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FOREST MEASUREMENTS

THIRD EDITION

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PREFACE

This third edition, prepared with a co-author, is, in essence, an expanded version of the first edition (1967) of *Forest Measurements*. Emphasis is on timberland inventory. Although the assessment of nontimber resources is not covered, it is relevant to note that the measurement principles and techniques discussed in this book apply equally well to any inventory that involves timber assessment, regardless of whether that inventory is conducted for timber, wildlife, recreation, watershed, or other management objectives.

With an introductory text of this nature, the final arbiters of what should and should not be included are the course instructors who adopt and use the book for their classes. In accordance with this concept, the contents of this third edition were determined largely through a detailed questionnaire sent to 113 forestry instructors in the United States and Canada. The overall response to our mail survey, which included both professional and technician schools, was nearly 60 percent.

Most of the respondents specifically requested a return to the first edition format, and a majority also wanted to return to English units of measurement rather than the metric units that characterized the second edition. This has been done, although metric equivalents or examples are also given in some instances. It is virtually impossible to give *both* systems equal treatment in books of this nature, because many basic tree measurements are not directly comparable in English and metric units. As of this writing, most organizations and agencies in the United States are still strongly resisting the voluntary (though inevitable?) changeover to the International System of Units.

New material found in this edition includes chapters on volumes and weights of trees, 3P sampling, and growth and yield models. Those schools that offer a two-course sequence in forest measurements may thus find that this expanded text will serve for both courses. As with previous editions, we have attempted to present the subject matter in a straightforward fashion that is easily grasped by students. It is presumed that readers will have some background in algebra and plane trigonometry; a prior knowledge of basic statistics and sampling methods will also be helpful, although elementary concepts are

reviewed herein. A knowledge of calculus, while not essential, will be useful for some of the material. Explanations which assume a background in calculus are placed in separate sections which can be omitted without loss of continuity.

In those occasional instances where masculine pronouns are used for succinctness, these pronouns are intended to refer to both males and females.

We would like to extend our thanks to those instructors in the United States and Canada who responded to our mail questionnaire; it was your suggestions that ultimately determined the contents of this book. We are also grateful to the Literary Executor of the late Sir Ronald A. Fisher, F.R.S., to Dr. Frank Yates, F.R.S., and to Longman Group Ltd., London, for permission to reprint Appendix Table 6 (The distribution of t) from their book, *Statistical Tables for Biological, Agricultural, and Medical Research* (6th Edition, 1974).

The following persons deserve special mention for providing illustrative materials and/or reviewing certain sections of the book manuscript: James P. Barrett, University of New Hampshire; John F. Bell, Oregon State University; Thomas E. Burk, Virginia Polytechnic Institute and State University; Frank Freese, U.S. Forest Service (retired); Ellis V. Hunt, Stephen F. Austin State University; Timothy A. Max, U.S. Forest Service; Roy A. Mead, Virginia Polytechnic Institute and State University; David P. Meador, Wayne Community College; Robert W. Neelands, U.S. Forest Service; Richard G. Oderwald, Virginia Polytechnic Institute and State University; David W. Robinson, Oklahoma State University; Marion R. Reynolds, Virginia Polytechnic Institute and State University; and James L. Smith, Virginia Polytechnic Institute and State University.

Finally, for on-the-job support, we wish to express our gratitude to our administrative and professional colleagues at Texas A & M University and at Virginia Polytechnic Institute and State University, respectively.

Thomas Eugene Avery

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CHAPTER 1

INTRODUCTION

1-1 Purpose of Book This book is intended for introductory courses in forest measurements. Although a "how-to-do-it" approach is employed, there are still many measurement problems for which no satisfactory solutions exist. Furthermore, there is room for considerable improvement in currently employed techniques and instruments. During recent years, new ideas have been responsible for such practices as weight scaling of wood, 3P sampling, and adaptation of electronic computers to mensurational problems. To a large degree, however, we are still measuring timber volumes, tree form, growth, cull factors, and mortality much as foresters did 5 decades ago. The continued need for personnel with imagination and inventiveness is clearly apparent.

1-2 Justification for Measurements Organizations that depend on wood as a raw material often have large capital investments in land and standing timber. Periodic inventories of these lands are required for tax records, for justification of various forest management expenditures, and for determining the amount and quality of wood available for utilization. Some inventories are concerned with plantation survival counts, some with wood stockpiles and land appraisal, and still others with studies of tree growth or site evaluation.

Forest inventories and measurement of cut-wood products are justified primarily as conveniences in making purchases and sales, or as aids in formulating timber management plans. When log scaling is relied upon as a basis for a business transaction, it is recognized that the estimate of board-foot volume is less accurate than that obtained from a tally of sawed lumber. However, it is

equally obvious that each truckload of logs cannot be individually tagged, sawed, and tallied when scores of such transactions are involved daily. Furthermore, payments to some wood suppliers might be delayed for weeks until their logs had been processed. The convenience and continued application of such activities as log scaling are thus established.

1-3 Measurement Cost Considerations In almost all resource inventories, cost factors are of primary importance; the forester must continually seek out more efficient methods for counting, measuring, and appraisal. The basic objective of most inventories is to obtain an estimate of acceptable statistical precision for the lowest possible expenditure. To achieve this objective requires a sound knowledge of sampling methods, because once the specific needs of management have been determined, the resource inventory becomes essentially a sampling problem.

The measurement of various resource parameters adds no real value to the materials or benefits being assessed; therefore, such measurements are regarded as service functions rather than control functions. Measuring techniques must be subordinate to the productive or beneficial phases of an operation, for the operation itself cannot be modified just to accommodate an inventory requirement. For example, every visitor to a crowded public campground cannot be delayed and required to complete a detailed questionnaire on recreational preferences—nor can a sawmill be shut down in order to measure or weigh a recent delivery of logs. Instead, an appropriate sampling scheme must be designed and employed to obtain the essential resource measurements without disrupting normal activities.

It is an obvious though commonly overlooked fact that the amount expended for a given inventory task should be geared to the value of the products or services being measured. Also, the nearer one approaches the finished product or ultimate benefit, the greater can be the allowable cost of measurement. Thus the measurement of high-quality black walnut trees, which may be worth several thousand dollars each, justifies a much greater unit expense than the assessment of small pine trees for pulpwood (Fig. 1-1). Similarly, the value of finished lumber warrants a greater inventory cost than the scaling of logs. The forest manager who becomes "cost conscious" early in his career has an attribute that will be highly respected by his employer.

1-4 English versus Metric Systems In spite of its obvious complexities and disadvantages, the English system persists as the primary basis for measurements in the United States. The more logical metric system, devised and adpoted in France around 1790, has gained limited acceptance in scientific research, but foresters are still surveying by feet and acres rather than meters and hectares. Bills requiring universal adoption of the metric system have been