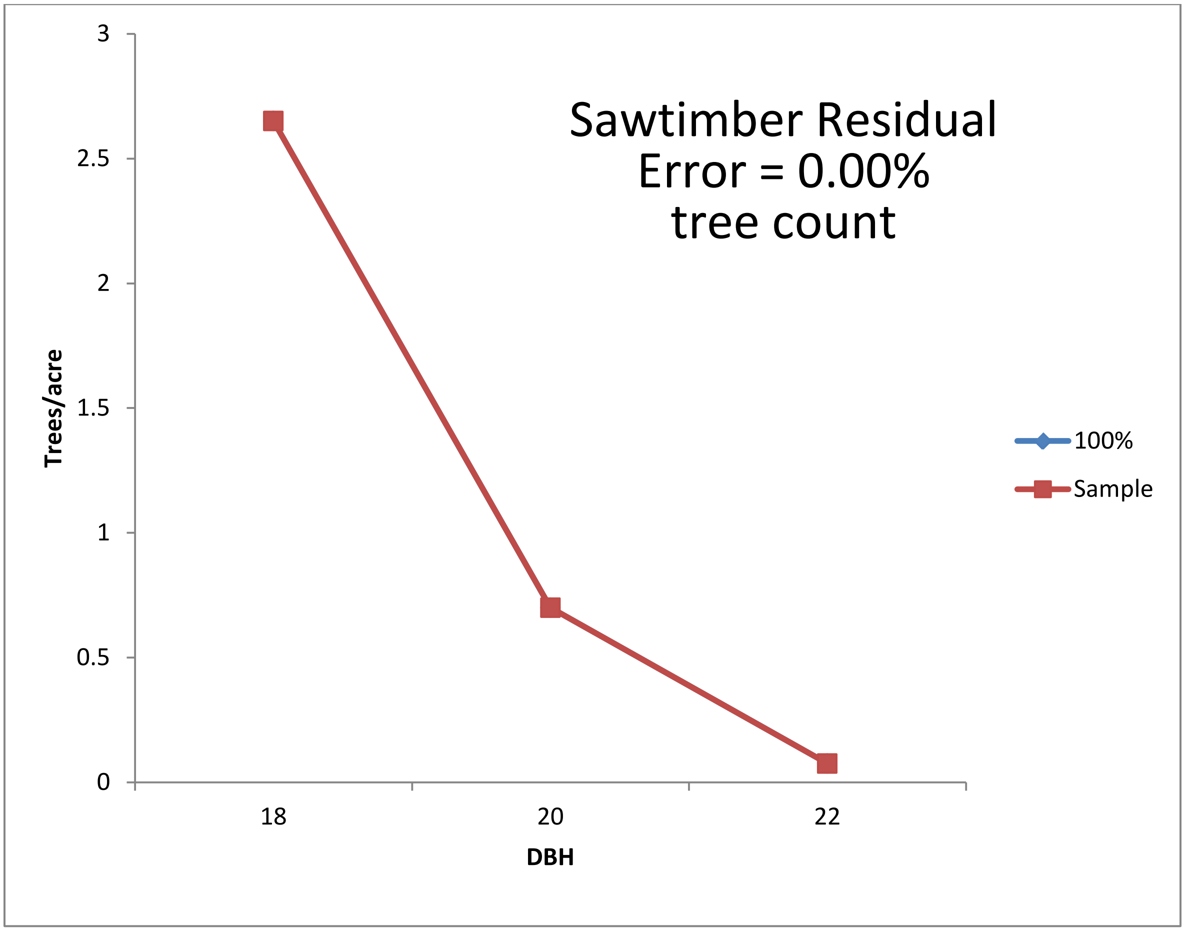


Table 7.8.2: Comp 102 Residual Stand. Pulpwood: 1/10 acre + DBAR; Poles: 1/10 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/10 DBAR + 1/10 DBAR + 10BAF) X WSR B=40, D=20, N=9

RESIDUAL STAND

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1341	117.024	1341	117.024	0.00	
6	818	160.614	818	160.614	0.00	
8	336	117.286	509	177.674	-33.99	
PW:	**2495**	**394.924 ft^2**	**2668**	**455.312 ft^2**	**- 6.48%**	**- 13.26%**
10	359	195.804	406	221.439	- 11.58	
12	337	264.679	283	222.268	+19.08	
14	259	276.874	208	222.355	+24.52	
16	133	185.703	159	222.006	- 16.35	
PO:	**1088**	**923.060 ft^2**	**1056**	**888.068 ft^2**	**+ 3.03%**	**+ 3.94%**
18	106	187.317	106	187.317	0.00	
20	28	61.086	28	61.086	0.00	
22	3	7.919	3	7.919	0.00	
ST:	**137**	**256.322 ft^2**	**137**	**256.322 ft^2**	**0.00%**	**0.00%**
All:	**3720**	**1574.306 ft^2**	**3861**	**1599.702 ft^2**	**- 3.65%**	**- 1.59%**

Under-stocked 3.52 trees/acre; under-stocked 0.63 ft^2/acre.

Figure 7.8.2.1: Graphic comparison of data from Table 7.8.2. Comp 102 Residual Stand. Pulpwood: 1/10 acre + DBAR; Poles: 1/10 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

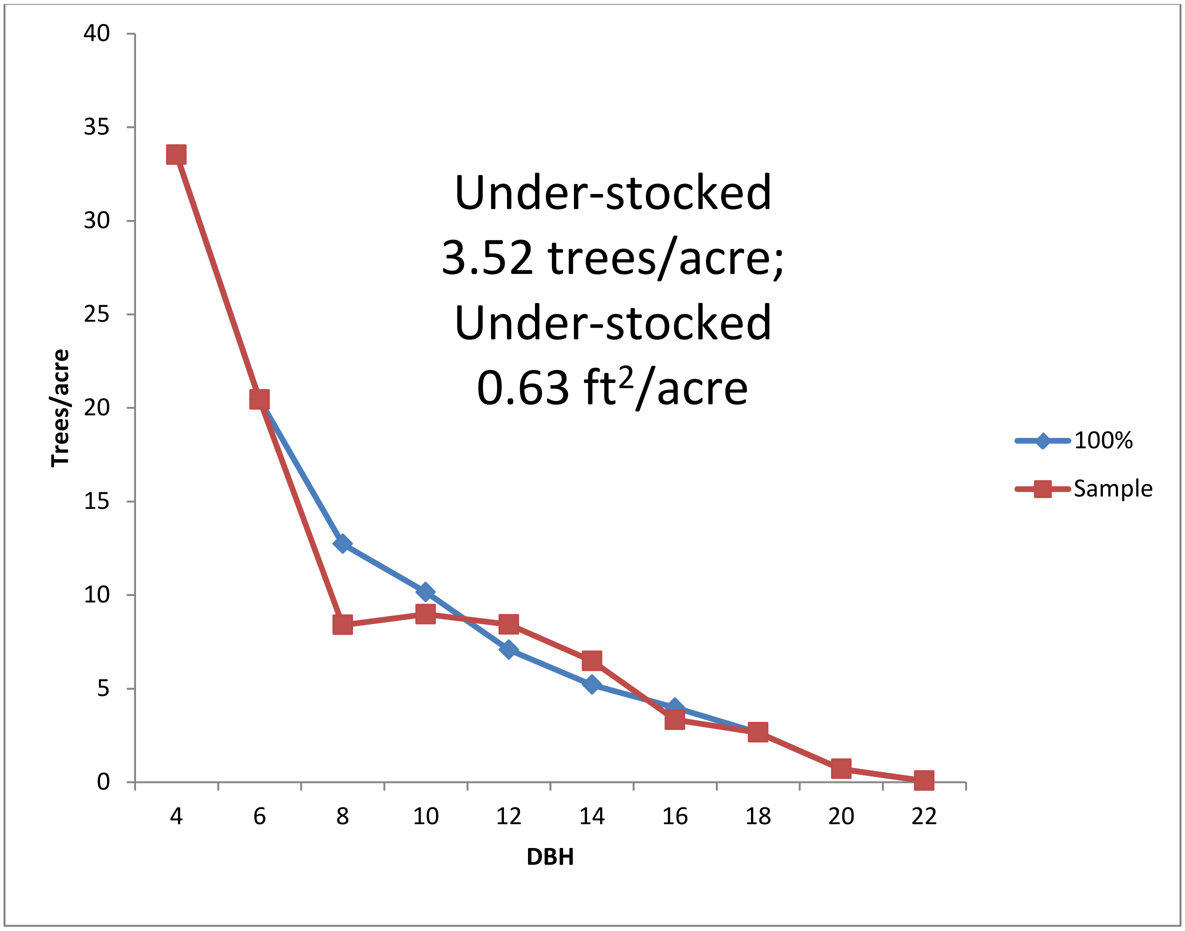


Figure 7.8.2.2: Graphic comparison of pole category. Data from Table 7.8.2. Comp 102 Residual Stand. **Poles: 1/10 acre + DBAR.** 2x2.5 chain grid, compared to 100% inventory.

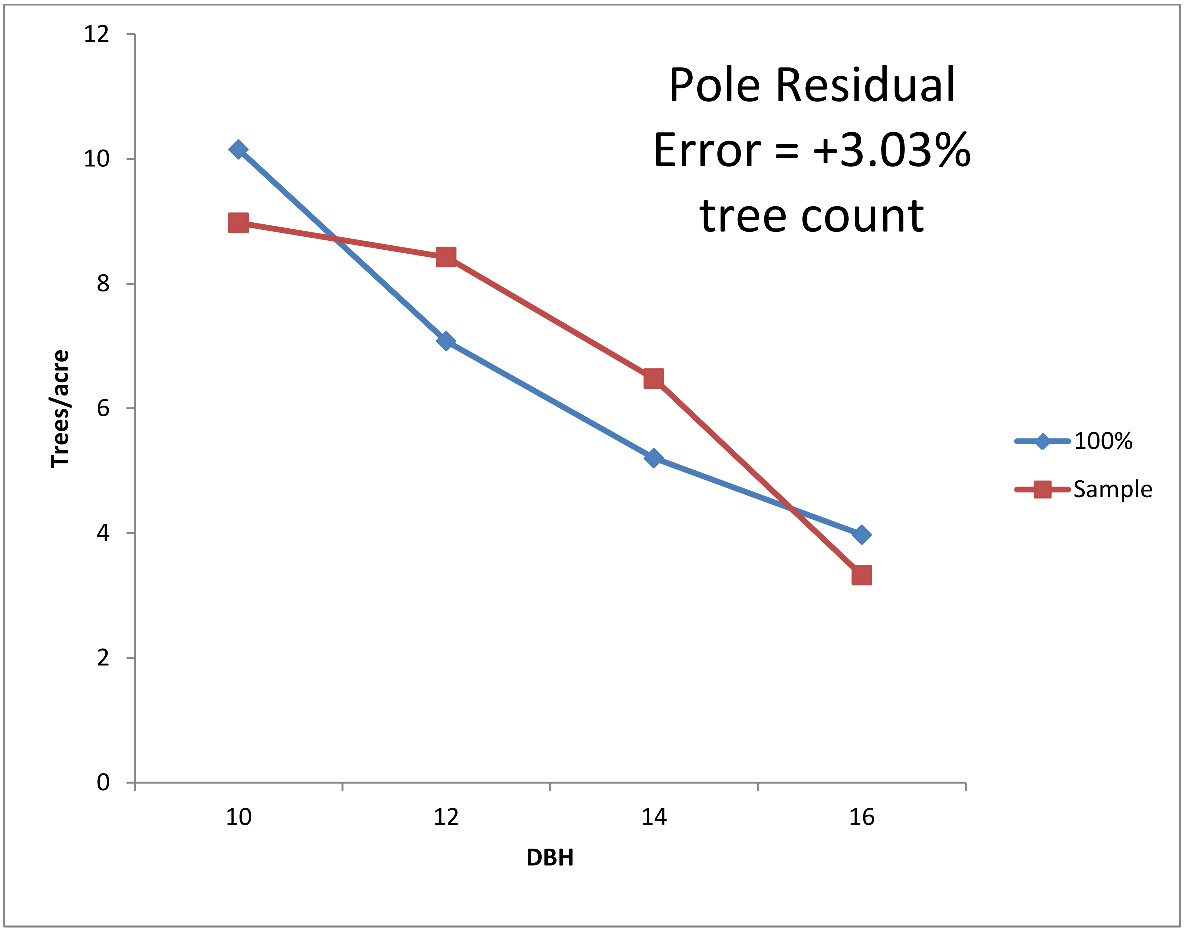


Table 7.8.3: Comp 102 Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/20 DBAR + 10BAF + 10BAF) X WSR B=40, D=20, N=9

RESIDUAL STAND

	CRUISE		**100%**		**% ERROR**	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1341	117.024	1341	117.024	0.00	
6	818	160.614	818	160.614	0.00	
8	351	122.522	509	177.674	-31.04	
PW:	**2510**	**400.160 ft^2**	**2668**	**455.312 ft^2**	**- 5.92%**	**- 12.11%**
10	295	160.898	406	221.439	- 27.34	
12	347	272.533	283	222.268	+22.61	
14	246	262.977	208	222.355	+18.27	
16	141	196.873	159	222.006	- 11.32	
PO:	**1029**	**893.281 ft^2**	**1056**	**888.068 ft^2**	**- 2.56%**	**- 0.59%**
18	106	187.317	106	187.317	0.00	
20	28	61.086	28	61.086	0.00	
22	3	7.919	3	7.919	0.00	
ST:	**137**	**256.322 ft^2**	**137**	**256.322 ft^2**	**0.00%**	**0.00%**
All:	**3676**	**1549.763 ft^2**	**3861**	**1599.702 ft^2**	**- 4.79%**	**- 3.12%**

Under-stocked 4.62 trees/acre; under-stocked 1.25 ft^2/acre.

Figure 7.8.3.1: Graphic comparison of data from Table 7.8.3. Comp 102 Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

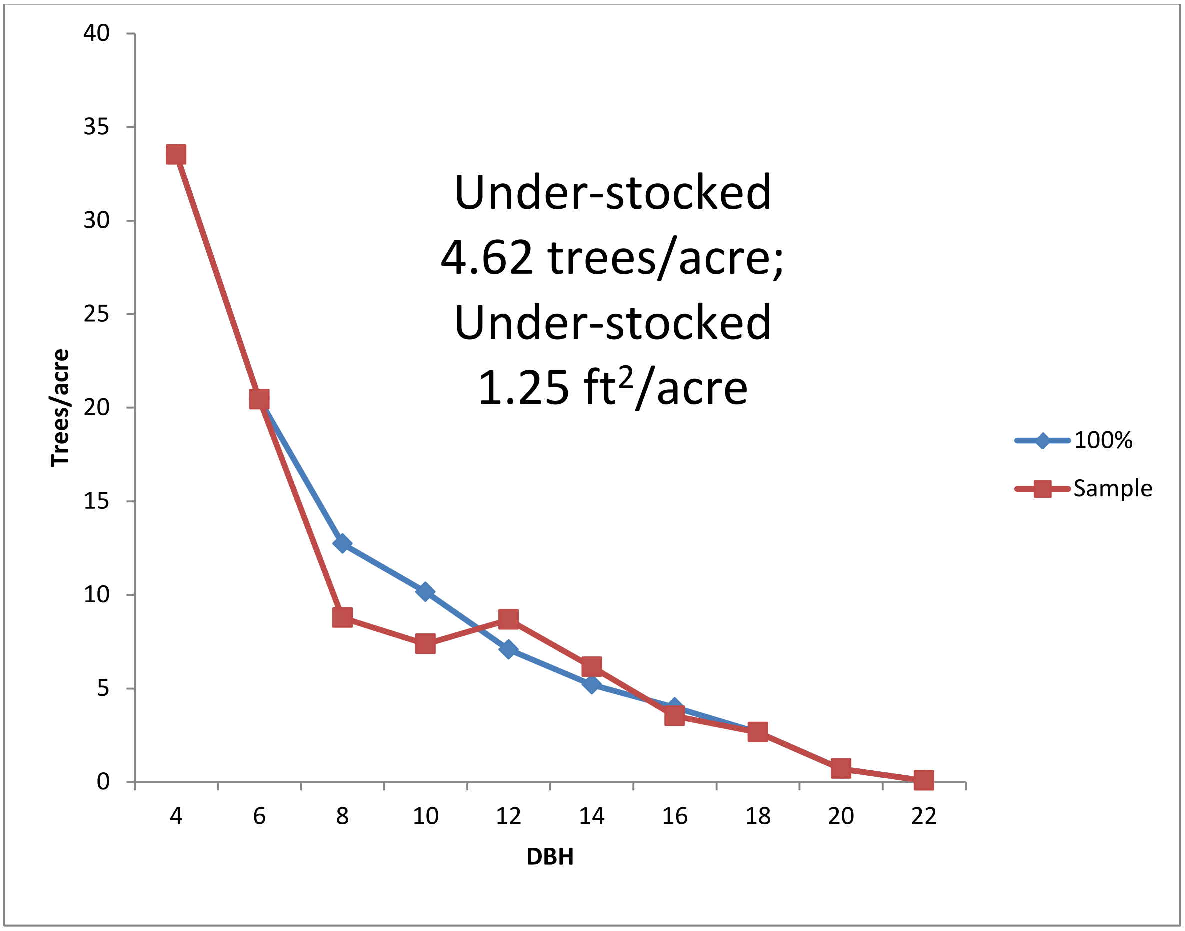


Figure 7.8.3.2: Graphic comparison of pulpwood category. Data from Table 7.8.3. Comp 102 Residual Stand. **Pulpwood: 1/20 acre + DBAR.** 2x2.5 chain grid, compared to 100% inventory.

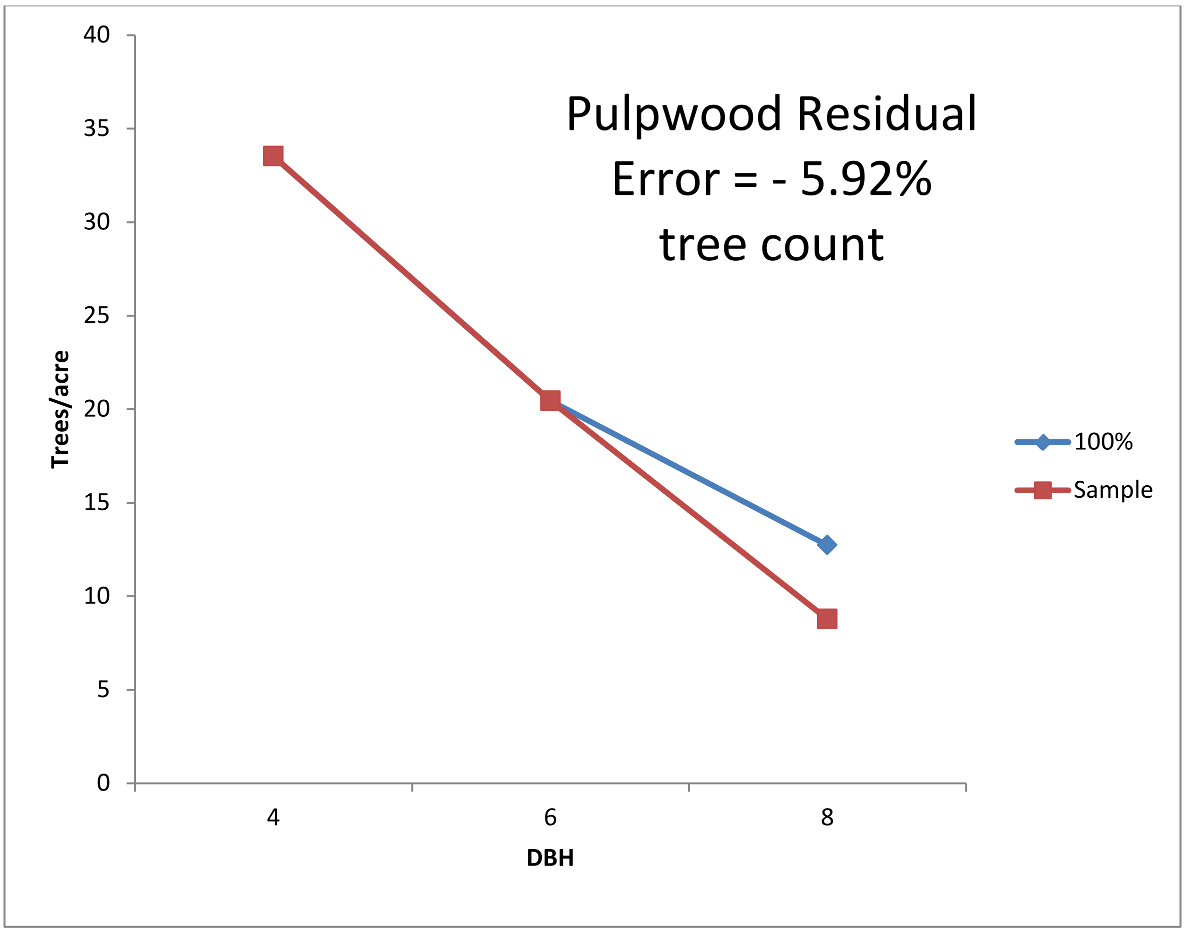


Table 7.8.4: Comp 102 Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 1/20 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

(1/20 DBAR + 1/20 DBAR + 10BAF) X WSR   B=40, D=20, N=9

RESIDUAL STAND

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	1341	117.024	1341	117.024	0.00	
6	818	160.614	818	160.614	0.00	
8	351	122.522	509	177.674	-31.04	
PW:	**2510**	**400.160 ft^2**	**2668**	**455.312 ft^2**	**- 5.92%**	**- 12.11%**
10	327	178.351	406	221.439	- 19.46	
12	394	309.447	283	222.268	+39.22	
14	261	279.013	208	222.355	+25.48	
16	171	238.761	159	222.006	+ 7.55	
PO:	**1153**	**1005.572 ft^2**	**1056**	**888.068 ft^2**	**+ 9.18%**	**+13.23%**
18	106	187.317	106	187.317	0.00	
20	28	61.086	28	61.086	0.00	
22	3	7.919	3	7.919	0.00	
ST:	**137**	**256.322 ft^2**	**137**	**256.322 ft^2**	**0.00%**	**0.00%**
All:	**3800**	**1662.054 ft^2**	**3861**	**1599.702 ft^2**	**- 1.58%**	**+ 3.90%**

Under-stocked 1.52 trees/acre; overstocked 1.56 ft^2/acre.

Figure 7.8.4.1: Graphic comparison of data from Table 7.8.4. Comp 102 Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 1/20 acre + DBAR; Sawtimber: 10BAF. 2x2.5 chain grid, compared to 100% inventory.

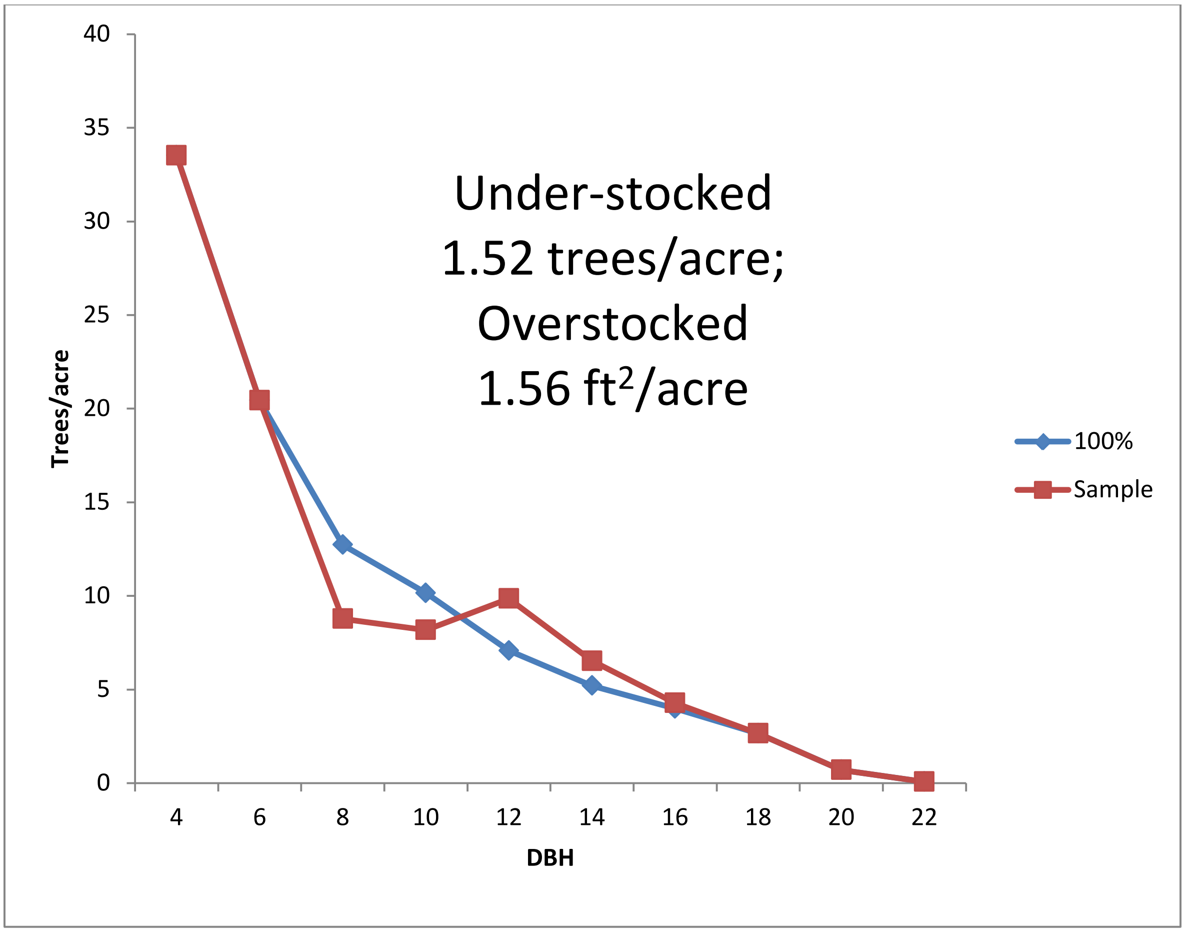
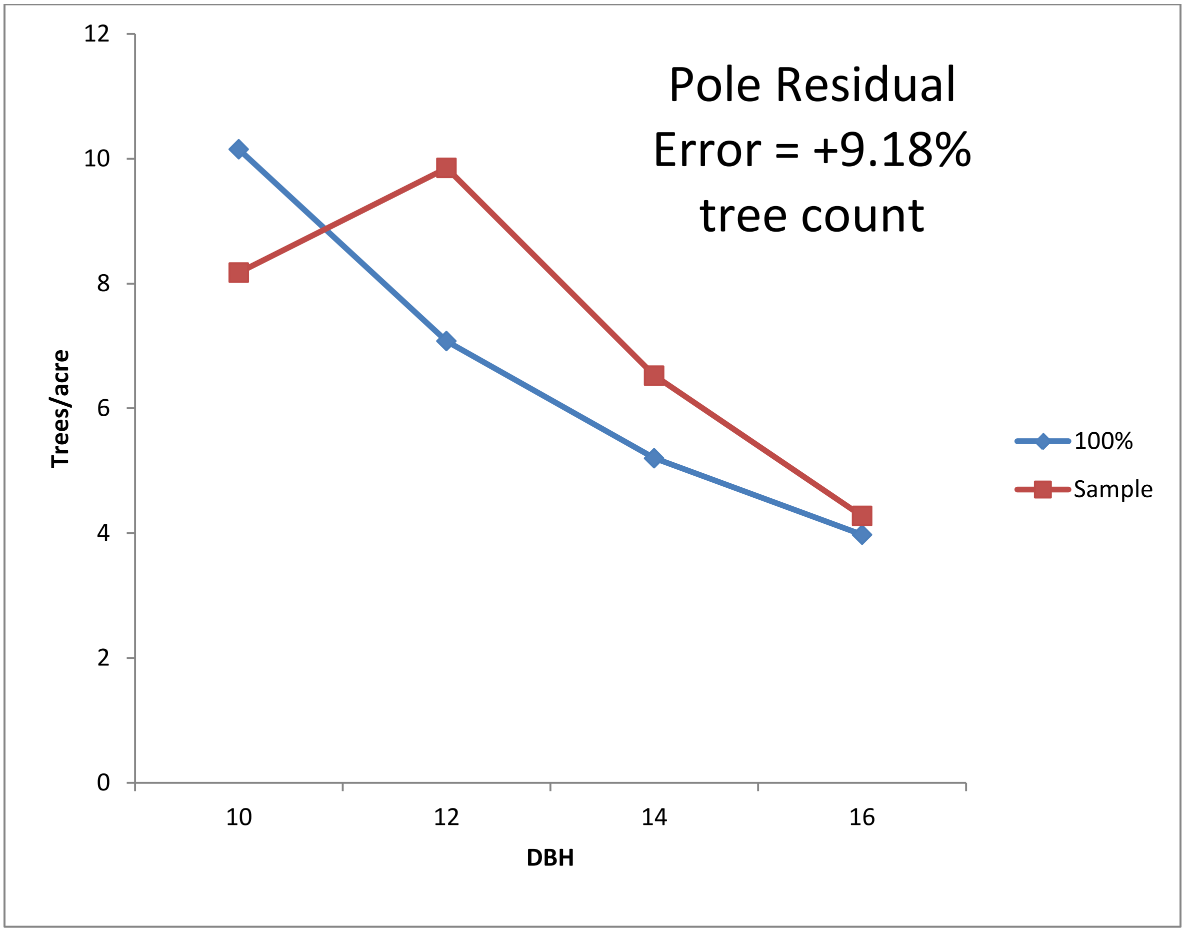


Figure 7.8.4.2: Graphic comparison of pole category. Data from Table 7.8.4. Comp 102 Residual Stand. **Poles: 1/20 acre + DBAR.** 2x2.5 chain grid, compared to 100% inventory.



Appendix 7.9: Residual Stand Estimates, Farm Forty + Comp. 102

Table 7.9.1: Comp. 102 + Farm Forty Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x5 chain grid, compared to 100% inventory.

(1/20 DBAR + 10BAF + 10BAF) X WSR B=40, D=20, N=9

RESIDUAL STAND

	CRUISE		**100%**		**% ERROR**	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	3379	294.873	3379	294.873	0.00	
6	1872	367.566	1811	355.589	+ 3.37	
8	1194	416.785	1018	355.349	+12.87	
PW:	**6445**	**1079.224 ft^2**	**6208**	**1005.811 ft^2**	**+ 3.82%**	**+ 7.30%**
10	529	288.525	654	356.702	- 19.11	
12	434	340.863	456	358.142	- 4.82	
14	242	258.701	335	358.120	- 27.76	
16	298	416.086	257	358.840	+15.95	
PO:	**1503**	**1304.175 ft^2**	**1702**	**1431.804 ft^2**	**- 11.69%**	**- 8.91%**
18	230	406.444	237	418.813	- 2.95	
20	98	213.802	98	213.802	0.00	
22	47	124.071	47	124.071	0.00	
24+	0	0.000	0	0.000	0.00	
ST:	**375**	**744.317 ft^2**	**382**	**756.686 ft^2**	**- 1.83%**	**- 1.63%**
All:	**8323**	**3127.716 ft^2**	**8292**	**3194.301 ft^2**	**+ 0.37%**	**- 2.08%**

Overstocked 0.78 trees/acre; under-stocked 1.66 ft^2/acre.

Figure 7.9.1.1: Graphic comparison of data from Table 7.9.1. Comp 102 + Farm Forty Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 10BAF; Sawtimber: 10BAF. 2x5 chain grid, compared to 100% inventory.

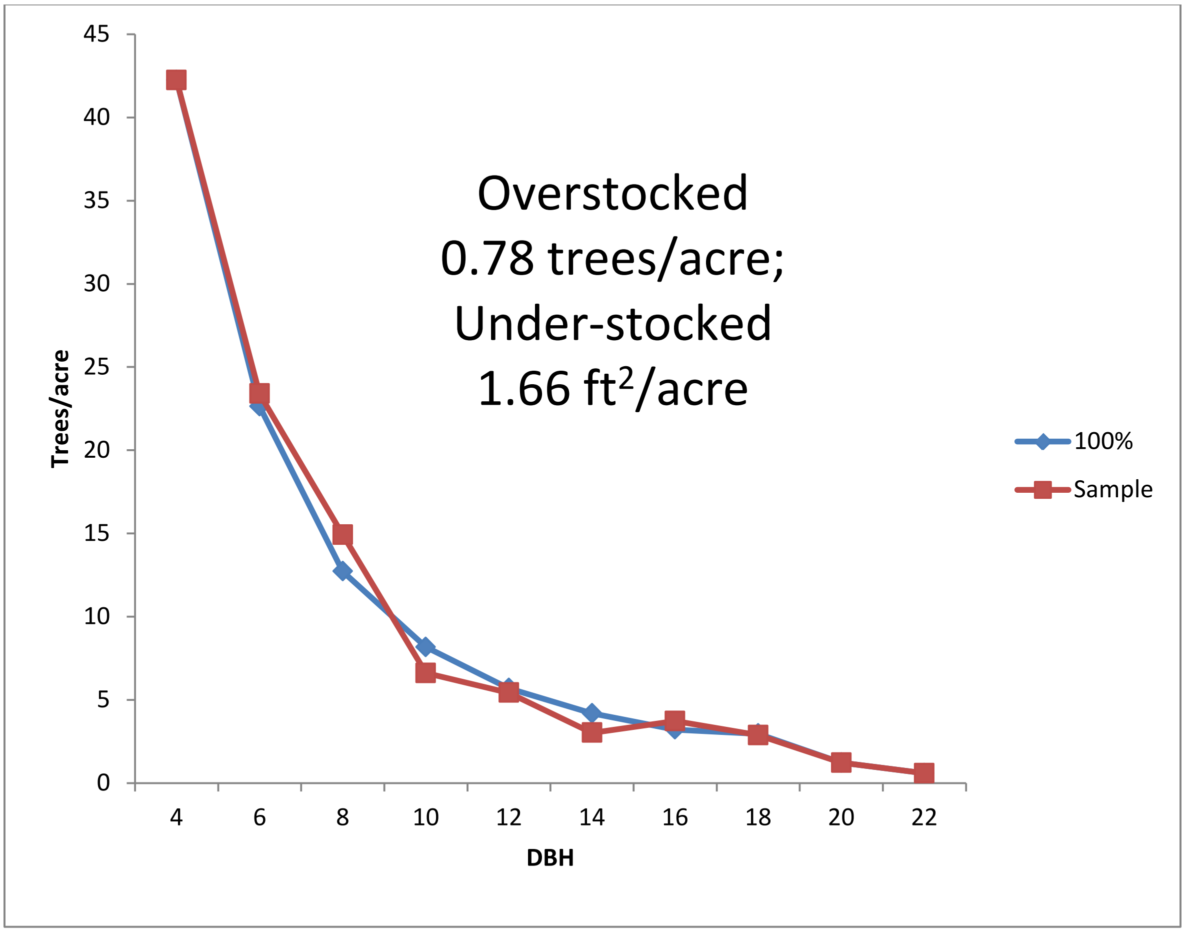


Figure 7.9.1.2: Graphic comparison of pulpwood category. Data from Table 7.9.1. Comp 102 + Farm Forty Residual Stand. **Pulpwood: 1/20 acre + DBAR.** 2x5 chain grid, compared to 100% inventory.

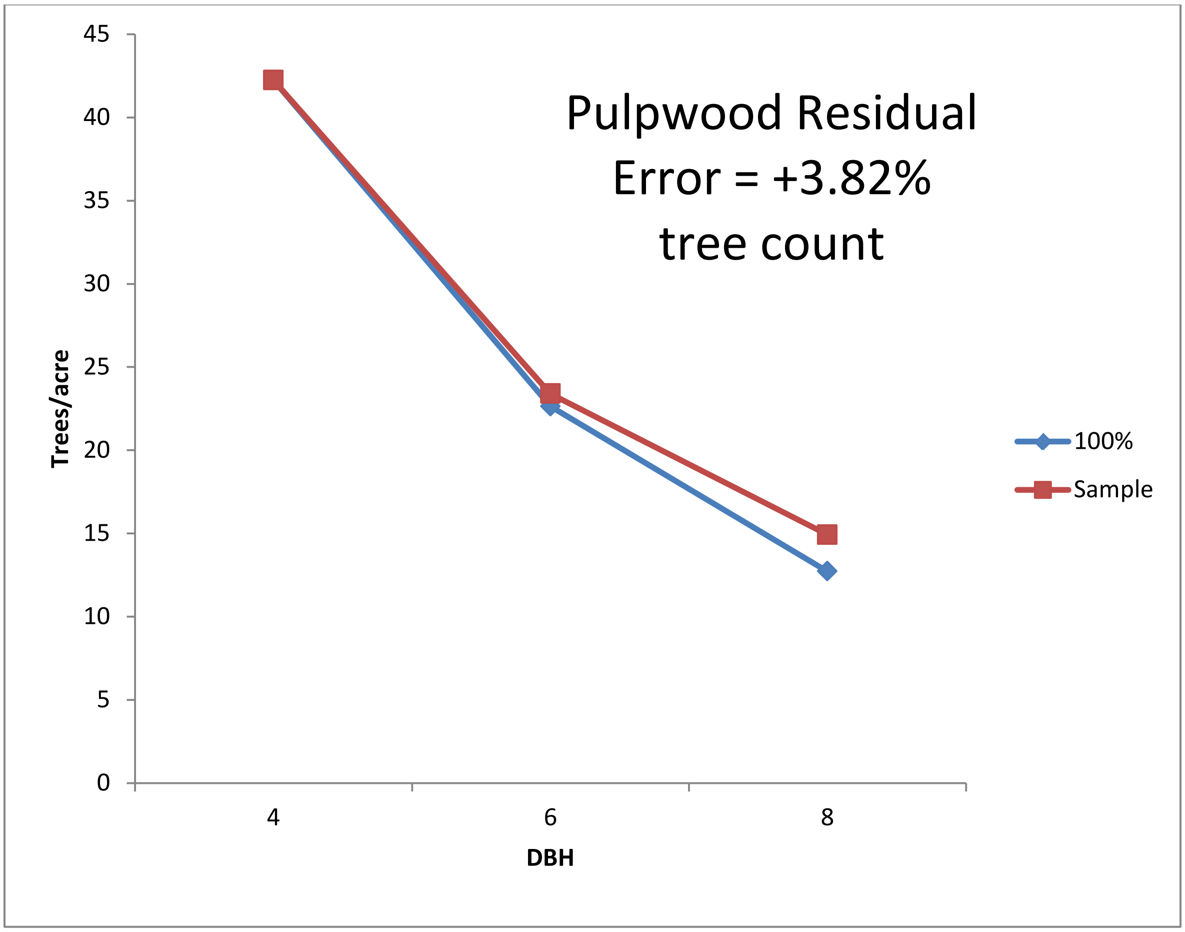


Figure 7.9.1.3: Graphic comparison of pole category. Data from Table 7.9.1. Comp 102 + Farm Forty Residual Stand. **Poles: 10BAF.** 2x5 chain grid, compared to 100% inventory.

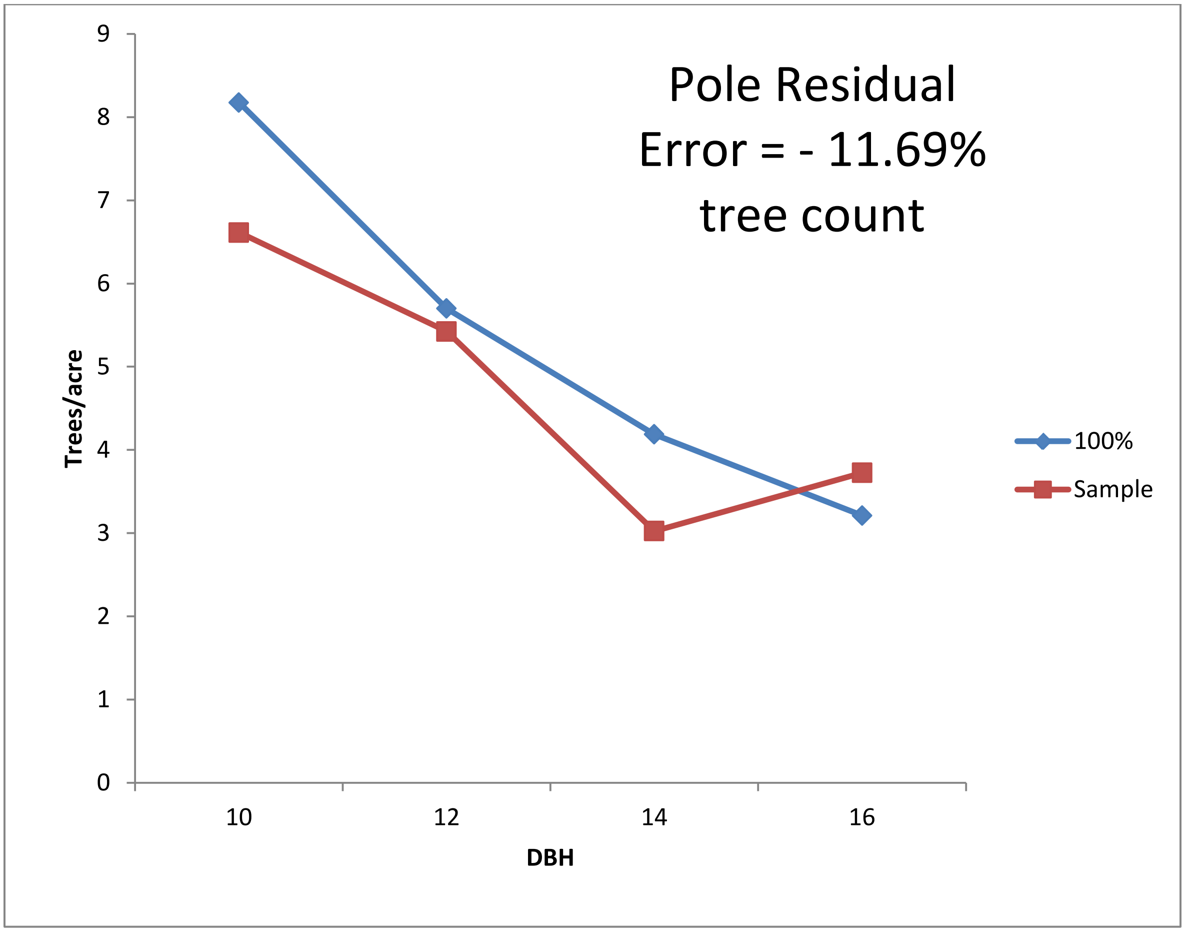


Figure 7.9.1.4: Graphic comparison of sawtimber category. Data from Table 7.9.1. Comp 102 + Farm Forty Residual Stand. **Sawtimber: 10BAF**. 2x5 chain grid, compared to 100% inventory.

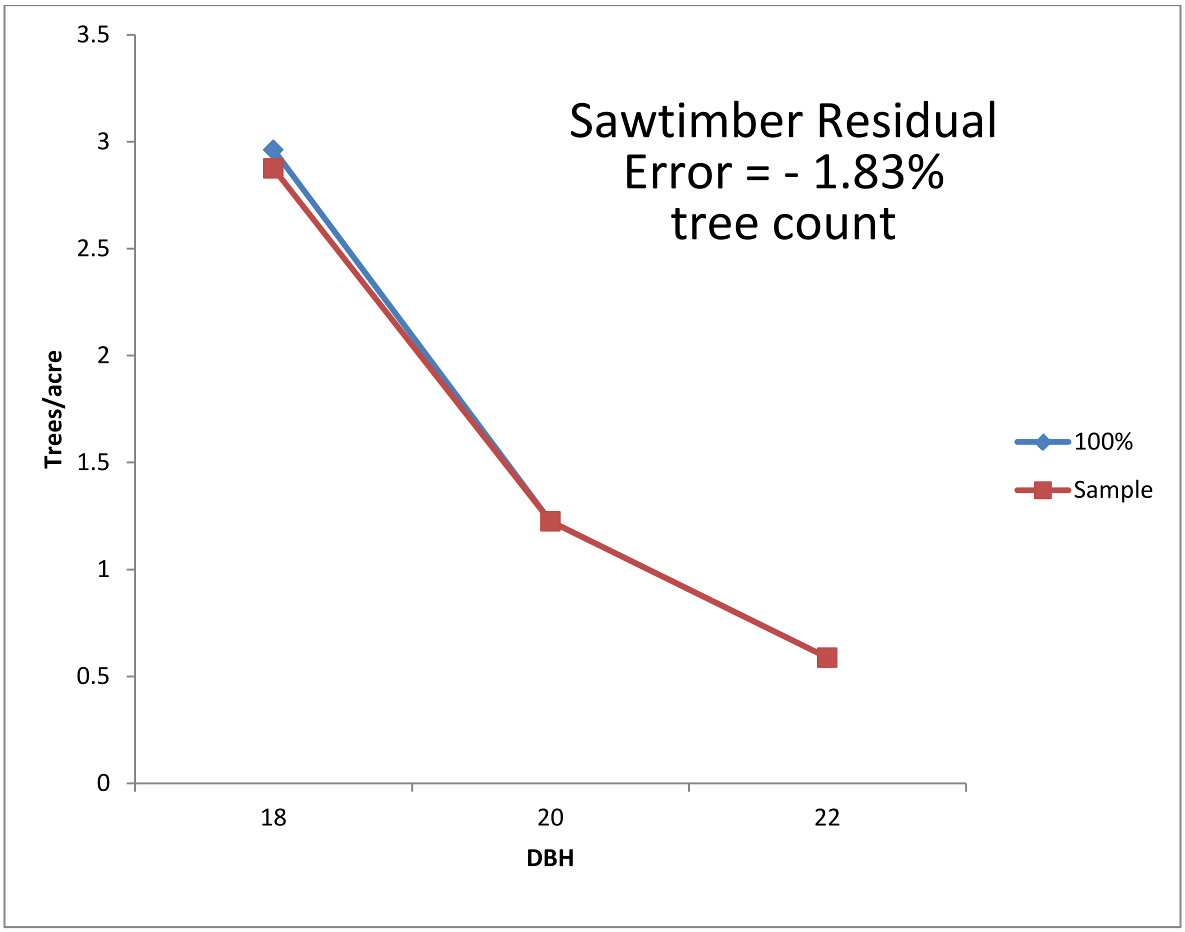


Table 7.9.2: Comp. 102 + Farm Forty Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 1/20 acre + DBAR; Sawtimber: 10BAF. 2x5 chain grid, compared to 100% inventory.

(1/20 DBAR + 1/20 DBAR + 10BAF) X WSR B=40, D=20, N=9

RESIDUAL STAND

	CRUISE		100%		% ERROR	
dbh	**No. Trees**	**BA**	**No. Trees**	**BA**	**No. Trees**	**BA**
4	3379	294.873	3379	294.873	0.00	
6	1872	367.566	1811	355.589	+ 3.37	
8	1194	416.785	1018	355.349	+12.87	
PW:	**6445**	**1079.224 ft^2**	**6208**	**1005.811 ft^2**	**+ 3.82%**	**+ 7.30%**
10	569	310.341	654	356.702	- 13.00	
12	474	372.279	456	358.142	+ 3.95	
14	360	384.845	335	358.120	+ 7.46	
16	276	385.369	257	358.840	+ 7.39	
PO:	**1679**	**1452.834 ft^2**	**1702**	**1431.804 ft^2**	**- 1.35%**	**+ 1.47%**
18	230	406.444	237	418.813	- 2.95	
20	98	213.802	98	213.802	0.00	
22	47	124.071	47	124.071	0.00	
24+	0	0.000	0	0.000	0.00	
ST:	**375**	**744.317 ft^2**	**382**	**756.686 ft^2**	**- 1.83%**	**- 1.63%**
All:	**8499**	**3276.375 ft^2**	**8292**	**3194.301 ft^2**	**+ 2.50%**	**+ 2.66%**

Overstocked 5.18 trees/acre; overstocked 2.05 ft^2/acre.

Figure 7.9.2.1: Graphic comparison of data from Table 7.9.2. Comp 102 + Farm Forty Residual Stand. Pulpwood: 1/20 acre + DBAR; Poles: 1/20 acre + DBAR; Sawtimber: 10BAF. 2x5 chain grid, compared to 100% inventory.

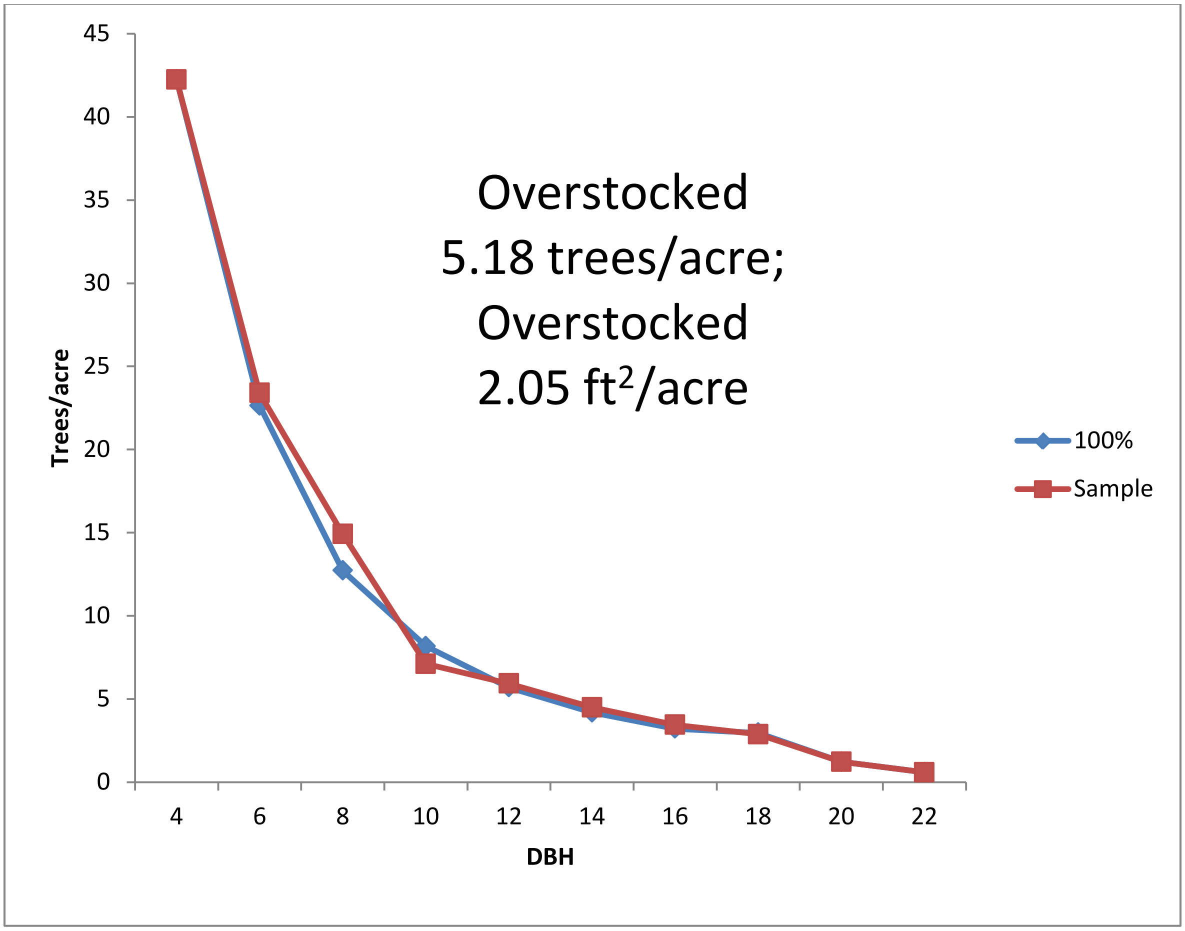


Figure 7.9.2.3: Graphic comparison of pole category. Data from Table 7.9.2. Comp 102 + Farm Forty Residual Stand. **Poles: 1/20 acre + DBAR.** 2x5 chain grid, compared to 100% inventory.