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Reproducibility in forest sciences

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Highlights: Reproducibility requires that study materials, methods, and analyses are well described. Special attention must be made on data exclusion and inclusion criteria. Biological materials and environmental conditions should be reported following appropriate standards when available. Data and software should be made publicly available when possible yet only the authors are responsible on the accuracy and reproducibility of the reported work.

Keywords: Exclusion, Inclusion, Methodology, Openness, Replication, Statistics

Introduction

Ideally, a scientific article is written so that a knowledgeable reader will be able to repeat the study on the same or a different data set. Recently, the biomedical research community was shattered by the news that the biotech company Amgen was able to reproduce only 6 out 53 high-profile cancer studies and a bit earlier another company, Bayer, reported reproduction of 14 biomedical studies out of 67 (Kaiser 2015). This has opened a vivid discussion on reproducibility of published studies and openness of the data and methods in the field. Last year, National Institutes of Health of the USA published guidelines for reporting biomedical research in a way that makes reproduction of the published studies a real opportunity (NIH 2014). Many guidebooks written on scientific editing seem to fall short of fulfilling the NIH's standards (e.g. Blackwell and Martin 2011). Especially vague instructions have been proposed for forest scientists (Nair 1995).

Forest science is not a single science with general standards for research methodologies. Reproducibility issues vary widely from laboratory studies in forest pathology to long-term ecological research to economic studies. Thus, no single set of instructions can be written for forest scientists. While randomisation in a forest pathology laboratory may follow the NIH's recommendation, field sampling is the main issue in forest ecology. In this article, I will deal with some of the reproducibility issues in forest science, with an obvious bias towards ecological research because of my scientific background, and how they should be taken into account when writing a scientific manuscript. I also attach a suggestion for a check list of reproducibility in forest research, again with emphasis on ecology and silviculture.

Writing materials and methods - and results

When scientists are advised to write the materials and methods section of their manuscript so that a reader may repeat the study, the principle is often diluted with the advice that standard methodologies need not to be described (Nair 1995; Blackwell and Martin 2011). However, many "standard" methodologies have been implemented in a bit different ways in different laboratories. For example, while stating that soil phosphorus concentration was determined using the Olsen method is a standard, the often stated modified Olsen method is not. In this case, modifications of the Olsen method in the analysis laboratory must be detailed. Further, something an author believes to be a standard may be completely obscure for a reader in another country; e.g., stating that a study stand was managed according to the Good Forest Management Practice of Finland does not tell anything to a reader in Canada or Brazil. The only way to make the study reproducible - even just understandable - is to shortly describe the management of the study stand.

Writing out honestly the data analyses is another necessary step for reproducibility. Modern statistical software efficiently crunch numbers making it easy to try several different analytical methods until desirable or at least acceptable results are obtained. This kind of adaptive analysis applied in a careless way has been identified as a major reason for statistical significances that other scientists are unable to reproduce (Dwork et al. 2015). Adaptive analysis may be necessary in ecological field research because of unexpected results or need for noise reduction but in this case, proper controls must be used (Dwork et al. 2015). Thus, all steps applied in the statistical analyses must be disclosed in the materials and methods section.

Often neglected aspect of data analyses is the treatment of observations considered outliers yet inclusion or exclusion of some data has a strong effect on the statistical results. All exclusions of data must be fully justified in the article. It is also advisable to show results with the excluded variables in the supplementary materials of the article, with exception of bona fide exclusions of measuring errors. In all cases, the justification why a data point (or data points) was excluded as a measuring error must be disclosed.

Writing an article in a reproducible way concerns also the results section where the data are usually presented. Minimum requirement is that a reader clearly understands if all data or just some of it is shown. In the latter case, it must be clear why all data is not presented. Journal editors may be strict about concise writing and request only "significant" results to be shown but they are often quite liberal with supplementary data accompanying an article. Methods for summarising the data to treatment means, used dispersion and precision measures, and - most importantly - distribution of raw data must be disclosed.

Reproducibility and openness

Much of the ecological field research is inherently non-reproducible. For example, repetition of a 25-year data set on the development of the tree line in Northern Fennoscandia would require another 25 years of measurements yet the environment would not be exactly the same because of the global climate change and successional dynamics of the forests, and several biotic factors may alter the development of the tree line. In such a case, the only way for controlling the research quality is a fair openness in reporting, which includes also the results that do not necessarily support the main findings. The only way for full reproducibility is opening of data and analyses for the research community, e.g. by following the guidelines suggested by the Center for Open Science of the University of Virginia (Nosek et al. 2015). Not all of these guidelines apply to forest science but I will highlight citations, data and material transparency, and design and method transparency.

First, all organisms and environmental factors must be reported according to the best international practice. Full Latin binomials of all taxa studied must be reported and the nomenclature must be in agreement of an internationally recognised database. Local soil classifications must be avoided and all soils must be determined according to the USDA or FAO classification. Weather data must be available through a stable URL, e.g., in a national meteorological institute. Second, data of non-reproducible studies should be made freely available within a reasonable time after the end of the study; e.g., Dryad (http://www.datadryad.org) is a good data base for ecological data. In connection to the data, all research materials must be fully described, either in a supplementary file or in a public data base with stable URL.

Study design must be fully described and justified: why a particular design is selected to reach the aims of the study? It is quite common that the study design must be modified during the course of a long-term ecological field research. All these modifications must be fully described and justified. However, the reason for modifications should not be that the original design did not yield expected results. All methods used in different phases of a study must be reported and programme codes should be made publicly available. The open code is very important in studies with a strong modelling component. If the full programme code is not released, e.g., for proprietary reasons, it must be available upon request to the reviewers of a manuscript.

Finally, reporting an experiment in a reproducible and open way does not transfer the responsibility on the research quality to the journal reviewers and editors or the readers of a scientific article. Only the researcher him/herself is responsible on the quality of the reported research. Reproducibility and openness just convince the readers on the quality.

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Suggestions for reporting forest research

These suggestions are adapted from the guidelines recommended by the National Institutes of Health of the USA for preclinical biomedical research (http://www.nih.gov/about/reporting-preclinical-research.htm). While some studies in forest sciences may be very close to the biomedical research - notably in genetics and forest pathology - some fields will require further consideration before these guidelines may be applied.

Standards
Use community-based standards (such as nomenclature and reporting standards), where applicable. It is especially important to properly identify the studied organisms. For plant and animal nomenclature, use consistently only one data base. If you use e.g. a guide to local flora in the field, verify its nomenclature against an internationally recognised data base (like http://www.tropicos.org for plants). Soils must be described according to the USDA (http://www.soils.usda.gov/wps/portal/nrcs/main/soils/survey/class/) or FAO (http://www.fao.org/soils-portal/soil-survey/soil-classification/en/) classification.

Biological material
Provide enough information to uniquely identify biological materials (e.g., unique accession number in a repository, or seed source, lot number, provenance, date of collection, etc.).

Environmental conditions
Describe environmental conditions with sufficient detail so that the readers understand where you worked. Provide weather data summary and a link to a stable data base (e.g., a national meteorological institute). In addition to soil classification, give necessary fertility details. Describe growth substrate so that a reader can make an equal substrate and provide enough details on growth chamber conditions for repetitions.

Replicates
Report how often each experiment was performed and whether the results were substantiated by repetition under a range of conditions. Sufficient information about sample collection must be provided to distinguish between independent biological data points and technical replicates. Pseudoreplicates may be unavoidable in ecological field research but you must identify them as such and use appropriate statistical methods.

Statistics
Statistics must be fully reported in the article, including the statistical test used, exact number of observations, definition of centre, dispersion and precision measures (e.g., mean, median, standard deviation, standard error of mean, confidence intervals), and distribution tests.

Sampling and randomization
Justify the sampling method based on your research problem. Describe why a non-random sampling (e.g., systematic or cluster-sampling) is used and how it is considered in the data analyses. Non-random sampling is seldom justified when you can control the study conditions, e.g., in a laboratory, growth chamber, greenhouse, or nursery. If samples were randomised, specify the method of randomisation.

Sample-size estimation
State how sample size was estimated and whether an appropriate sample size was computed when the study was being designed. Include the statistical method of computation.

Inclusion and exclusion criteria
Clearly state the criteria that were used for exclusion of any data or subjects. Consider describing any outcomes or conditions that were measured or used and are not reported in the results section, e.g. in the supplementary materials of the article. Most journals accept supplementary online material.

Data and material sharing
All datasets on which the conclusions of the paper rely must be made available upon request (where ethically appropriate) during consideration of the manuscript (by editors and reviewers) and upon reasonable request immediately upon publication. Deposit datasets in public repositories, where available. Datasets in repositories must also include all data excluded from the article with justification why they were excluded. The dataset should be linked to the published article in a way that ensures proper attribution of data production. Materials should be open for sharing after publication. Consider sharing of software and, at the minimum, state in the manuscript if the software used is available and how it can be obtained.