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# Should we estimate plant cover in percent or on ordinal scales?

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## Abstract

**Question**: We explored the error resulting from different methods for recording the cover of plants in vegetation plots, specifically the direct estimation of percent cover vs. the use of ordinal cover scales (7-step Braun-Blanquet and 5-step Hult-Sernander-Du Rietz). **Methods**: We simulated 121 plant species of different cover, sampled with 13 different levels of estimation precision. Estimation precision was either based on a constant coefficient of variation (0.1–1.0) across all cover values or on empirical data from Hatton et al. (1986, Journal of Range Management 39: 91–92) (× 0.5, × 1.0, × 1.5). Each sampling was repeated 10 times. Subsequently, we determined the mean relative and absolute errors that occurred in the data used for ensuing numerical analyses. **Results**: Except for few cases with unrealistic settings (very high estimation error and ignorance of species with lower cover values), direct estimation in percent yielded better results than the use of ordinal scales. Based on the empirical values of estimation accuracy, the use of ordinal scales inflated the mean absolute and relative errors nearly 2-fold in case of the 7-step Braun-Blanquet scale and about 1.5-fold in case of the Hult-Sernander-Du Rietz scale if only considering cover values above 1%. **Conclusions**: From our personal experience, the careful application of an ordinal scale is not faster than the direct estimation of percent cover. For this reason, we see no plausible argument supporting the use of ordinal cover scales when essentially all subsequent analyses are numeric.

**Abbreviations:** Br.-Bl. = 7-step variant of the Braun-Blanquet scale and its numerical replacement as in Table 2; CV = coefficient of variation; H.-S. = Hult-Sernander-Du Rietz scale and its numerical replacement as shown in Table 1.

## Keywords

Braun-Blanquet scale, estimation, Hult-Sernander-Du Rietz scale, numerical analysis, observer error, ordinal scale, percent estimate, plant cover, simulation, species abundance, transformation, vegetation-plot record

## Introduction

Plant cover assessment is a central methodological step in vegetation ecology, phytosociology and habitat monitoring. While there are many other methods for estimating species importance in plant communities, such as frequency analysis, line-intercept analysis, estimation of basal area or harvest of biomass (Mueller-Dombois and Ellenberg 1974; Dierschke 1994; Kent 2012), the by far most often applied approach is to estimate the cover of individual plant species (Dengler et al. 2011; Bruelheide et al. 2019). However, while percent cover is considered the relevant measure, most researchers do not note percent covers directly, instead using an ordinal cover scale or cover-abundance scale. Many such scales have been proposed and further modified, so that virtually dozens of variants exist (see reviews by Whittaker 1973; Dierschke 1994; Peet and Roberts 2013; Table 1). The

Braun-Blanquet scale is the most popular among these ordinal scales (Bruelheide et al. 2019) and goes back to Josias Braun-Blanquet, who published different variants in the three editions of his textbook (first: Braun-Blanquet 1932; last: Braun-Blanquet 1964). However, most researchers are apparently not aware of the definition in Braun-Blanquet (1964) and instead use some self-made modification (see Table 1). Although a few methodological standards (e.g. the EDGG standard sampling methodology, Dengler et al. 2016) suggest that direct recording of percent cover should be preferred, ordinal scales remain very popular in phytosociology and national biodiversity monitoring programs (e.g. Mróz 2017; Bergamini et al. 2019; Schmidt and Van der Sluis 2021). In the most comprehensive vegetation-plot database on Earth, sPlot, 66% of all plots were recorded using one of the many variants of the Braun-Blanquet scale, 15% direct percent cover, and 19% one of 55 other numeric or ordinal measures, including just presence-absence (Bruelheide et al. 2019)

Most of the ordinal scales of plant importance were proposed long before the advent of numerical methods in plant community ecology. They were mainly introduced to provide an efficient tool for the standardised description of plant communities (relevés) which could then be used for different purposes, such as vegetation classification by manual table sorting (Braun-Blanquet 1964; Dengler et al. 2008). While the methods of recording have scarcely changed since the 20th century, most of the vegetation plots in the 21st century are sampled for numerical analyses, such as cluster analyses, ordination, analyses of mean ecological indicator values (EIVs), community-weighted means (CWMs) of plant functional traits or diversity indices, to name just a few (Dengler et al. 2008; Kent 2012; van der Maarel and Franklin 2013a). Subjecting vegetation-plot data recorded with an ordinal scale to a numerical method essentially requires back-translation of the categories of the scale into percent cover (or another numeric scale). The established approach is to replace each cover category with the arithmetic mean of its two class borders, as already proposed by Braun-Blanquet (1964), but there have also been other suggestions, including replacement based on the empirical frequency distribution of cover values (McNellie et al. 2019) or replacement with ordinal transform values (OTVs) (van der Maarel

**Table 1.** Four typical ordinal scales used to estimate the importance of plant species in plant communities with their definitions and their proposed back-transformation into percent cover. We compare the original 6-step Braun-Blanquet (1964) scale, a 7-step version of the Braun-Blanquet scale as implemented in the widespread computer program TURBOVEG (Hennekens and Schaminée 2001), a 9-step version of the Braun-Blanquet scale from van der Maarel and Franklin (2013b; similar to Wilmanns 1998) and the Hult-Sernander-Du Rietz scale (Trass and Malmer 1973).

| Scale | Category | Min. cover % | Max. cover % | Abundance | Replacement in % |
|---|---|---|---|---|---|
| **6-step Braun-Blanquet scale**[1] | + | >0% | 1% | (or few individuals) | 0.1% |
| (Braun-Blanquet 1964) | 1 | >1% | 10% | (or abundant) | 5% |
| | 2 | >10% | 25% | (or very abundant) | 17.5% |
| | 3 | >25% | 50% | NA | 37.5% |
| | 4 | >50% | 75% | NA | 62.5% |
| | 5 | >75% | 100% | NA | 87.5% |
| **7-step version of the Braun-Blanquet scale**[2] | r | NA | NA | NA | 1.0% |
| (as in TURBOVEG) | + | NA | NA | NA | 2.0% |
| | 1 | NA | NA | NA | 3.0% |
| | 2 | NA | NA | NA | 13.0% |
| | 3 | NA | NA | NA | 38.0% |
| | 4 | NA | NA | NA | 68.0% |
| | 5 | NA | NA | NA | 88.0% |
| **9-step version of the Braun-Blanquet scale** | r | >0% | 5% | 1–3 individuals | NA |
| (van der Maarel and Franklin 2013b) | + | >0% | 5% | few individuals | 1% |
| | 1 | >0% | 5% | abundant | 2.25% |
| | 2m | >0% | 5% | very abundant | 4% |
| | 2a | >5% | 12.5% | NA | 8.75% |
| | 2b | >12.5% | 25% | NA | 18.75% |
| | 3 | >25% | 50% | NA | 37.5% |
| | 4 | >50% | 75% | NA | 62.5% |
| | 5 | >75% | 100% | NA | 87.5% |
| **Hult-Sernander-Du Rietz scale** | 1 | >0% | 6.25% | NA | 3.125% |
| (Trass and Malmer 1973) | 2 | >6.25% | 12.5% | NA | 9.375% |
| | 3 | >12.5% | 25% | NA | 18.75% |
| | 4 | >25% | 50% | NA | 37.5% |
| | 5 | >50% | 100% | NA | 75% |

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[1] Braun-Blanquet's textbook (1964) contains a total of four inconsistent definition tables for species importance (p. 37, p. 39-upper, p. 39-lower, p. 52). In contrast to frequent claims in the literature, all four agree in setting the border between "1" and "2" at 10% rather than at 5%. Moreover, Braun-Blanquet (1964) presents once a 5-step scale (p. 37) and three times a 6-step scale, but never a 7-step scale as often assumed in the literature. Only in a footnote to the upper table on p. 39 does he mention that one could additionally use "r" as a seventh category. However, from his wording on the same page (*Man bedient sich hierzu einer konventionellen 6teiligen Skala* = One uses a conventional 6-step scale for this purpose), it appears that he does not favour the 7-step scale. Lastly, Braun-Blanquet (1964) includes both pure cover scales (p. 37, p. 52) and a combined cover-abundance scale (p. 39: upper table and text).

[2] The built-in replacement for "4" in the 7-step Braun-Blanquet scale of TURBOVEG is 68%, not 63% as claimed in Tichý et al. (2020).

2007). Particularly challenging (and essentially unsound) is back-translation in the case of combined cover-abundance scales, such as various variants of the Braun-Blanquet scale (e.g. Wilmanns 1998). However, even if a pure cover scale is applied, it must be asked why one should use such a categorisation when essentially all subsequent analyses will need the original cover values.

While many vegetation ecologists seem to apply an ordinal scale out of respect for tradition, others argue that the estimation of Braun-Blanquet categories is less "error-prone" or better "reproducible" than the direct estimation of percent cover of each species. We were interested in whether the latter argument is true, and thus applied a simulation study to quantify the effects of the double-transformation when using an ordinal cover scale vs. the direct estimation of percent cover.

## Methods

We set up a simulation experiment in which 10 virtual observers with identical skills made independent estimates of the cover of plant species using direct percent cover values and two widespread ordinal scales, namely a purely cover-based 7-step variant of the Braun-Blanquet scale (Table 2; "Br.-Bl.") and the 5-step Hult-Sernander-Du Rietz scale (Table 1; "H.-S.") (Figure 1). To ensure comparability, we assumed that the cover was estimated with the same precision in all three cases, and differences in the final values originated only from the subsequent double transformation (Figure 1). We simulated 121 species whose true covers ranged from 0.001% to 92.709% with a 1.1-fold increase between subsequent species, thus ensuring equal coverage of the whole range of possible covers in the log-scale.

Our basic assumption was that any cover estimate by an observer necessarily comes with an error, i.e. over- or underestimation of the true cover. Since the precision of estimates is unknown and varies depending on the skills of the observer, the complexity of the vegetation, the plot size and other factors, we simulated 13 settings with different levels of estimation accuracy and its relationship to cover. For that we used two approaches: (i) "Constant CV": We assumed that the mean estimation error is proportional to the true cover and implemented this by ten different levels of CV (coefficient of variation), ranging from 0.1 to 1 in increments of 0.1. (ii) "Hatton": We took the empirical data from Hatton et al. (1986) who analysed with 24 graduate students how precisely they could estimate fractional areas of artificial paper forms of different size and aggregation within a 0.25-$m^2$ sampling plot. Their reported results translate into a scale-dependent CV that closely follows a power law of the equation $CV = 1.2583\ A^{-0.616}$, with $A$ being the true fractional area in %. To reflect that other researchers under other conditions might be more or less precise in their estimates, we additionally implemented versions with 50% better and 50% worse estimates, i.e. in total three variants (Hatton × 0.5, Hatton × 1.0 and Hatton × 1.5).

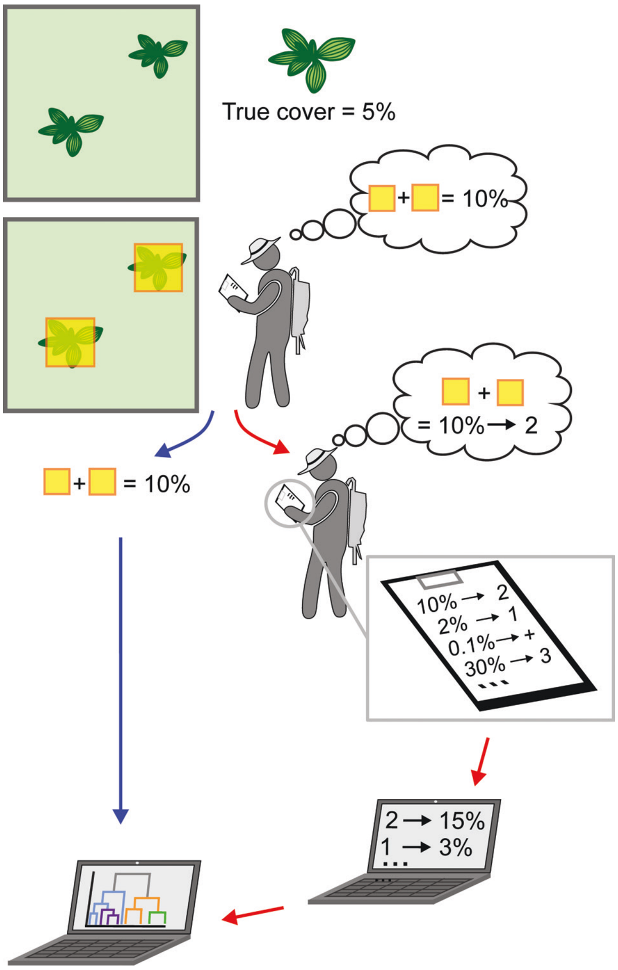

**Figure 1.** Visualisation of the different steps involved in observing a real plant in a vegetation plot and using its estimated cover in a wide range of numerical analyses. In both cases, the same estimation error of the observer is involved (in the case depicted, the botanist estimates 10% while the plants of this species only have 5% cover). In the case of direct percent estimation (blue path), this estimation error is the only source of error prior to statistical analysis, but when using an ordinal scale (red path), there are two additional transformation steps involved, each of which adds to the overall error.

**Table 2.** Variant of the 7-step Braun-Blanquet scale used for the simulation.

| Cover category | Min % | Max % | Replacement % |
|---|---|---|---|
| r | >0 | 0.1 | 0.1 |
| + | >0.1 | 1 | 0.5 |
| 1 | >1 | 5 | 3 |
| 2 | >5 | 25 | 15 |
| 3 | >25 | 50 | 37.5 |
| 4 | >50 | 75 | 62.5 |
| 5 | >75 | 100 | 87.5 |

To simulate the perception of 10 equally skilled observers, we always drew a random number from a normal distribution with the true value as mean and a standard deviation equalling CV × true value. If the random number was smaller than 0 or larger than 100, we replaced it with 0.0001 or 100, respectively. With these settings, the relative estimation errors in the case of "constant CV" slightly decreased towards the largest plot sizes (because then the random draws above 100% were set to 100%), but strongly in the case of "Hatton". Likewise, the absolute errors largely peaked around 70% for "constant CV" (not shown) and around 55% (Hatton et al. 1986).

Individual percent cover estimates were taken as they were, while in the case of ordinal scales, we first assigned them to the proper category according to Tables 2 ("Br.-Bl.") and 1 ("H.-S."), and then back-transformed them to percent with the replacement for this category according to the same tables (Fig. 1). We then calculated for each of the 121 species and each of the 10 observers how much the final cover estimate (i.e. the one normally used in numerical analyses) deviated from the true cover value, relatively and absolutely. We averaged these values across species and then across observers to get a general impression of the end effect. Additionally, we made these calculations for those subsets of species reaching a cover value greater than a certain threshold. All these calculations were done both for the absolute errors in % and the relative errors (i.e. absolute error / true value). Further, we compared the mean absolute and relative errors when using the ordinal Braun-Blanquet scale vs. the direct percent estimate as a ratio, calling the resulting factor "error inflation". Finally, we compared the information loss of the Hult-Sernander-Du Rietz scale vs. the analysed 7-step Braun-Blanquet scale, also with error inflation factors.

# Results

In nearly all cases, we found that the errors in the final numbers (those normally used for numerical analyses) were higher in the case of the two ordinal scales compared to direct cover estimates in percent (Table 3 and Suppl. material 1: error inflation rates > 1). In the simulations based on the empirical data for estimation precision and modifications thereof (i.e. "Hatton"), the error inflation factor was a minimum of 1.2 and reached as high as 103.6 (Suppl. material 1). Only for "constant CV" in combination with very high estimation error (CV = 0.5 and more), and mostly when restricting virtual species to cover values of 10% or more, were there a few cases when the ordinal scales performed slightly better than direct percent estimation (error inflation rate of 0.9) (Table 3 and Suppl. material 1). Generally, the error inflation rates were higher when the estimation precision of the observers was higher (i.e. lower CV), higher for relative error than for absolute error and higher when all cover values were included vs. when only the species with large covers were included (Table 3, Suppl. material 1). Considering the empirical data from Hatton ("Hatton × 1.0") and focussing on species with at least 1% cover, the mean relative estimation error in the field was 32.3%, meaning the average deviation from the true cover was 2.9% (green line in Table 3 and Suppl. material 1, Figure 2). However, when in this situation ordinal scales were applied, the mean relative estimation error after back-transformation increased to 60.2% (1.9-fold error inflation) in the case of "Br.-Bl." and 44.1% (1.4-fold error inflation) in the case of "H.-S.". This

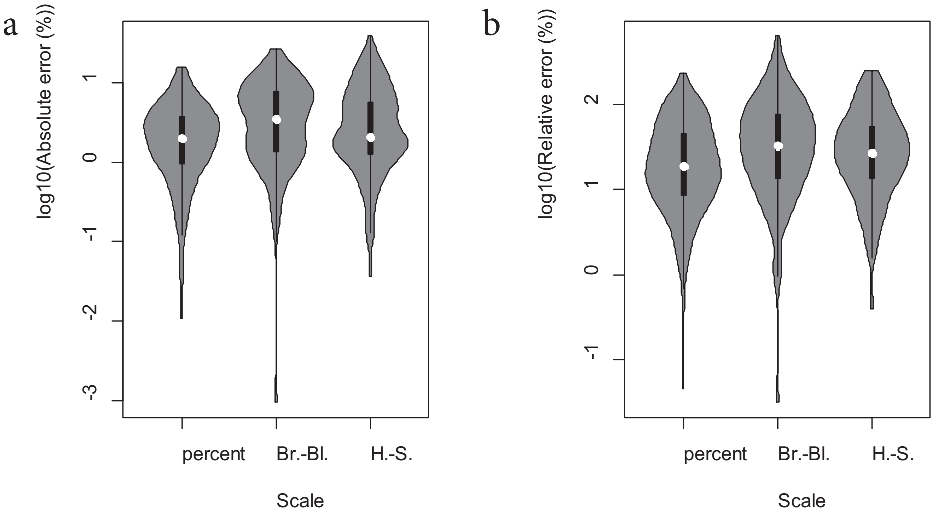

**Figure 2.** Example violin plots for the estimation errors in the final data comparing direct percent estimation and two purely cover-based ordinal scales (7-step Braun-Blanquet scale = "Br.-Bl.", 5-step Hult-Sernander-Du Rietz scale = "H.-S."). The example refers to the setting that we consider most realistic and relevant, i.e. estimation errors based on the empirical data from Hatton et al. (1986) ("Hatton" × 1.0) and considering only the 48 virtual species with more than 1% actual cover (i.e. the case marked green in Table 3 and Suppl. material 1), each with 10 replicates (i.e. independent assessments). Part (a) of the figure displays the relative errors, part (b) the absolute errors. To achieve better homoscedasticity, the errors were log10-transformed in both cases. The violin plots show the density distribution of values (violin), the interquartile range (black bar) and the median (white circle). In ANOVAs with Error term = Replicate.ID nested in Species.ID, there was a highly significant ($p < 0.001$) difference in the performance of the three methods in both cases, with the errors of percent < H.-S. < Br.-Bl. (for mean values, see Suppl. material 1).

**Table 3.** Example of results of the simulation for different levels of estimation error in the field, either with varying CV (coefficient of variation) or based on the empirical data by Hatton et al. (1986). The comprehensive version including the Hult-Sernander-Du Rietz scale can be found in Suppl. material 1. In each case, the mean relative and absolute error was averaged over all simulated species and 10 runs both for sampling with direct percent cover estimate and with the 7-step Braun-Blanquet scale shown in Table 2 ("Br.-Bl."). The error inflation due to the use of the ordinal scale is expressed as the ratio of the mean error with the ordinal scale to the mean error without (bold = inflation of error; normal font = no effect or minimal reduction of error). The row marked green refers to the example discussed in the text.

| Setting (estimation precision) | Covers considered | Mean relative error with percent | Mean relative error with Br.-Bl. | Mean absolute error with percent | Mean absolute error with Br.-Bl. | Inflation relative error with Br.-Bl. | Inflation absolute error with Br.-Bl. |
|---|---|---|---|---|---|---|---|
| CV = 0.1 | All | 7.8% | 901.5% | 0.685 | 1.876 | **114.9** | **2.7** |
| | > 0.01% | 7.9% | 122.3% | 0.864 | 2.339 | **15.5** | **2.7** |
| | > 0.1% | 8.0% | 66.2% | 1.151 | 3.096 | **8.3** | **2.7** |
| | > 1% | 7.8% | 48.1% | 1.710 | 4.511 | **6.1** | **2.6** |
| | >10% | 8.3% | 19.5% | 3.147 | 5.968 | **2.3** | **1.9** |
| CV = 0.3 | All | 23.5% | 905.4% | 1.771 | 2.489 | **38.5** | **1.4** |
| | > 0.01% | 23.1% | 127.1% | 2.232 | 3.112 | **5.5** | **1.4** |
| | > 0.1% | 22.6% | 69.2% | 2.973 | 4.124 | **3.1** | **1.4** |
| | > 1% | 22.8% | 51.4% | 4.416 | 6.036 | **2.3** | **1.4** |
| | >10% | 21.9% | 26.6% | 7.933 | 9.065 | **1.2** | **1.1** |
| CV = 0.5 | All | 39.0% | 916.2% | 3.026 | 3.467 | **23.5** | **1.1** |
| | > 0.01% | 38.7% | 140.7% | 3.814 | 4.345 | **3.6** | **1.1** |
| | > 0.1% | 37.6% | 77.9% | 5.079 | 5.760 | **2.1** | **1.1** |
| | > 1% | 37.9% | 67.8% | 7.544 | 8.494 | **1.8** | **1.1** |
| | >10% | 38.4% | 38.2% | 13.624 | 13.152 | 1.0 | 1.0 |
| CV = 1.0 | All | 72.5% | 932.1% | 4.751 | 4.842 | **12.9** | 1.0 |
| | > 0.01% | 70.6% | 160.8% | 5.988 | 6.078 | **2.3** | 1.0 |
| | > 0.1% | 69.9% | 96.3% | 7.974 | 8.068 | **1.4** | 1.0 |
| | > 1% | 69.0% | 87.6% | 11.818 | 11.884 | **1.3** | 1.0 |
| | >10% | 60.7% | 56.9% | 20.718 | 19.350 | 0.9 | 0.9 |
| Hatton × 0.5 | All | 273.5% | 1222.0% | 0.631 | 1.922 | **4.5** | **3.0** |
| | > 0.01% | 88.8% | 216.6% | 0.788 | 2.387 | **2.4** | **3.0** |
| | > 0.1% | 41.3% | 80.0% | 1.024 | 3.123 | **1.9** | **3.0** |
| | > 1% | 16.9% | 50.0% | 1.387 | 4.410 | **3.0** | **3.2** |
| | >10% | 6.9% | 18.3% | 1.967 | 5.475 | **2.7** | **2.8** |
| Hatton × 1 | All | 537.3% | 1720.4% | 1.273 | 2.234 | **3.2** | **1.8** |
| | > 0.01% | 155.7% | 291.3% | 1.588 | 2.765 | **1.9** | **1.7** |
| | > 0.1% | 70.5% | 109.3% | 2.071 | 3.610 | **1.6** | **1.7** |
| | > 1% | 32.3% | 60.2% | 2.872 | 5.086 | **1.9** | **1.8** |
| | >10% | 13.0% | 20.9% | 4.084 | 6.430 | **1.6** | **1.6** |
| Hatton × 1.5 | All | 812.5% | 1925.2% | 1.773 | 2.622 | **2.4** | **1.5** |
| | > 0.01% | 237.3% | 360.0% | 2.216 | 3.251 | **1.5** | **1.5** |
| | > 0.1% | 103.0% | 160.0% | 2.886 | 4.239 | **1.6** | **1.5** |
| | > 1% | 43.0% | 71.7% | 3.993 | 5.853 | **1.7** | **1.5** |
| | >10% | 19.4% | 23.5% | 5.824 | 7.451 | **1.2** | **1.3** |

means that the true cover was missed by 5.1% in absolute terms (1.8-fold error inflation) in the case of "Br.-Bl." and 4.7% (1.6-fold error inflation) in the case of "H.-S." (highlighted line in Tables 3 and Suppl. material 1). In most cases, the error inflation was higher for "H.-S." than for "Br.-Bl.", while for all assessments restricted to cover values above 1% "H.-S." slightly outperformed "Br.-Bl." (Suppl. material 1).

## Discussion

We found that the use of ordinal scales instead of direct estimation and recording of percent cover introduces an additional, biologically relevant error to the data in nearly all cases. We conducted our simulation using two widespread ordinal scales and obtained largely consistent results. We also repeated the analyses for 13 different settings based both on empirical data and simple simulation data, which were meant to reflect different levels of experience of the surveyors and different degrees of vegetation complexity. The high consistency of the results for all combinations of settings underlines the generality of our findings. This was to be expected, since the error mathematically results from the information loss due to the two additional translation steps involved, each of which on average must increase the estimation error (Figure 1). This error does not result from the peculiarities of a specific ordinal scale. Logically, one can assume that the problem is less severe when an ordinal scale contains more categories (such as 9-step variants of the Braun-Blanquet scale or the Londo scale; see Dierschke 1994). This aspect was also highlighted by Hahn and Scheuring (2003), who demonstrated that the use of ordinal scales comes with the so-called partition error, which increases the overall estimation error and decreases with the number of ordinal categories. Our findings point in the same direction, since error inflation generally was worse for the 5-step "H.-S." scale than for the 7-step "Br.-Bl." scale, but not so when focusing only on the cover range from 1% to 100%. When considering this range, it seems that the particular disadvantage of this variant of Braun-Blanquet scale comes from the cover class "2", which comprises a five-fold range in cover values (5–25%), while in the Hult-Sernander-Du Rietz scale each cover class (except the lowest) has a two-fold range in cover values.

Therefore, one might ask why so many researchers are attached to the Braun-Blanquet scale or other ordinal scales. Since we ourselves made thousands of relevés with the Braun-Blanquet scale before we changed our approach, and since we have discussed this issue with many colleagues, we see three main reasons. (1) Many researchers may continue to use this method because they learned it as such and never questioned the wisdom of this methodological choice. By contrast, we believe that a scientific discipline can only then remain vital when its representatives ask themselves from time to time whether the methodological choices that made sense in the past are still adequate. (2) Other colleagues argue that one makes a smaller estimation error when using an ordinal scale than when directly recording cover values in percent. This seems to be a misconception about error size. When the real cover for example is 26%, and one person notes 25% and another 27%, their values on paper are different, but their estimates in fact are highly consistent with reality and among each other. If in the same case two researchers note "3" on the Braun-Blanquet scale, these estimates seem to be consistent, but they are far from the reality, as the back-transformation of "3" is typically 38%. Hahn and Scheuring (2003) nicely captured this aspect by highlighting that mis-estimation error (i.e. the assignment to the "wrong" category, which moderately increases with the number of categories) is only part of the relevant estimation error overall, while the other component, the partition error, strongly decreases with the number of categories. (3) Colleagues often also argue that estimating Braun-Blanquet categories is faster than estimating percentages. However, this argument is only true if little attention is paid to class borders. If researchers consider that there is a major difference between "2" and "3," they should estimate the real cover at least as precisely in cases when it is around class borders than researchers using percent.

We can report from our own experience that the shift from estimating Braun-Blanquet categories to percent cover values required only a short adjustment period and did not result in a loss in speed, i.e. we now complete approximately the same number of relevés per day with percent cover than we did before with different variants of the Braun-Blanquet scale. Indeed, when students are taught how to perform relevés for the first time, many of them say that estimation in percent is faster, because if they are asked to note Braun-Blanquet categories they first estimate percent cover before translating it to the ordinal system. However, the actual speed needed for doing the same relevé with percent and an ordinal scale will vary between individuals and depend on their prior training. While it would be desirable to test this experimentally in a future study, this would be methodologically quite challenging, since it is hard to separate the scale from the assessment precision. Many persons might be tempted to do the assessment less carefully when asked to do it with an ordinal scale than with percent estimates. By contrast, we based our simulation on the assumption that the observer worked with the same estimation error in both cases. This means that, in practice, using an ordinal scale might indeed be slightly faster for some vegetation scientists, but at the price of an even higher error inflation rate than reported here.

Last but not least, one should highlight that our simulation was carried out for a purely cover-based variant of the Braun-Blanquet scale (Table 2; see also Braun-Blanquet 1964; Pfadenhauer et al. 1986; Dengler 2003). Traditionally, many variants of the Braun-Blanquet scale were combined cover-abundance scales (Braun-Blanquet 1951; Barkman et al. 1964; Westhoff and van der Maarel 1973; Wilmanns 1998; van der Maarel and Franklin 2013b). It is self-evident that mixing two incompatible measures such as percent cover and abundance (number of individuals) comes with additional mathematical problems (e.g. Dengler 2003) beyond those which we have discussed for pure cover-based ordinal scales.

## Conclusion

Except a minority of rather unrealistic settings, we found that using ordinal scales for the cover estimation of plants introduces a relevant additional error to the data. Under the setting that can be assumed to be closest to reality (the row marked green in Table 3 and Suppl. material 1), the error inflation was nearly 2-fold for "Br.-Bl." and about 1.5-fold for "H.-S.", irrespective of whether the focus is on relative or absolute error. Why should one accept such an additional error? Most modern methods in vegetation ecology rely on good data on the relative importance of species. This applies for ordination and classification methods, as well as for the calculation of mean ecological indicator values or community-weighted means of traits. It is likely that some methods will be affected more by this additional error than others. For example, it has been shown that ordination methods yield similar results when using ordinal scales or percent cover (Ricotta and Feoli 2013; Camiz et al. 2017). One can assume that the calculation of Shannon diversity and Shannon evenness indices should be particularly sensitive as they use ln(cover). Values that are extremely different on the ln-scale and which easily can be distinguished in the field, such as 0.1 and 0.001, are equalised in any of the ordinal scales presented here. Moreover, most researchers now apply parametric statistical tests, which is justified for directly estimated percent cover values, but is dubious for ordinal scales, particularly if they have only a few steps. Finally, there are methods in community ecology that are not applicable to ordinal scales. For example, the analysis of species-abundance distributions (for plants, in fact, usually species-cover distributions) is not possible if only a small number of cover categories is distinguished (Ulrich et al. 2022).

While the negative effects of the additional errors introduced by ordinal scales have not been extensively quantified for the wide range of methods typically applied to vegetation data, one could argue that one should avoid any unnecessary error, if this comes at no cost (see our arguments above). Based on our findings, we recommend that vegetation ecologists abandon the use of ordinal importance scales of plants in vegetation plots. While this method made sense in a pre-computer era, it has severe disadvantages in an age where nearly all relevant analyses require back-transformation to a numeric scale (see also Podani 2006). We thus would like to encourage all vegetation ecologists who are still using ordinal scales for recording vegetation plots to try estimating cover directly in percent and see whether it works for them.

## Data availability

The study was based on simulated data, which are provided in aggregated form in an online appendix and can be requested from the authors.

## Author contributions

J.D. conceived the idea of this study. Both authors jointly conducted the analyses and wrote the manuscript, while I.D. prepared the conceptual figure.

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## Supplementary material

**Supplementary material 1**

**Comprehensive results of the simulation for different levels of estimation error in the field, based either on constant levels of CV (coefficient of variation) or on the empirical data by Hatton et al. (1986) (*.pdf).**

Link: https://doi.org/10.3897/VCS.98379.suppl1