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Short Communication
Derivation of nutritional threshold values from cumulative concentration distributions

Axel Göttlein[1]*

[1] Professorship of Forest Nutrition and Water Resources, Technische Universität München, Hans-Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany

Abstract

For many tree species nutritional threshold values are not available. Because the derivation of such values by fertilization experiments would be very time consuming and cost intensive a relatively easy method is proposed. By interpreting cumulative concentration distributions the thresholds for the range of normal nutrition as well as the threshold for deficiency can be deduced. As shown for the species spruce, pine and beech this method delivers values, which are in most cases very close to the known thresholds from literature. Provided that a suitable data set exists or can be set up the proposed procedure can be used to derive nutritional thresholds for species for which up to now no such values are available.

Key words: beech / nutritional threshold values / pine / spruce

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1 Introduction

Since decades an assessment of the nutritional status of trees by means of needle or leaf analytical values is a usual diagnostic practice. For common and some less common species nutritional threshold values are available (*Göttlein* et al., 2011; *Göttlein* and *Zehle*, 2018). However, there are many species for which such values are not accessible. The derivation of physiologically based threshold values by means of fertilization experiments would need an extremely high effort, both in terms of time and costs. Thus, it would be advantageous to have a method that allows deducing thresholds from easily available data.

2 Material and methods

Trees with extreme deficiency or extreme excess of a nutrient element are not viable in the long term, which means that the realized range of concentration values per nutrient element and tree species must be limited. If the frequency distribution of element concentrations is evaluated accordingly, deficiency and excess should occur at the edges of the distribution, whereas the frequency maximum should be in the range of normal to optimal nutrition. Since an evaluation of frequency distributions is mathematical less convenient, for the derivation of nutritional thresholds cumulative frequency distributions are used. Working with percentiles is less successful than evaluating the shape of the curve. This was obvious for the data of S, which contain, due to emission history, an elevated percentage of high and very high values.

Figure 1 shows the cumulative frequency distribution of nitrogen concentrations in first year needles of spruce from the BZE1+BZE2 dataset (1st and 2nd German forest soil survey). An at least 8th degree polynomial function is fitted to the cumulative distribution of the nearly 1,400 individual observations, and the first and second derivatives are formed from this. The point of the strongest left curvature of the fitted function (A) (= maximum of the second derivative) represents the deficiency threshold, the point of the strongest right curvature (C) (= minimum of the second derivative) is taken as upper threshold of the range of normal nutrition. The lower threshold of the range of normal nutrition, which is the border to latent deficiency, results from the intersection of two tangents (B), tangent 1 at the deficiency threshold and tangent 2 at the inflection point of the curve (= maximum of the first derivative).

3 Results and discussion

The threshold values derived in Fig. 1 fit very well to the respective thresholds for spruce available in the literature (Fig. 2). For the lower and upper threshold of normal nutrition, the values determined according to Fig. 1 are in the range of the 25–75% percentile of the literature values compiled by *Göttlein* (2015). For the deficiency threshold, the calculated value is just above the 75% percentile.

The comparison of the threshold values, derived according to Fig. 1 for the main nutrient elements of spruce, pine and beech with the literature data given in *Göttlein* (2015), is summarized in Tab. 1. In 43 out of in total 54 comparisons, which is equal to 79.6% of the cases, the threshold values determined from cumulative frequency distributions are in the

* Correspondence: A. Göttlein; e-mail: goettlein@forst.tu-muenchen.de

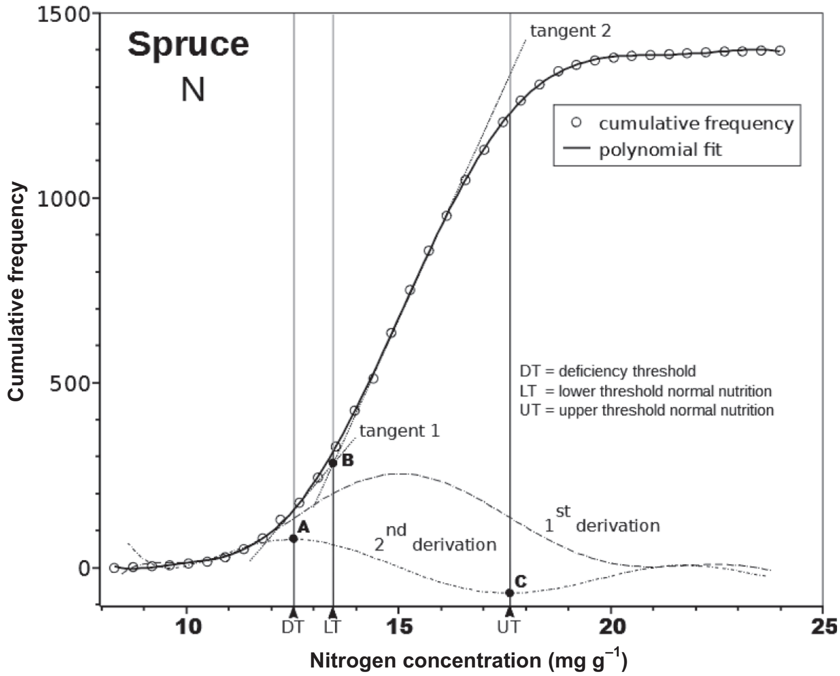

Figure 1: Derivation of nutritional threshold values from a cumulative frequency distribution using the example of nitrogen concentrations of spruce from the German BZE1+BZE2 data basis.

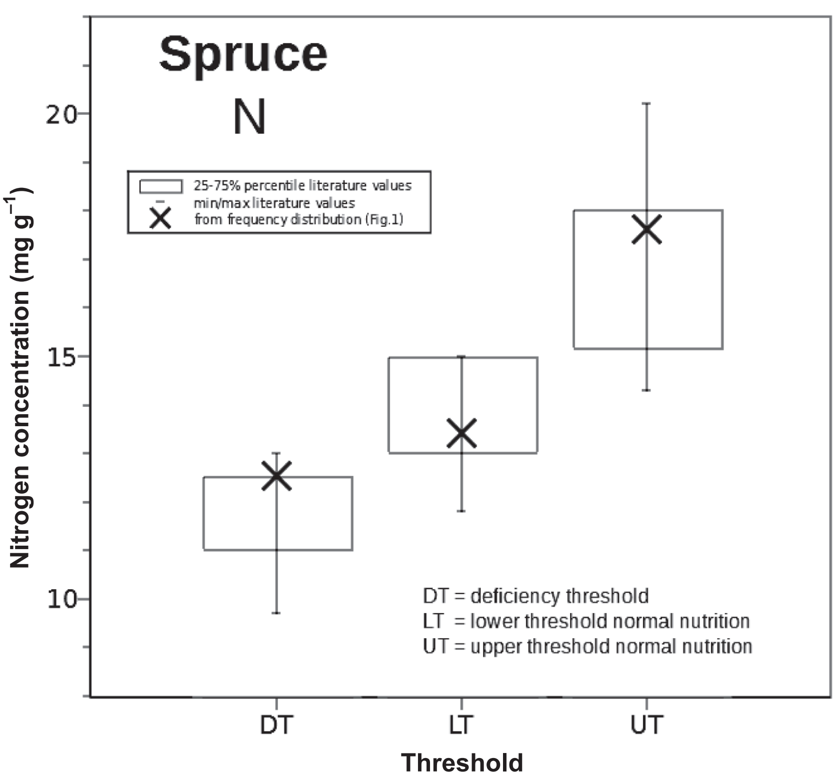

Figure 2: Comparison of threshold values derived from Fig. 1 with corresponding thresholds from the literature compilation of *Göttlein* (2015).

range of the known literature values, in 48.1% of the cases even in the range of the 25% to 75% percentile. In seven out of 11 cases were values derived according to Fig. 1 that are outside the literature range, their deviation from the nearest literature value is less than 10%. At the lower threshold of normal nutrition, *i.e.*, the border between normal nutrition and latent deficiency, which is most important for nutritional evaluations, the procedure delivers pleasing good values. With the exception of only one value (N for beech), all values derived from the frequency distribution are in the range of the previously known literature, more than half even in the range of the 25% to 75% percentile.

For spruce and pine a Ca-deficit is nearly not existent, because only less than 1% of the total observations are lower than the highest respective threshold in literature (*Göttlein*, 2015). Consequently, in this case the respective deficiency thresholds derived according to Fig. 1 are too high. For sulfur, the high immissions at the end of the 20th century in some regions, especially in eastern Germany, lead to excessive concentrations in foliage. As consequence the cumulative frequency distribution at its higher end shows a long steady increase. Thus, the point of the strongest right curvature is shifted to the left, leading to an underestimation of the upper threshold of normal nutrition for all three tree species. For beech all derived thresholds for nitrogen are higher than the respective literature values. One reason for this may be the long lasting excessive nitrogen input, leading to a generally higher level of foliar nitrogen concentrations. Also for pine, in tendency, this phenomenon can be observed.

4 Conclusions

The above outlined approach of deriving nutritional thresholds from cumulative frequency distributions is a promising tool. However, it is necessary to use a data set covering all situations of nutritional supply, for each tree species and each nutrient element. A nutritionally biased distribution would result in also biased thresholds. Independent of the amount of data, a smooth, s-shaped curve is a good indicator for a homogeneous data set. The big advantage of the proposed procedure is that it can easily be recalculated as soon as new data are available, thus leading gradually to improved threshold values.

Table 1: Comparison of the threshold values derived according to Fig. 1 from the data of BZE1+BZE2 with literature data from *Göttlein* (2015); marking of the fields according to the quality of the values as shown in Fig. 2: dark field: value is in the range between 25% and 75% percentile of literature values; gray field with +: value is in the range of literature values above the 75% percentile; gray field with –: value is within the range of literature values below the 25% percentile; for all values outside the range of literature values, their relative deviation from the nearest literature value is given.

	Norway spruce			Scots pine			European beech		
	DT	**LT**	**UT**	**DT**	**LT**	**UT**	**DT**	**LT**	**UT**
N	+			+1.5%	+	+	+9.2%	+5.6%	+6.6%
P		–	–	+		–		–	–9.8%
S			–1.7%			–7.9%	–		–13.0%
K				+		–			
Ca	+21.0%			+20.7%	+			+	
Mg	+			+		–	–11.7%	–	

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