Uneven-Aged Silviculture, Southern Style

Data spanning 60 years on uneven-aged loblolly-shortleaf pine stands in Arkansas show that two regulation methods have been successful in regulating stand development. Key attributes of these methods are that regulation is more important than balance, residual basal area drives stand development, and regeneration is the first indicator of sustainability. Marking uneven-aged stands is best kept simple: mark to cut the poorest trees and leave the best, regardless of target structure or method of regeneration. **To be** successful in the long term, new methods of regulating uneven-aged and multiaged stands should share these attributes.

By James M. Guldin and James B. Baker

Efforts to develop a wider variety of tools to regulate uneven-aged stands and multiaged stands are laudable and appropriate (O'Hara 1998), given the increasing importance of uneven-aged silviculture in modern forestry (Guldin 1996). This is especially true if the new tools have an ecological basis consistent with the silvics of the species being considered. But new tools certainly don't invalidate the old tools, nor make less applicable the lessons that the old tools provide.

Arkansas is one of the national repositories of old tools for uneven-aged silviculture. Research with uneven-aged silviculture in loblolly-shortleaf (*Pinus taeda* and *P. echinata*) stands of the west Gulf coastal plain in southern Arkansas has been ongoing since 1937 (Reynolds 1959, 1969; Baker et al. 1996). Empirical practice by industries in the region with both coastal plain loblolly-shortleaf stands and pure shortleaf stands in the Ouachita Mountains has been under way since the 1950s.

That long-term experience provides a basis for several comments we think are important in applying uneven-aged silviculture to southern pine forests. The comments are consistent with the historical record for uneven-aged silviculture, and we think they should apply as increasingly unbalanced stands and new methods for regulation are investigated in research and in practice.

Balance versus Regulation

The Arkansas experience points to the need for a clearer distinction between balance and regulation. Balance refers to the conformance of the stand to the *q* factor (e.g., Leak 1964); *q* defines the relationship between the number of stems in an existing diameter class and the number in the next higher or lower class. Stands that conform to a reverse-J curve established by the *q* factor are said to be well balanced, and those that do not are said to be poorly balanced or unbalanced.

In the absence of management, natural southern pine stands typically have a variety of age classes. Some of these stands may have been well balanced in the past-, under the actions of disturbances like windstorms, fire, or a history of unregulated cutting (Cain and Shelton 1996). But fire control in the 1930s led to the development of hardwoods in the midstory and understory; the well-balanced all-aged pine stand is today more theoretical than real. Some pine stands with a prominent hardwood midstory may appear to have a reverse-J curve when all species are considered but may be poorly balanced in the pine component. This raises an important point--the stand structure of interest is that of the desired species component, not necessarily all the species in the stand.

Regulation is a different concept from balance. It refers co the ability to maintain yields over time (Baker et al. 1996). The *q* factor alone is not a regulation method or tool but rather a point estimate of balance in a stand. Whether the stand can be regulated is independent of balance. Theoretically, both well-balanced and poorly balanced stands can be well regulated. But the more poorly balanced the stand, the greater the need to follow its regulation over time to ensure that yields, density, and stocking are sustainable under the chosen regulation method.

The two principal methods by which the loblolly-shortleaf pine stands in southern Arkansas, and southern pine stands elsewhere in the South, have been regulated are the volume control-guiding diameter limit (GDL) method (Reynolds 1959, 1969; Reynolds et al. 1984; Farrar et

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A typical uneven-aged loblolly-shortleaf pine stand in the Crossett Experimental Forest, photographed in 1991 after 54 years of management, shows the effects of the simple rule of marking, "Cut the worst trees and leave the best." Because good seed crops occur so frequently in the region, however, the regeneration success found in Arkansas may be more difficult to obtain elsewhere.

al. 1989; Baker et al. 1996; Farrar 1996), and the BDq method of structural control (Marquis 1978; Baker et al. 1996; Farrar 1996).

Other regulatory methods that have a more elegant theoretical basis, such as the leaf area index approach (O'Hara 1996) or the stand density index approach (Long and Daniel 1990), might well be feasible in these or other forest types. But the passage of time is a critical element in applying a given regulation method; recall that 20 years passed between the exposition of maturity selection as a regulation method (Kirkland and Brandstrom 1936) and its disavowal (Isaac 1956). The greater the degree to which a stand is poorly balanced, the greater the need to test regulation methods over time, if for no other reason than the dearth of research or long-term empirical experience in stands with poorly balanced structures.

Regulation by volume control. The volume control-GDL method does not rely on the q factor at all. Rather, it uses periodic inventories to measure growth; growth (or a portion of growth in understocked stands) is then established as the allowable cut. The guiding diameter limit is that size class in which an inverse cumulative tally of volume meets the allowable cut. The classic rule of marking under this method is to "cut the worst trees and leave the best," regardless of the GDL.

The difficulty of the method is in its application, at which Reynolds excelled. When a tree above the GDL was retained, an equivalent volume was thinned in the diameter classes below the GDL. This provided for improvement cutting in all sawtimber classes. Even more remarkable is the empirical observation made shortly after Reynolds retired: a q of 1.2 for I-inch classes fit Reynolds's stands with a high R^2 value (Farrar 1981). Most of the uneven-aged pine stands in the South, not only loblolly-shortleaf pine stands in Arkansas but also southern pine stands elsewhere (e.g., Farrar et al. 1989), have been imposed using variations on volume control. Therefore, most have been managed without attention to the q factor.

The volume-control method has some limitations. It requires an experienced marking crew to impose. Reynolds and his crews kept the cumulative volume tally mentally as they marked the stand, which required a rather high degree of silvicultural skill. Because regulation is based on the sawtimber component, there is no way to evaluate whether subsawtimber classes are making acceptable development other than by subjective evaluations or independent inventories, especially to determine adequacy of regeneration.

Regulation by the BDq method. The BDq regulation method improves on the volume-control method by providing an objective means for monitoring subsawtimber classes. The method does not rely on the q factor alone but rather creates a unique after-cut target stand structure based on three stand parameters: B, the residual basal area; D, the maximum retained diameter in the residual stand; and the q factor.

The BDq computation produces a target residual stand structure. An inventory is taken in the stand being managed, and the existing stand inventory is compared with the BDq target. Invariably, some diameter classes in the stand being managed will have more trees than the target, and some fewer. The computation requires that the basal area deficits in those diameter classes below the target be redistributed above the target among the surplus classes, so as to retain the basal area. This is done even if it means egregiously violating the q.

Thus, as applied in the South, the BDq method is better described as a basal area-based regulation method rather than a q-based method. Why use the q factor at all, then? Simply because it provides a starting point to apportion basal area among the various size classes below the D. There may be reasons to dislike the constant q across all diameter classes in some forest types, as O'Hara (1998) carefully points out; some other shape parameter x (such as a power function, changing q, or another more complex function) may be more ecologically sound than q.

But even if q is replaced by this new x, the BDq-based framework is still an extremely robust way to regulate the stand. Instead of generating the target curve on the q factor, one would simply generate the target curve on the new shape parameter x. Then the BDq becomes a BDx regulatory method, where the existing stand to be marked is compared against the target structure generated by the BDx parameters. One would retain B, then D, then x, compensating for deficit basal area in classes below the BDx target in the classes where surplus basal area above the BDx is found, such that the target basal area is retained with highest priority. The spreadsheets used to calculate BDq parameters could easily be modified to generate a target stand, compare the inventories, calculate the residual stand, and generate marking tallies for any BDx shape parameter.

Residual Basal Area

The well-balanced stand may exist in tolerant species but is naturally a rare commodity in the southern pines. O'Hara (1998) suggests that a well-balanced uneven-aged stand can be viewed as a normal (in the regulatory sense) series of even-aged stands regulated by area. But other data suggest a subtle but conceptually important difference between a selection stand and a normally distributed set of even-aged stands (Assmann 1970). As one decreases the size of area occupied by a given age cohort, edge effect increases, which has two effects: it provides more crown space for larger trees, and it promotes suppression of smaller trees near the edge. Thus, according to Assmann (1970), the hypothetical well-balanced uneven-aged stand has slightly fewer small stems than a normally distributed progression of even-aged stands, and slightly more large trees (*fig.* I).

For intolerant species, such as the southern pines, this balance between overstory and understory is critical for regeneration development. Well-balanced uneven-aged loblolly-shortleaf pine stands on the upper coastal plain grow about 3 ft^2/ac of basal area per year, and shortleaf pine stands in the interior highlands grow about 2 ft^2/ac per year (Baker et al. 1996). Regeneration development in both forest types becomes suppressed at basal areas above 75 ft^2/ac, but the overstory becomes so understocked at basal areas less than 45 ft^2/ac that a new regeneration cohort is likely to become established across the entire stand, defeating the purpose of creating the uneven-aged stand.

If residual basal area is too high, regeneration will be suppressed by the growing overstory toward the end of the cutting cycle. If residual basal area is too low, regeneration will become established and will develop across the entire stand, essentially creating an irregular shelterwood. The latitude with D and q are far wider than with basal area. From this we infer that basal area, not D or q, is the most critical determinant of successful regeneration development in uneven-aged stands, especially of intolerant species such as the southern pines. The regulation method must reflect this.

Thus, as practiced in the South, the term BDq is more than just an alphabetic acronym—the letters reflect the priority of marking (Baker et al. 1996; Farrar 1996). Basal area is the most critical target, since future stand growth is highly correlated to residual basal area (Murphy and Farrar 1982, 1988). The D can be violated if doing so retains a tree making exceptional growth or contributing to the target basal area. Meeting the q factor is the least important element of the regulation method.

Regeneration

Reynolds and his field crews didn't worry about whether regeneration occurred after the cutting cycle harvests, given the difficulty they had walking through it. The regeneration potential of loblolly-shortleaf pine stands in southern Arkansas is such that adequate seed crops occur in eight of 10 years, and bumper crops exceed 1,000,000 seeds per acre (Cain and Shelton 1996). Coupled with the scarification associated with frequent logging and the periodic control of competing vegetation, regeneration is easily obtained.

As a result, the Arkansas experience doesn't shed much light on how to predict regeneration success from the regulation method. Hypothetically, one might predict regeneration numbers by extrapolating the BDq target curve back to the regeneration size class. But this usually suggests fewer than the recommended minimum of 200 seedlings per acre (Baker et al. 1996). Most practitioners in the region barely feel comfortable with two or three times this number distributed uniformly across the site (Farrar 1996).

In well-balanced southern pine stands, obtaining regeneration after every cutting cycle harvest is not critical. Reynolds was not overly concerned if regeneration failed to follow a given cutting cycle harvest. If this occurred, he would undertake supplemental site preparation in association with the subsequent cutting cycle harvest to ensure that regeneration did

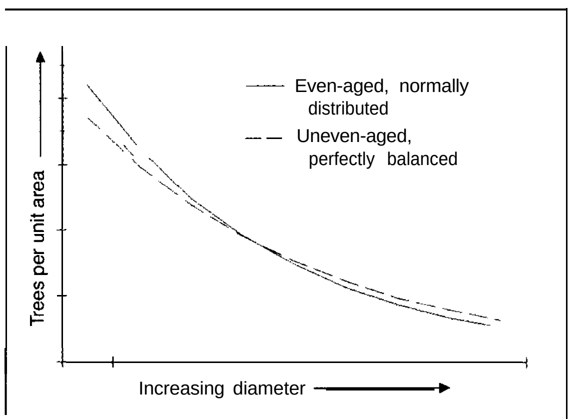

figure I. Theoretical diameter distribution of a series of normally distributed area-regulated even-aged stands, and a corresponding well-balanced uneven-aged stand. After Assmann (1970).

not skip two cutting cycle harvests.

But in instances where uneven-aged silviculture is just being initiated in poorly balanced stands, where cutting cycles are longer than five to 10 years, or where one is working in a forest type where regeneration is difficult to obtain, the establishment and development of regeneration of the desired species is absolutely essential. The success of not only regeneration establishment but also regeneration development through the point of the subsequent cutting cycle harvest is the first indicator of sustainability when applying traditional or nontraditional reproduction cutting methods or regulation methods in a given forest type.

Reynolds did report that where pine regeneration was absent, hardwood competition was the probable cause. Competition control is periodically required in uneven-aged pine stands on the productive sites in southern Arkansas. It promotes regeneration establishment and development through both site preparation and release (Cain 1987, 1991). Experience suggests that chemical control using approved selective herbicides every 10 to 20 years (every two to three cutting cycles, usually in association with a cutting cycle harvest) provides effective vegetation management (Baker et al. 1996).

Following the cutting cycle harvest in an uneven-aged pine stand, regeneration may trickle in for several years. But that which occurs in the year following harvest has the highest likelihood of acceptable development (Shelton and Murphy 1997). Thus, these stands are not all-aged; rather, they are multiple-cohort stands whose age cohorts occur in synchrony with cutting cycle harvests, good seed crops, and competition control.

This leads to another question that the Arkansas experience does not yet address-managing mixed pine-hardwood stands using uneven-aged silviculture. Data suggest that the canopy cover of hardwoods is greater than that of pines; if uniformly distributed across a site, 1 square foot of hardwood basal area is equivalent to 2 square feet of pine basal area in suppressing regeneration (Shelton and Murphy 1997). The ability of the selection method to meet broad species diversity objectives, therefore, is probably limited to situations where hardwoods can be limited to intermittent or perennial stream drainages, clusters within the stand, and similarly sequestered sites.

Marking

The most elegant method of regulating stands will fail if it is difficult to impose in the woods. Pragmatically, the methods by which uneven-aged stands are marked are, in our view, most easily applied by woodsworkers if they are kept simple.

Both the volume control-CDL and the BDq method are imposed by providing the timber markers with a tally of trees to cut by diameter or product class. For the GDL class and for all classes in the BDq, the marking tally is easily expressed as a proportion of trees to cut by diameter class (e.g., 25 percent of the 10-inch class, 33 percent of the 12-inch class, 20 percent of the 14-inch class, and so on). We have seen marking crews pencil these guides on a strips of masking tape affixed to their hard hats. Similar guidelines have been successfully applied to broader product classes-large sawtimber, medium sawtimber, small sawtimber, and pulpwood-under empirical practice in the region.

The key is this: that marking crews cut the worst trees and leave the best within each diameter or product class and among classes if necessary. Field crews can easily adapt to such instructions. If new regulation methods are devised, they must be easy to apply in the woods, such as by generating a tally by diameter or product class. They must also give the field crew sufficient flexibility to adapt the tally so as to cut the poorest trees and leave the best, even at the expense of structure. Even the most elegant and ecologically based regulation method will fail if it results in a confused field crew and a poor job of marking.

Summary

Our comments can be summarized in four tenets:

1. Balance is less important than regulation.

2. Regeneration is the first indicator of sustainability.

3. Residual basal area is critical, even at the expense of structure.

4. Mark to cut the poorest trees and leave the best, regardless of target structure or method of regulation.

Our experience is that the existing volume control-GDL and BDq regulation methods are extremely flexible, provide considerable latitude to the careful forester when applied, are easy for marking crews to implement in the woods, and have been sustainable over time. New regulation methods should have these attributes as well.

In our opinion, those tenets supplement rather than contradict the points raised by O'Hara (1998). The fundamental premise that unites the various articles presented in this volume is that the silviculture of balanced and unbalanced stands of multiple age cohorts and sizes is feasible, technically within the profession's grasp, and timely for the future development of the profession.

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