A New Index for Measuring Practical Knowledge Diversity: The Combination Use Diversity Index (CUDI) Applied to Cross-Cultural Ethnobotany

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Research Methods and Methodology

Abstract

Background: Since quantitative indices are essential for quantifying the depth of ethnobotanical knowledge, most current measures aim to account for the complexity of practical knowledge combinations by focusing on species importance or consensus. One new way to measure cultural variation in plant-use knowledge is the Combination Use Variation Index (CUDI), which is introduced in this study.

Methods: CUDI is calculated by taking the number of unique "species × use" combinations a group reports and dividing it by the total number of possible combinations. Five imagined datasets for different cultural groups were created to see how the index works under different conditions of species variety, use category variety, and knowledge organization. Comparative analyses with established indices (UV, ICF, BEI, RFC, RSI) were performed.

Results: CUDI values proved highly sensitive to the structure and breadth of knowledge, increasing with greater functional diversity and polyvalence in plant-use combinations, while remaining robust to differences in sample size. Comparative analysis showed that CUDI adds to traditional indices by focusing on practical usefulness instead of just how often something is cited or how much agreement there is among informants.

Conclusions: When it comes to ethnobotanical research, CUDI gives researchers a transparent, robust, and easily reproducible way to quantify practical knowledge variety. Researchers can modify it for use in different fields of ethnobiology, and it addresses a methodological need in research that spans cultures and communities. Possible future uses include tracking how our understanding evolves, ranking conservation efforts, and honing quantitative ethnobotany.

Keywords: CUDI, Cross-cultural comparison, Ethnobiology, Ethnobotany, Intra-group comparison, Quantitative analysis, Traditional knowledge

Background

Due to its vital role in generating innovative crops and medicines and showcasing human biocultural history, ethnobotany—the study of interactions between humans and plants—has gained more attention in recent decades (Martin 2010). From their medical uses to their edible ones, from their material uses to their ceremonial roles, ethnobotanists have an interest in numerous facets of the human-plant interaction (Balick & Cox 2020). The cultural importance of plants is another area of interest for ethnobotanists, who typically try to compare the ethnobotanical knowledge of different human cultures (Sulaiman *et al*. 2024). The number of publications that publish ethnobotanical studies has increased dramatically during the last several decades, from a handful to dozens (Medeiros *et al*. 2011). Ethnobotany is an interdisciplinary field that has evolved since its 1896 introduction by Hirschberger, including several scientific disciplines such as anthropology, ecology, and botany, among others (de Albuquerque *et al*. 2010). Different concepts and approaches used by these fields open up a wealth of potential areas for investigation. According to Phillips (1996), quantitative indices are a prime example of how the scientific rigor of ethnobotanical studies has increased over the last several decades as a result of their widespread use. Quantitative evaluation of botanical resource management is one of the most important initiatives in ethnobotany, according to Martin (1995). Therefore, when using quantitative indices, the goals of ethnobotanical researchers differ greatly. Historically, quantitative data analysis in ethnobotany has been more descriptive and subjective when it came to plant inventories, but over time, this approach has become more objective and experimental (Medeiros *et al*. 2011). Various quantitative and qualitative methods have been devised to address inquiries concerning the relationship between humans and plants. Even though many ethnobotanical indices have been created, Heinrich et al. pointed out that a lot of ethnobotanical studies relied too heavily on stories from qualitative research and didn't have enough strong statistical support. To address this challenge, ethnobotanists have developed various Relative Cultural Importance (RCI) indices, including the widely adopted Use Value (UV) and Informant Consensus Factor (ICF), among others (Phillips & Gentry 1993, Prance *et al*. 1987, Kvist *et al*. 1995, Lykke *et al*. 2004). These indices have greatly improved the field by allowing comparisons between different cultures, highlighting important plant species, and providing clearer insights into how local plants are used. Phillips (1996) reviewed 41 papers published between 1966 and 1994, analyzing the methods used in ethnobotanical studies to investigate the many functions and cultural importance of plants. Quantitative methods provide significant advantages for improving the state of ethnobotany research, according to his results. Also in a similar spirit, Albuquerque (2009) presented the history of "quantitative ethnobotany" and how it greatly impacted biological conservation efforts by shedding light on the importance of various plant types to human populations and the ways in which human activities are destroying these ecosystems. The idea of relative cultural importance (RCI), which includes several methods used for data analysis by Phillips (1996) and others, was further investigated by Hofman & Gallaher (2007). Ethnobotany now often uses relative cultural importance indices, like the "use value" meter suggested by Prance *et al*. (1987), to assess how important certain plants are to people. New methods in ethnobotany have been driven by these number-based approaches, which have greatly helped in confirming statistics, comparing different studies, and testing ideas in the field. Ethnobotanists have benefited from quantitative approaches for assessing people's plant resource knowledge and incorporating several informants' perspectives (Fraser & Junqueira 2020); however, indices have come under fire from some scholars. Gaoue *et al*. (2017) noted that while ethnobotanical research has improved in its methods, it often overlooks the need for a solid theoretical framework, focusing instead on using quantitative indices and statistical methods from ecology. Furthermore, Leonti (2022) noted that these indices aren't always appropriate, especially in ethnopharmacological settings, because they don't take into account important variables impacting plant use, like the accessibility of pharmaceutical alternatives or the severity of the conditions being treated. Additionally, he stated that numerical indices are unable to completely embody the cultural importance and worth of plants, particularly medicinal species and botanical medicines.
Hofman & Gallaher (2007) classified the various indices used in ethnobotany into four main groups:

- simple lists of all known uses for each species;
- subjective allocation indices like use value (Prance *et al*., 1987) and the index of cultural significance (Turner, 1988);
- measures of informant consensus based on tallies, such as the Corrected Fidelity Level (Ali-Shtayeh *et al*. 2000) and species use values for individual or all informants (Phillips and Gentry 1993);
- and measures of informant consensus based on scoring, like the Informant Score Method (Kvist *et al*. 1995) and Choice Value (Kremen *et al*. 1998).

To better understand how different cultural groups use species, researchers often use additional measures like the Jaccard Similarity Index. However, no index has been created that specifically measures general ethnobotanical knowledge within a human population. In light of this lack of a standard methodology, the current study sets out to fill this need by presenting a new instrument for quantitatively evaluating the depth of ethnobotanical knowledge, with a focus on general knowledge comparisons across groups and intra-group comparisons according to gender, age, or time.

Materials and Methods

This paper presents the development and demonstration of a new quantitative index, the Combination Use Diversity Index (CUDI), which is designed to measure the practical diversity of ethnobotanical knowledge within and between groups. Proposed by Cheikh Yebouk, the CUDI index was applied to a dataset consisting of five hypothetical datasets that represent five cultural groups (A, B, C, D, and E). The main goal was to test and show how useful CUDI is as a strong, unbiased way to measure the variety of “species × use” combinations shared by the people involved in the research.

The method involved creating and studying imaginary datasets, each representing a different cultural group, with controlled differences in the number of species, variety of uses, and unique “species × use” combinations. This design aimed to test how variations in ethnobotanical knowledge affect the performance of CUDI and to allow for direct comparisons with well-known ethnobotanical indices (for more detail, see Appendix 1).

We compared CUDI with other popular ethnobotanical indices—Use Value (UV), Informant Consensus Factor (ICF), Botanical Ethnoknowledge Index (BEI), Relative Frequency of Citation (RFC), and Rahman’s Similarity Index (RSI)—to show what makes CUDI different in its analysis. The strengths and limitations of each index were summarized in a comparative table (Table 2).

This method offers a straightforward and repeatable way to evaluate the variety of practical knowledge, making it useful for both imagined and actual ethnobotanical data sets.

Results

A New Index: Combination Use Diversity Index (CUDI)

The Combination Use Diversity Index (CUDI) serves as a robust quantitative indicator of valuable ethnobotanical knowledge. Unlike traditional measures that emphasize the number of species mentioned or the level of agreement among informants, CUDI focuses on the intricacy of the knowledge by counting each unique "species × use" pairing noted by a group. We developed a normalized Combination Use Diversity Index (CUDI) to enable fair comparisons across different groups, regardless of their varying sizes and amounts of ethnobotanical knowledge. The CUDI is calculated by adding up all the different "species × use" combinations reported by a group and then dividing that number by the total number of species and the number of use categories identified in that group. This approach ensures that CUDI values range from 0 (indicating a complete lack of diversity) to 1 (signifying full disclosure of all possible combinations).
The CUDI is presented in the following formula:

$$\boldsymbol{CUDI = \frac{\sum Nsu}{Nsp \times Nu}}$$

Where:

- Nus = Number of unique “species × use” combinations reported by the group
- Nsp = Number of species represented in the group.
- Nu = Number of unique uses represented in the group.

CUDI values range from 0 (no diversity) to 1 (maximum diversity: all possible “species × use” combinations are cited).
Interpretation

- CUDI = 0: No diversity; only a single (or repeated) “species × use” pair is recorded.
- CUDI = 1: Maximum diversity; every possible combination (each species × each use) is present in the group’s knowledge.
- Intermediate values: Indicate the proportion of the potential plant-use knowledge space that is actually filled by the group.

Application Example: CUDI Across Five Hypothetical Cultural Groups

To show how the Combination Use Diversity Index (CUDI) works, we proposed five sets of data representing five different cultural groups (A, B, C, D, and E) to demonstrate how useful this index can be. Each group varies in a specific component that contributes to the final CUDI value, allowing us to isolate and examine the effect of that factor on ethnobotanical knowledge diversity.

Group A serves as the baseline, with standardized values for the number of species, the number of uses, and the number of unique "species × use" combinations (Table 1). In each of the other groups (B-E), one parameter is varied while the others are kept constant, enabling direct comparison and sensitivity analysis of the CUDI formula.

Table 1: Application of the Combination Use Diversity Index (CUDI) in the Comparison of Five Groups

Group	Nsp (Species)	Nu (Uses)	∑Nsu (Unique Species × Use Combinations)	CUDI Value
A	9	10	45	0.50
B	9	10	54	0.60
C	13	10	52	0.40
D	9	7	36	0.57
E	9	10	38	0.42

The results indicate that reasonable differences in sample size minimally affect CUDI. For example, the CUDI value for Group B is very close to that of Group A, even though both groups share the same knowledge space (species × uses) but differ in the number of unique combinations. This indicates that CUDI reflects the polyvalence of ethnobotanical knowledge more than it does the sample size itself. The comparison between Groups C and A confirms that increasing the total number of species (Nsp) without a proportional increase in the number of unique combinations (∑Nsu) results in a lower CUDI value. This illustrates a dilution effect, where higher species richness does not necessarily lead to greater practical diversity. Likewise, the results for Group D, compared to Group A, show that reducing the number of use categories (Nu) does not necessarily decrease knowledge diversity. Conversely, maintaining a relatively high number of unique combinations leads to an increase in CUDI. This suggests that more intensive and polyvalent plant use within a reduced number of categories can still yield a high level of practical knowledge diversity. Finally, the results for Group E, which has the same number of species and use categories as Group A, show a lower CUDI value due to a reduction in the total number of combinations. This illustrates that a decrease in practical diversity—such as redundancy or narrower plant-use specialization—leads to a lower index value. These findings confirm that CUDI is a sensitive indicator of the structure of practical ethnobotanical knowledge. It increases with knowledge versatility, decreases when species richness is not accompanied by functional diversity, and remains stable despite changes in sample size. Thus, CUDI provides a powerful yet simple tool for detecting meaningful differences in functional knowledge richness across cultural groups.

Comparison of CUDI with Five Ethnobotanical Indices

This comparative analysis demonstrates that each ethnobotanical index serves a distinct analytical purpose. The Combination Use Diversity Index (CUDI) highlights the variety of ways different species are used, giving a detailed picture of the diversity in practical knowledge. In contrast, the Botanical Ethnoknowledge Index (BEI) offers a broad, multidimensional assessment by integrating factors such as species richness, citation frequency, and distribution. The Use Value (UV) and Relative Frequency of Citation (RFC) indices focus primarily on citation frequency, making them particularly useful for ranking species according to their perceived importance (table 2). The Informant Consensus Factor (ICF) is specifically designed to measure consensus around use categories, such as treatments for particular ailments. Finally, the Rahman's similarity index (RSI) quantifies the similarity of ethnobotanical uses between groups, considering both the presence of shared species and the similarity of their uses. As mentioned in this study, CUDI adds to these existing measures by addressing an important need: it measures the variety of ethnobotanical knowledge without relying on how often it is cited or how much agreement there is. This makes it especially valuable in cross-cultural comparisons, where traditional indices may fail to fully capture the breadth and versatility of plant use knowledge within and between communities.

Table 2. Key Features and Formulas of Major Ethnobotanical Indices, Including the Newly Proposed CUDI.

Dimension	CUDI (Combination Use Diversity Index) (Yebouk 2025)	BEI (Botanical Ethnoknowledge Index) (Sulaiman 2025)	UV (Use Value) (Phillips & Gentry1993)	ICF (Informant Consensus Factor) (Trotter et al. 1986)	Relative Frequency of Citation (RFC) (Tardío et al. 2008)	(RSI) Rahman's similarity index (Rahman et al.2019)
What it measures	Polyvalence: Diversity of "species × use" combinations	Global knowledge: richness + frequency + dissemination	Depth: Average citations per informant	Cohesion: Agreement on uses	Popularity: frequency of mention	Ethnobiological similarity: Common use reports between groups
Formula	$CUDI = \frac{\sum Nsu}{Nsp \times \mathrm{Nu}}$	$BEI = \left(\frac{ms}{sg}\right) + \left(\frac{mc}{N}\right) * \frac{sg}{st}$	$\mathrm{UV} = \sum Ui/n$	$ICF = \frac{Nur - Nt}{\mathrm{Nur} - 1}$	$\mathrm{RFC} = \mathbf{FC}/\mathrm{N}$	$RSI = \frac{d}{a + b + c - d}$
Scale	0 à 1	0 à 1	0 à ~n	0 à 1	0 à 1	0 à ~n
Interprétation	Higher = broad functional diversity; 1 = maximum potential exploited	Higher = rich and widespread knowledge	Higher = citation importance	Higher = highly consensual uses	Higher = High local importance	Higher = greater similarity in uses of common species
Focus	Fine-grained combinations ("species × use")	Group	Species	Use category	Species frequency	Common species & uses between groups/sites
Sensitivity	Normalized by number of informants; stable across group sizes	Complex, aggregates several dimensions	Biased if few species dominate	Sensitive to the number of use reports (nUR)	Influenced by dominant species	Sensitive to real cultural similarity, not just presence
Main application	Identify polyvalent groups or taxa	Community-level comparisons	Rank culturally important species	Assess use consensus by disease	Identify culturally frequent species	Quantitative cross-cultural/cross-study comparison
Limites	Ignores citation frequency or consensus; not a substitute	May mask richness vs consensus	Doesn't reflect use diversity	Doesn't reflect use diversity	Doesn't consider versatility	Does not measure functional/knowledge diversity

Legend: ∑Nsu: Number of unique "species × use" combinations, Nsp: Number of species, Nu: Number of uses, ms: mean citations per species; sg: species group; mc: mean citations per use category; N: total informants; st: total species, Ui: Uses per informant; n: number of informants, Nur: Number of use-reports; Nt: Number of taxa, FC: Number of informants mentioning the species, a, b: Number of unique species in sites A, B; c: Common species; d: Common species used for similar ailments

Applications and Limitations

CUDI is highly adaptable and applicable in various contexts:

Intra-group comparison: by gender, age, occupation, education, or socioeconomic factors.

Temporal comparison: For tracking changes within a community over time.

Cross-group comparison: Across ethnic, regional, or cultural groups. CUDI can also be extended to ethnozoology or ethnomycology, where unique “animal × use” or “fungus × use” combinations are quantified.

Limitations: CUDI is best suited for groups from similar ecological zones; large differences in local flora may bias diversity estimates. Additionally, CUDI measures practical breadth but does not capture symbolic or cultural value.

Applications and Limitations

CUDI is highly adaptable for:

- o Intra-group comparison (by gender, age, occupation, education)
- o Temporal monitoring (knowledge loss, innovation, or change)
- o Cross-group comparison (across ethnic, regional, or cultural boundaries)
- o Extension to ethnozoology/ethnomycology (e.g., “animal × use” or “fungus × use”)

Limitations:

- o Best applied within groups of similar ecological backgrounds (to avoid bias from floristic variation)
- o Focuses on practical, not symbolic or cultural, knowledge value
- o It doesn't mirror the agreement among informants or the frequency of reporting for particular pairs.

Conclusion

This study proposes a novel index that will yield a specific numerical value representing the overall ethnobotanical knowledge of a particular human group. This study presents the Combination Use Diversity Index (CUDI), an important tool for ethnobotanical research that provides a simple and effective method to measure the variety of plant-use knowledge. The study concentrates on distinct "species use" combinations. CUDI facilitates quantitative comparisons across and within groups and supports monitoring of knowledge change and conservation priorities. Its straightforward calculation, versatility, and adaptability to other ethnobiological domains make it a valuable addition to the ethnobotanist’s methodological toolkit. Researchers are encouraged to apply and further refine CUDI in diverse contexts to enhance the clarity and precision of ethnobotanical and ethnobiological knowledge assessment.

Declarations

List of abbreviations: CUDI - Combination Use Diversity Index; BEI - Botanical Ethnoknowledge; UV - Use Value; ICF - Informant Consensus Factor: RSI- Rahman’s similarity index

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Appendix 1. Step-by-step description for calculating the Combination Use Diversity Index (CUDI)

Step 1 - Collect data on specific uses for each plant species in each ethnic group

Collect raw data from individual research participants for each species and each use category ("disease treated"). Each record is a unique "species × use" combination.
Table 3 below shows raw data for three ethnic groups (A, B and C)

Table 3. Raw ethnobotanical data for CUDI calculation in three ethnic groups

Group	Species	Use Category (Disease Treated)
A	Species 1	Use_1
A	Species 1	Use_2
A	Species 2	Use_1
A	Species 2	Use_2
B	Species 1	Use_1
B	Species 2	Use_1
B	Species 2	Use_2
C	Species 1	Use_1
C	Species 2	Use_2
C	Species 2	Use_3

Step 2 - Summarize unique species, unique uses, and unique "species × use" combinations per group

For each group, count:

- The number of unique species (Nsp) : Species_1, Species_2 (**Nsp = 2**)
- The number of unique uses (Nu) :

Group A ; Use_1, Use_2 (**Nu = 2**)
Group B ; Use_1, Use_2 (**Nu = 2**)
Group C ; Use_1, Use_2, Use_3 (**Nu = 3**)

- The number of unique "species × use" combinations (**∑Nsu**) :

- Species_1× Use_1
- Species_1× Use_2
- Species_2× Use_1
- Species_2× Use_2

(∑Nsu=4)

Group A

- Species_1× Use_1
- Species_2× Use_1
- Species_2× Use_2

(∑Nsu=3)

Group B

- Species_1× Use_1
- Species_2× Use_1
- Species_2× Use_2

(∑Nsu=3)

Group C

Table 4. Summary of parameters for CUDI calculation

Group	**Number of species (Nsp)**	**Number of uses (Nu)**	**Unique "species × use" (∑Nsu)**
A	2	2	4
B	2	2	3
C	2	3	3

Step 3 - Apply the CUDI formula:

$$CUDI = \frac{\sum Nsu}{Nsp \times Nu}$$

Step 4 - Calculate CUDI for each group

Table 5. CUDI values for each group

Group	Formula	CUDI value
A	4 / (2 × 2) = 4 / 4	1.00
B	3 / (2 × 2) = 3 / 4	0.75
C	3 / (2 × 3) = 3 / 6	0.50

Step 5 - Interpretation

- **Group A**: Complete coverage of all possible “species × use” pairs (CUDI = 1).
- **Group B**: 75% of possible pairs are represented (CUDI = 0.75).
- **Group C**: 50% of possible pairs are represented (CUDI = 0.50).