The Place of Biometrics in Forestry Research

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Abstract

Biometrics has gained prominence as a very useful tool in all aspects of forestry research. It is used in designing experiments, analysing data and making inferences. The number of methods and approaches in biometrics is often daunting with many forest researchers wondering what is appropriate in each specific circumstance. In some instances, there had been misuse of methods leading to erroneous results and false conclusions. In this paper, an attempt is made to present some of the biometrics methods and approaches used in forestry research and indicate the conditions under which each of them is most appropriate. The importance of biometrics in various aspects of forestry research is discussed and suggestions made on how to improve the practice. It is hoped that this paper will serve as a quick reference material in deciding on the appropriate design to adopt in conducting forestry research. Readers will also gain useful tips that will assist them in ensuring proper conduct of their research.

Keywords: *Forest biometrics, Design and analysis of experiments, Forestry research, Experimentation*

Introduction

In recent years, biometrics has gained prominence as one of the matrices of experimental science. It functions as a tool in designing experiments, analysing data, and drawing conclusions from them (Akindele, 2004). Its usefulness in forestry research is extends from molecular level to the whole of biosphere. As applied statistics, biometrics has experienced rapid advances in theory, techniques and applications accentuated by the advent of computers. The sheer speed of handling complex calculations by computers such that large mass of data are analysed within seconds is a great impetus to the use of biometrics in forestry research. Consequently, successive measurements from long term experiments and data across wide landscape can be analysed with relative ease.

Forestry research is based on scientific method which is popularly known as the inductive-deductive approach. This method entails formulation of hypotheses from observed facts followed by deductions and verification repeated in a cyclical process. Across the globe, foresters have become increasingly quantitative in their approaches to research and management. With rising forest values, there is a concomitant increase in the demand for accuracy and precision in management prescriptions and projected outcomes. This has further brought biometrics to the fore. Biometrics offers valuable information for decision-making because it provides quantitative measures of current resources, means to compare differences between alternative experimental resource treatments, and methods to project future outcomes of management practices (Temesgen, *et al*., 2007).

In forestry research, biometrics covers three major aspects, namely:

- data collection methods including mensuration, remote sensing, experimental designs, sampling techniques and inventory for the collection of tree or forest data, or data relating to processes and populations that occur at tree or stand level;
- use of statistical methods to summarise and analyze forest data. This include the use of descriptive statistics and statistical inference (hypotheses formulation and testing); and
- interpretation of results from analysed forest data.

The number of methods and approaches in biometrics is often daunting with many forest researchers wondering what is appropriate in each specific circumstance. In some instances, there had been misuse of methods leading to erroneous results and false conclusions. Some aspects of forest research require special adaptation of standard techniques or development of new ones. Where the skill to do this is lacking, the usual practice is to force the data through one of the seemingly appropriate methods and obtain results, which are often questionable. In this paper, an attempt is made to present some of the biometrics methods and approaches used in forestry research and indicate the conditions under which each of them is most appropriate. The description of the methods is not exhaustive. According to Jayaraman (1999), refinements in methodology are happening continuously and there is always a possibility of utilizing the data further depending on the needs of the investigators. It is hoped that this paper will serve as a quick reference material in deciding on the appropriate design to adopt in conducting forestry research.

Biometrics as a tool in data collection

The role of biometrics as a tool in data collection is in the specification of appropriate experimental design to use and the procedure for collection of reliable data. Forestry research data may be generated through designed experiments on hypothetical population or sample surveys on naturally existing population. Experiments are conducted in laboratories, nurseries or on the field (forests or plantations). The quality of data they produce depends on a number of factors including the appropriateness of the experimental design used, and the level of compliance with the principles of experimentation. The basic principles of experimentation are randomization, replication and local control which are the prerequisites for obtaining a valid estimate of error and for reducing its magnitude.

Randomization refers to the random allocation of experimental units to the different treatments or vice versa. It ensures objectivity and eliminates bias. Care must be taken in experimentation to randomize properly, using any chance device. The principle of replication is to increase the reliability of the conclusions. Replication is the repetition of experiment under identical conditions; but in the context of experimental designs, it refers to the number of distinct experimental units under the same treatment (Jayaraman, 1999). It should be noted that repeated measurements on the same experimental unit or multiple readings for a treatment appearing once are not true replications (Akindele, 2004). A third principle of experimentation is local control, which refers to the amount of grouping or blocking of the experimental units used in the experimental design. It is aimed at ensuring that the units within each block are relatively homogenous while the units between the blocks are heterogeneous. Local control enhances the efficiency of experimental designs by reducing the effect of extraneous factors on the treatment comparison, thereby decreasing the error variance.

It should be emphasized that sound experimental design and adherence to the principles of experimentation are essential in forestry research. Failure to consider these issues will result in unnecessary waste and, in the worst case, bad decisions resulting in serious damage to sensitive forest ecosystems (Nemec, 1998). In addition to the foregoing, the following practical details must also be considered:

- All pertinent measurements of the experimental (sampling) units must be identified.
- Appropriate field procedures and data collection forms must be developed.
- Provision must be made for adequate supervision of the data collection.
- In large-scale studies, strategies for coordination and optimization of procedures should be put in place.

Several types of experimental designs are used in forestry research. Table 1 shows a general list of the designs and the conditions under which each of them is applicable. When properly applied, these designs lead to collection of reliable data. The data could be terminal data collected at the end of the experiment or periodic data collected at intervals during the experiment.

One aspect of experimentation that has gained prominence in forestry research is the use of factorial experiments. The term *factorial* describes a specific way in which the treatments are formed and does not, in any way, refer to the design used for laying out the experiment. Factorial experiments allow for the combination of factors to form treatment combinations which are then administered to the experimental units. A major advantage of this is that main effects of the factors and their interactions can be evaluated simultaneously in the same experiment. The major limitation is that as the number of factors increase, a set of factorial treatment combinations may become too large to be tested simultaneously in a single experiment. A logical alternative is an experimental design that allows testing of only a fraction of the total number of treatment combinations. A design uniquely suited for such situations is the fractional factorial design, which provides a systematic way of selecting and testing only a fraction of the complete set of factorial treatment combinations. In exchange, however, there is loss of information on some pre-selected effects. Further discussion of this design and its application in forestry research has been provided by Jayaraman (1999).

Biometrics as a tool in data analysis

This is perhaps the most popular use of biometrics in forestry research. When experimental designs are discussed, it is often with reference to data analysis. Design and analysis (statistical inference) are closely linked like inseparable twins. Design determines the kind of statistical inferences that are possible, while a consideration of the proposed method of analysis almost always influences design. In fact, failure to contemplate how the data will be analyzed invariably results in a poor design (Nemec, 1998).

Data analysis normally proceeds with application of relevant tools to condense the data and extract useful information from them. For experimental data, analysis of variance (ANOVA) methods are commonly applied. ANOVA has gained so much popularity that discussions of experimental designs are often more about ANOVA than fundamental issues of design. ANOVA is basically an arithmetic method of partitioning the total variation of the collected data into components representing the sources of variation recognised in the experiment (Akindele, 2004). The basic premise of ANOVA is that the observed variability in experimental data can be attributed to a finite number of identifiable sources, including factors under the control of the investigator, uncontrolled experimental errors, and various interactions.

With the advent of computers, other methods of data analysis have been used in forestry research. For instance, simulation is a method of considerable importance to forestry which has gained wider acceptance in recent times. It is particularly useful in forestry because simulation techniques can replace large scale field experiments which are extremely costly and time consuming. In addition, other approaches such as Bayesian statistics, multivariate analysis, generalised linear models, non-linear regression, stochastic approximations, and spatial analysis are now being used, but most forest scientists in the tropics are not familiar with these approaches.

Table 1: Experimental Designs used in Forestry Research

S/No.	Experimental Design	Requirements
1	Completely Randomised Design	• experimental units are homogenous; • the only source of variation in the experiment is the treatment effect; • Laboratory experiments, where environmental effects are relatively easy to control.
2	Randomised Complete Block Design	• experimental units are not homogenous; • field experiments where the number of treatments is not large and there exists a conspicuous factor based on which the experimental units can be classified, e.g. when soil heterogeneity shows unidirectional gradient; • presence of blocks of equal size, each of which contains all the treatments; • variability within each block is minimized and variability among blocks is maximized;
3	Latin Square Design	• presence of two factors that can be used to group the experimental units, e.g. when the fertility gradient occurs in two directions with both gradients equally strong and perpendicular to each other; • the number of treatments equals the number of levels of each factor.
4	Nested or Hierarchical Design	• used for single-factor experiments where experimental units are measured more than once or are sub-sampled; • there is more than one observation per experimental unit.
5	Split Plot Design	• two-factor experiments where one of the factors require large plot size for execution and also show large differences in their effects; • useful when an additional factor is to be incorporated into an on-going single-factor experiment; • the precision for the measurement of the effects of the main plot factor is sacrificed to improve that of the subplot factor.
6	Split-split Plot Design	• three-factor experiments where the factors require varying plot sizes; • useful when an additional factor is to be incorporated into an on-going split-plot experiment.
7	Split Block Design	• two-factor experiments where the interaction effect is to be estimated with greater precision than each of the main effects.
8	Lattice Design	• incomplete block design; • used for single-factor experiments having a large number of treatments; • reasonably small block size is maintained to ensure that each block do not loose its homogeneity due to the large size; • each block does not contain all treatments; • comparison of treatments appearing together in a block is made with greater precision than those not doing so.
9	Response Surface Designs	• used in experiments where one or more quantitative factors are tested at multiple levels with the aim of finding out how the levels of these factors affect the response; • a suitable model depicting the factor-response relationship is fitted.

Biometrics as a tool in data interpretation

The analysis of forest data normally produce results which must be interpreted to make meaning to forest managers and policy makers. In view of several statistics displayed in computer print-outs, there is the need to know what is relevant and how to draw inferences from them. In drawing inferences, there is the need to avoid the temptation of over-generalisation or over-interpretation. Although everyone wants to do a piece of research that has sweeping value in all reaches of a field. Unfortunately, this is very rarely the case, due to the inherent limitations of the research design and execution. All researchers need to appreciate that fact and not embarrass themselves by over-interpreting their findings (Roberts, undated).

When interpreting study results from research where it is not practically possible to adhere strictly to any of the principles of experimentation, researchers should account for the site-specific characteristics leading to the initial non-compliance. It should then be understood that such altered experiments can no longer provide reliable knowledge of cause, but only generates hypotheses for validation when future management actions are implemented. Similarly, when a study considers only a portion of the system of interest (due to lack of randomization, replication, or funding), generalization of the results to the entire system could be inappropriate and misleading (Marcot, 1998). In this case, the study objectives and scope must be re-evaluated.

Concluding Remarks

To many researchers, the major role of biometrics in research is in the analysis of their data. There are several instances where researchers consult with the biometrician only at the data analysis stage of their research. They approach the biometrician with data heaped up from their experimentation and expect the biometrician to assist with the analysis. This is very undesirable. Since no amount of statistical manipulation can make a poorly designed experiment produce reliable results, involvement of the biometrician should be right from the planning and design stages of the research.

The training programmes for biometricians need to be reviewed. At present, in most of the biometrics (or statistics) courses, the emphasis is far too great on theories and technical procedures. Far too few students or researchers really realize how to go about planning and designing a study that will give the best chance of finding first, what they are looking for and second, things of importance. Similarly, most biometricians are heavy on details of computational procedures but light on practical ramifications of poor design and implementation. This situation should change. Biometricians need far more instruction and homework in the components of research that are non-computational. Their training programmes should involve spending much more time on design rather than computation of collected data.

References

Akindele, S. O. (2004). *Basic Experimental Designs in Agricultural Research*. Montem Paperbacks, Akure, Nigeria. 190p.

Jayaraman, K. (1999). *A Statistical Manual for Forestry Research*. Food and Agriculture Organization of the United Nations, Regional office for Asia and the Pacific, Bangkok. 231p.

Marcot, B. G. (1998). Selecting Appropriate Statistical Procedures and Asking the Right Questions: A Synthesis. In: Sit, V. and B. Taylor (editors). *Statistical Methods for Adaptive Management Studies*. Research Branch, British Columbia Ministry of Forests, Victoria, BC, Canada. Land Management Handbook No. 42: 129 – 143.

Nemec, A.F.L. (1998). Design of Experiments. In: Sit, V. and B. Taylor (editors). *Statistical Methods for Adaptive Management Studies*. Research Branch, British Columbia Ministry of Forests, Victoria, BC, Canada. Land Management Handbook No. 42: 9 – 18.

Roberts, D. (undated). The Overrated Importance of Statistics in Research. Internet document accessed in April 2008. www.personal.psu.edu/users/d/m/dmr/papers/Roberts.pdf

Temesgen, H., M.E. Goerndt, G.P. Johnson, D. M. Adams, and R. A. Monserud (2007). Forest Measurement and Biometrics in Forest Management: Status and Future Needs of the Pacific Northwest USA. *Journal of Forestry* 105 (5): 233 – 238.