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Analysis of tree measurement errors in the Austrian National Forest Inventory

Eine Analyse der Messfehler an Bäumen im Rahmen der Österreichischen Waldinventur

By Ambros Berger [1], Thomas Gschwantner [1], Karl Gabler [2] † and Klemens Schadauer [1]

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Schlagwörter: Messfehler; Unsicherheit; Präzision; Genauigkeit; Österreichische Waldinventur; Kontrollerhebung.

Summary

The aim of this paper is to quantify the uncertainty of individual tree measurements such as diameter at breast height *DBH*, tree height *H*, upper diameter at 3/10 of the tree height *D03H*, and height to the living crown base *HK*. When these values are determined in inventory measurements, errors occur. The magnitude of these measurement errors is analysed using three data sets. The experimental settings for collecting the data were very different and illustrate the broad range of possibilities to conduct studies

[1] Department of Forest Inventory, Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW), Seckendorff-Gudent-Weg 8, 1131 Wien, Austria
[2] Dr. Karl Gabler, Department of Forest Inventory, Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW), deceased.

on measurement errors. Data from harvesting sites that compare measurements of standing and felled trees, remote diameter measurements of plates of known size under controlled conditions, and data from the control survey of the Austrian NFI were analysed. Accordingly the results are diverse and provide a good overview of the errors made in inventory measurements. *DBH* turned out to be the most precisely measured variable in the control survey, followed by *H*, *D03H* and finally *HK*. Average differences between measurements of standing and felled trees and their standard deviations were lower for *H* compared to *D03H*. The measurement of *HK* showed a considerable variability but the average error was close to zero. Under controlled conditions the measurements of *D03H* showed less variability than in the other data sets. The average relative errors showed a quite large range of values likely due to the exceptional measurement situations that were part of this study. In general, the measurement conditions play an important role and bad conditions can more than double the standard deviations of the measurements. The results from this analysis are discussed with regard to the experimental setup, the method to quantify measurement errors, and are compared to findings from other studies.

Zusammenfassung

Das Ziel dieser Arbeit ist die Quantifizierung der Unsicherheit von Einzelbaummessungen wie Durchmesser in Brusthöhe *DBH*, Baumhöhe *H*, oberer Durchmesser in 3/10 der Baumhöhe *D03H* und Höhe bis zum Kronenansatz *HK*. Werden diese Werte im Zuge einer Inventur erhoben, so sind sie von Fehlern beeinflusst. Das Ausmaß dieser Messfehler wird anhand von drei Datensätzen analysiert. Die Gegebenheiten für die jeweiligen Datenerhebungen waren sehr unterschiedlich und führen die Bandbreite der verschiedenen Möglichkeiten Messfehler zu untersuchen vor Augen. Auf Holzernteflächen wurden Daten erhoben um Stehend- mit Liegendmessungen vergleichen zu können. Zur Untersuchung der optischen Durchmessermessung mit dem Spiegelrelaskop wurden Plastikplättchen von bekannter Größe unter kontrollierten Bedingungen gemessen. Der dritte Datensatz stammt aus einer Kontrollerhebung der Österreichischen Waldinventur (ÖWI). Entsprechend den Datensätzen sind die Resultate breit gefächert und liefern einen guten Überblick über die Fehler, die bei Inventurerhebungen gemacht werden. Es stellte sich heraus, dass *DBH* am präzisesten gemessen wurde, gefolgt von *H*, *D03H* und schließlich *HK*. Sowohl die mittlere Differenz zwischen Stehend- und Liegendmessung als auch die Standardabweichung waren für *H* niedriger als für *D03H*. *HK* wies eine beträchtliche Variabilität auf, aber der mittlere Fehler war nahe bei 0. Unter

optimalen Bedingungen waren die *D03H*-Messungen deutlich präziser als in den anderen Datensätzen, doch die mittleren Fehler schwankten relativ stark, was wahrscheinlich durch die außergewöhnlichen Messsituationen in diesem Experiment erklärt werden kann. Ganz allgemein spielen die Bedingungen, unter denen eine Messung durchgeführt wird, eine wichtige Rolle und die Standardabweichungen der Messwerte können dadurch mehr als verdoppelt werden. Die Ergebnisse der vorliegenden Analyse werden im Hinblick auf Experimentaufbau und Methode der Fehlerbestimmung diskutiert und mit den Resultaten anderer Studien verglichen.

1 Introduction

Any measurement is influenced by factors that cause errors in the recorded value. In forest inventories, measurement errors are one component among several sources of error that contribute to the overall uncertainty of estimates. Cunia (1965) classifies errors of a volume estimate from a forest inventory sample into sampling error, function error, and measurement error. Grouping error is recognised by Gertner (1989) and Gertner and Köhl (1992) as additional error source. A different classification is followed by Canavan and Hann (2004) since they sort measurement error into mensuration error, grouping error and sampling error. However, they describe mensuration error as error that arises when a recorded value is not exactly the same as the true value because of a flaw in the measurement process. In accordance to this description, the errors occurring during the measurement process on individual trees are subject to this analysis, but will be referred to as measurement errors instead of mensuration errors.

Measurement errors may be random or systematic, and result for example from errors in measuring, recording and transmitting information, from finite instrument resolution, inexact measurement standards, approximations and assumptions incorporated in the measurement method, and variations in repeated observations under apparently identical conditions (IPCC 2006). Westfall and Patterson (2007) distinguish between the deviation from the true value and the variability of repeated measurements using the same procedure. This distinction is similar to the statistical terms accuracy and precision. According to Cochran (1966) accuracy refers to the size of deviations from the true value, whereas precision refers to the size of deviations from the mean obtained by repeated application of the sampling procedure. In practice, the determination of the ‚true' value is accomplished with a more accurate and precise measurement instrument whose error is considered to be relatively small and negligible in comparison to the tested measurement device. Nevertheless, also this measurement is affected by error