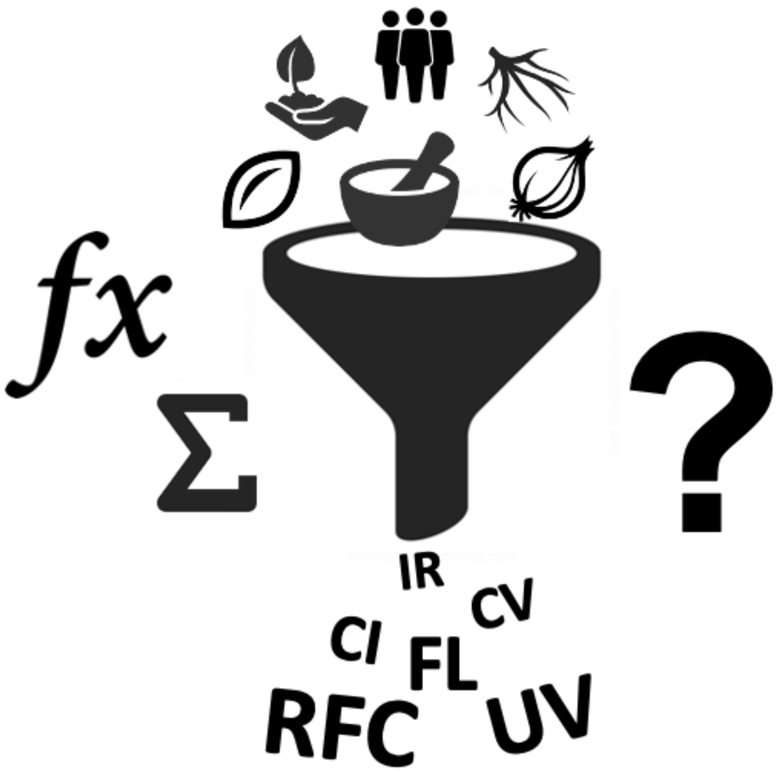
Journal of Ethnopharmacology 288 (2022) 115008

The relevance of quantitative ethnobotanical indices for ethnopharmacology and ethnobotany

Marco Leonti[a*]

[a]Department of Biomedical Sciences, University of Cagliari, Cittadella Universitaria, 09042, Monserrato (CA), Italy



https://doi.org/10.1016/j.jep.2022.115008

Received 24 November 2021; Received in revised form 5 January 2022; Accepted 17 January 2022

*Corresponding author, Tel.: +390706758712,

E-mail addresses: marcoleonti@netscape.net; mleonti@unica.it

Keywords: Ethnobotanical indices, fidelity level, use value, relative importance, cultural value, relative frequency of citations

Abstract

Ethnopharmacological relevance: As an interdisciplinary field of research ethnopharmacology draws on methodologies and methods from a variety of disciplines. A range of ethnobotanical indices are frequently used to transform primary data obtained through field studies into statistical measures. These indices are claimed to serve as a proxy for efficacy or drug discovery (Fidelity Level 'FL') and to show the importance of botanical drugs and plants used as medicines (Relative Importance 'RI', Use Value 'UV' or Cultural Importance Index 'CI', Cultural Value Index 'CV', Relative Frequency of Citation 'RFC'). This is, however, doubtful, as these indices have not been developed by statisticians, nor by pharmacologists while a proof of concept is lacking. Moreover, the question whether a simple number can summarize the cultural value or importance of plants is not only mathematical but also epistemological.

Material and methods: The FL, RI, UV/CI, CV and the RFC are shortly reviewed. Their statistical rigour is explained and the relevance for ethnobotany, ethnopharmacology and drug discovery discussed.

Results: The effect of the sample size on the dispersal of data and the differential probability of botanical drugs being used for the different categories of use are not being considered by these indices. They lack statistical rigour and are simple percentage calculations. Moreover, important factors influencing plant use, such as the availability of pharmaceutical drugs, or the severity of diseases covered by the use-categories, are not accounted for.

Conclusion: Especially unexperienced and young researchers may be ensnared by using ethnobotanical indices to describe their field data. However, the cultural value and importance of plants in general, and more specifically, of medicinal plants and botanical drugs cannot be summed up by numbers. The discussed indices encrypt parts of the primary data but fail to show the value or importance of plant use because the reasons for which plants are valued or important to people are far more complex than what the formulations of these indices suggest. The indices also lack the power to pinpoint plant species or botanical drugs for drug discovery that contextualized primary data has. Botanical drugs may be useful for a range of disorders or only for specific indications, according to their pharmacologic properties. Therefore, the exclusiveness of therapeutical applications (FL) does not serve as a proxy for effectiveness. The solution is to use and understand the contextualized primary data.

1. Introduction

As an interdisciplinary field of research ethnopharmacology draws on a range of different disciplines, such as anthropology, pharmacology, botany, zoology, medicine, chemistry and statistics. The documentation and critical evaluation of traditional empirical knowledge about the therapeutical use and medicinal properties of botanical and animal drugs are the main foci of ethnopharmacology (Gertsch, 2009; Heinrich and Jäger, 2015; Bruhn and Rivier, 2019). Field study results consist of descriptive qualitative data and quantitative primary data (Bernard, 2011). Quantitative ethnomedical field data is the raw or primary data and is usually presented in a table describing the cultural consensus of botanical and animal drug use (Weckerle et al., 2018). It is readily accessible for statistical analysis and serves as a starting point and hypothesis for laboratory research (Verpoorte, 2012; Gertsch, 2009). Primary data shows how many times a plant drug was reported to be used or known to be useful for a specific emic ailment or disease including its form of administration. Primary data includes the sample size and the share of respondents determines the consensus. Yet a high consensus does not imply that the respective remedy is also effective though this may constitute a working hypothesis. However, the sheer fact that a large part of a population relies on a specific treatment warrants its preferential assessment of the toxicological risks and the clinical effectiveness. One of the challenges of interdisciplinary research projects is to combine deep and focused thinking as well as thinking broad, across multiple areas (Lach, 2014). Another challenge is combining the whole range of available methodology and accepting and integrating concepts and methods from other fields (McLeod, 2018; Leonti et al., 2020). This means that the methods used are recognized, developed, and approved in the pertinent disciplines, which entails, that biological methods, such as *in vitro* and *in vivo* models adhere to pharmacological standards, that plant identification and taxonomy follow botanical standards and that statistical models and methods are recognized in statistics. For the same reasons that we agree to follow plant taxonomy developed in botany we should agree to follow statistics developed in statistics.

However, still many manuscript submissions to this journal come along with calculations of ethnobotanical indices, whose correctness and relevance for ethnopharmacology are doubtful. Now ethnobotanists can even use an R package (ethnobotanyR: https://rdrr.io/cran/ethnobotanyR/) to transform primary data into indices. However, most of these indices were not developed by statisticians, published in statistics journals and nor are they grounded in well-supported statistical approaches. For the presentation of field studies such indices are often selected randomly from the confusing diversity of existing indices without that any specific motivations for the choices would be presented. On the other hand, there seems to exist a misunderstanding as it is also thought that such indices may serve as a proxy for drug discovery or for identifying the most effective medicines as claimed by Friedman et al. (1986). Especially unexperienced and young researchers may be ensnared by ethnobotanical indices because for comparing and discussing numbers no anthropological, pharmacological, chemical, and therapeutical knowledge is required.

2. Problem statement

There is a continued fashion of indiscriminate and uncritical use of ethnobotanical indices instead of concentrating the effort of trying to understand what the gathered primary data are showing in terms of medical anthropology, pharmacology, medicine and overall novelty and its potential for future studies. The question is: Is there anything a simple number can tell us about the importance, value or efficacy of a botanical drug or medicinal species (that primary data can't)? The question whether a simple number can summarize these aspects of plant use is not only mathematical but also epistemological.

3. Methods

I shortly present and explain the statistical rigour of a few of the most-commonly used indices for describing the results of ethnobotanical and ethnopharmacological field studies that focus on the 'value' and 'importance' of single species. These indices include the 'Fidelity Level' (FL), 'Relative Importance' (RI), 'Use Value' (UV) or 'Cultural Importance Index' (CI), the 'Cultural Value Index' (CV) and the 'Relative Frequency of Citation' (RFC). They were published in journals dedicated to the use of plants including the Journal of Ethnopharmacology and Economic Botany (Friedman et al., 1986; Phillips and Gentry 1993, Prance and Bennett, 2000; Tardío and Pardo-de-Santayana, 2008). Another frequently used index is the Informant Consensus Factor (ICF) or Informant Agreement Ratio (IAR) by Trotter and Logan (1986). It estimates the consensus of treatment options for categories of therapeutical use and has been reviewed before (Leonti and Weckerle, 2015).

Fidelity level (FL) of plant X = number of use-reports of the most frequently mentioned use-category of plant X divided by the number of total use-reports for plant X. A FL of 100% means that a botanical drug or medicinal plant is used exclusively for one therapeutic indication or category of use while a

FL of 50% means that 50% of the use-reports gathered for plant/botanical drug X concentrate on one specific use-category (and that the other 50% of use-reports may be distributed otherwise) (Friedman et al., 1986).

Relative importance (RI) of species X = (Number of use categories for species X divided by the number of use categories for the most versatile species) plus (number of pharmacological properties (uses) of species X divided by the number of pharmacological properties (uses) of the most versatile species) (Prance and Bennett, 2000).

Use value (UV) or Cultural Importance Index (CI) of species X = total number of use-reports across all use-categories for species X divided by total number of informants (Tardío and Pardo-de-Santayana, 2008 adapted from Phillips and Gentry, 1993).

Cultural Value Index (CV) of species X = (number of use categories for species X divided by total number of use-categories) multiplied by (number of informants mentioning species X as useful divided by the total number of informants) multiplied by (total number of use-reports across all use categories for species X divided by total number of informants) (Reyes-García et al., 2006).

Relative frequency of citation (RFC) of species X: Number of informants mentioning the use of species X divided by total number of informants (Tardío and Pardo-de-Santayana, 2008).

4. Results and Discussion

All the above presented indices attempt in one way or another to measure the value, the importance, or the efficacy of plants. All indices draw, in different formulations, on primary data such as the number of use-reports per category and across categories, the number of use-categories, number of specific uses and the specific and total number of respondents. Therefore, these indices are not independent from each other and tend to behave similarly (Dudney et al., 2015). However, while some aspects of the primary data are factored into these ethnobotanical indices, they do never include all relevant data. All mentioned indices are species specific but at least for ethnopharmacological research questions they would need to be drug specific (because e.g., *Aloe* spp. gel consisting of polysaccharides is mainly used for topical applications and stomach ulcers while anthrone glycosides rich *Aloe* spp. sap is a potent laxative and bitter agent).

Friedman et al. (1986) invented the fidelity level (FL) because they were unable to interview patients previously treated with plant-based medicines in their attempt to verify or negate the efficacy of treatment. The specificity for therapeutic indications focused on with the fidelity level (FL) is a circumstance, that can readily be observed, along with the whole use profile when looking at the primary data organized in a well-structured table. It is also well known that specific botanical drugs and medicinal plants can be effective for a range of ailments while others are indicated for specific therapeutic needs (e.g., Wichtl, 2002; Barnes et al., 2002). The use-profile of botanical drugs, besides depending on tradition, is conditioned by pharmaco-therapeutic properties and observed toxicity, which is also the reason why some drugs are exclusively applied topically, such as for instance phytotherapeutic products obtained from the inflorescence of *Arnica montana* L. (Asteraceae). Having anti-inflammatory, antimicrobial, spasmolytic, anxiolytic, sedative and muscle relaxant properties, the inflorescences of chamomile (*Matricaria chamomila* L., Asteraceae) are applied internally as well as externally for a whole range of indications (Wichtl, 2002, p. 420-424; Barnes et al., 2002 p. 125-129) which would result in a low FL. The core wood of *Guaiacum officinale* L. (Zygophyllaceae) which is not used anymore in herbal medicine was exclusively used to treat syphilis, and probably had a FL of 100% across Renaissance Europe even though it is completely useless against *Treponema pallidum* infections (Waugh, 1982; Mann, 1984). While the FL shows the consensus of the most frequently mentioned use it provides a value of 100% also with only one single use-report. What is also misleading is that the FL was conceptualized for assessing plant use and not for assessing botanical drug use (Friedman et al., 1986). These examples show that the value of the FL is not robust and does not serve as a proxy for effectiveness or even drug discovery because cultural and pharmacological realities are more complex.

The RI was intended as a general measure for the diversity of uses and is based on the versatility of use-categories as well as more specific uses without taking the number of informants and the probability of allocation into one of the categories into consideration. It is not clear why simply counting the different use-categories and uses is not sufficient for assessing the use versatility.

The UV/CI simply provides the average number (mean) of use-reports per informant and species. This is so whether you separately sum up the mean values of respondents per category of use and species (CI) or whether you determine the mean value of the total number of use-reports per species (UV). Why this technical consideration led to the formulation of two separate indices is not clear. However, contrary to what Tardío and Pardo-de-Santayana (2008) claim for the CI, the versatility of uses is *not* taken into account. Only the total number of use-reports is considered.

The CV index factors in the versatility of uses, the share of respondents, and the average number of use-reports for the total number of informants (UV). Although these single factors tend to correlate with each other it is one of the more objective attempts of measuring 'cultural value' or maybe better the 'cultural use of a species'. However, like the previously presented indices the effect of the sample size on variance as well as the differential probability of allocation of uses into use categories is not accounted for.

The RFC is a very intuitive and basic percentage calculation used in anthropological and social sciences (do you make use of item X?) ever since (Bernard, 2011) and does not need to be turned into a specific index.

The FL, UV/CI and the RFC are simple percentage calculations and naming them in adventurous ways such as 'fidelity level', 'use-value' and 'cultural importance' is misleading and generating wrong expectations. Emblematic for this situation is that one and the same index has been published under two different names (Use value and Cultural Importance Index) leaving a critical reader with the question, as to which criteria were used to invent these names and how they represent the formula. Maybe percentage shares should simply be called "percentage of X or Y" or in this specific case "average number of use-reports per species and study participant". Of course, depending on the research question percentage calculations can be useful. However, due to the fact, that these indices are percentage calculation of sampled data or multiple percentage calculations (RI, CV) they also lack statistical rigour. This hampers their application for hypothesis testing and comparative studies because a division like $1/10^2$ is treated identically as $10^4/10^6$ ignoring the different sample sizes and the dispersal of the data (variance) (Watt et al., 2007; Weckerle et al, 2018). Higher sample sizes reduce variance and the dispersal of the data. However, primary data is not afflicted by such problems. For instance, relevant for the UV/CI are the total number of use-reports per plant species and the number of study participants (sample size). Both metrics belong to the essential primary data and therefore the relation between both values (and thus without issues like variance) should be reported in all studies (e.g., plant X, 50 use-reports; 100 study participants). Moreover, it is also crucial to know how many study participants contributed use-reports, in order to correct for individual preferences. Such data is more accurate and transparent than stating that the UV/CI of plant X is 0.5 because a UV of 0.5 can be the result of e.g., a sample size comprising two informants resulting in one use-report or a sample size of 1000 informants resulting in 500 use-reports for plant X. While the observed proportion of both cases is the same, the inference that can be drawn from these two percentage calculations on the true relationship among the whole population is dramatically different. Given a certain proportion p, its standard deviation is the square-root (SQRT) of (p(1-p)/N), where N is the sample size used to calculate p and the denominator of the fraction. Using the central limit theorem the true proportion lies within $p \pm 1.96 \times \mathrm{SQRT}(p(1-p)/N)$ with a probability of 95%. In practice the difference between proportions can be claimed with a certain probability when their respective intervals do not overlap (e.g., Watt et al., 2007). Most importantly, however, the uses can be very divers. Different implications would result from all 50 study participants reporting to use plant X as a X-mas tree, or to shoot their wedding photo underneath or to use its leaves for treating a severe disease. This crucial information is only provided by the primary data.

Also, all indices assume that the different uses and use-categories of each species or botanical drug are of identical importance. They don't take the differential probability of botanical drugs being used for a certain category into account. Due to ecological, phytopharmacological, ethnomedical and epidemiologic reasons, but also conditioned by the classification into use categories, not for all categories the same number of botanical drugs are used. Moreover, categories of use don't reflect treatments of health issues with identical severity and importance. Thus, species or drugs used for a small or/and severe group of health problems might be more important or valuable culturally. Another factor that, unfortunately, is rarely considered in ethnomedical field studies in general, and difficult to assess is the effect of the availability of modern pharmaceutical drugs on the use of traditional medicines. Although allopathic and traditional medicine may coexist (Giovannini and Heinrich, 2009), an impact on traditional medicines and their allocation to use categories through the availability of pharmaceutical drugs does occur (Mann, 1984; Le Fanu, 2011).

Thus, while these indices lack statistical rigour as well as a surplus of information content with respect to the primary data, they cannot reflect the complexity of primary data and even less so the complexity of pharmacology and efficacy. This would be so also in case the statistics was correct.

Another frequently applied metric is the informant agreement ratio (IAR) or informant consensus factor (ICF) by Trotter and Logan (1986). It is the ratio between (the number of use-reports for category of use X minus the number of species used for category of use X) and (the number of use-reports for category of use X minus 1) (Trotter and Logan, 1986). It is used to assess intra-cultural consensus with respect to the plant species/botanical drugs used for a specific ailment category and ranges from 0 to 1 while 1 indicates maximal agreement. This ratio lacks robustness because the distribution of use-reports between the species is not reflected (Leonti and Weckerle, 2015). Also, for a reasonable application of this index large data sets are required because small categories of use readily provide erratic values.

It has also been claimed that multiple indices may serve to identify species being most important to a community so that these plants "can be targeted for conservation and restoration activities" (Paniagua Zambrana et al., 2017). The ethnobotanical uses of the plant species in Paniagua Zambrana et al. (2017) are listed without providing the number of times these different uses were mentioned in the different communities. For instance, the uses for *Vismia macrophylla* Kunth, (Hypericaceae) are reported to be as follows (see footnote[1]). The use metrics provided for *V. macrophylla* are the UV (4.2), Community Cultural Importance (2.73), Informant Cultural Importance (1.55) and the Shannon diversity index of uses (0.59). However, for issues such as conservation and sustainable use it makes quite a difference whether a plant is used for its trunk in construction or as fuel or whether you eat the fruits or use the leaves for treating malaria. Therefore, it would be quite important to know how many individuals reported these different uses. If all informants claim to use the trunk in construction and as firewood, those who use the leaves or its bark for medicine may already have supply problems. If all report to use the leaves for treating malaria it would be important to assess their safety and efficacy. However, maybe the species is so common and weedy that the different use pressures do not culminate in conservation issues. Be that as it may, the problem is that we can't tell because the primary data as well as the qualitative species-specific descriptive data (ecology and abundance, possible reports about shortages, shrinking population) is missing while the calculated indices do not provide any tangible information useful for issues such as conservation and restoration. It is also

[1] "CONST: Houses (Chira Xahui, Trunk; Frame house, Bark; House post, Trunk; Jënë Jabati, Trunk; Jihuixaca, Trunk; Manipoatí, Trunk; Muchacho - Ninotí, Trunk; Nasëcamëti , Trunk; Pasa ratón - Xoya jabatí, Trunk; Ridgepole - Maracatí, Trunk; Roof beam - Canoxoco, Trunk; Solera - Chitao, Trunk; Tëtëmatsisi, Trunk; Tie - Xahui, Bark; Tirante - Cano bëpotó, Trunk; Tirante corto - Cano Bësëcamë, Trunk; Tirante largo - Cano pixquëna, Trunk; To tie house, Bark); Other constructions (Huaracha, Trunk); Thatch (To tie roof, Bark); CULT: Personal adornment (Ornament - Maxëití, Seeds; Ornament - Shinoxëta, Seeds); FUEL: Firewood (Firewood - Caro, Trunk); HUMFOOD: Food (Edible, Fruit); MEDVET: Digestive system (Malaria and fever, Leaf; Stomach ache, Leaf); Endocrine system (Liver pain, Leaf and seeds); Infections and infestations (Malaria and fever, Bark and leaf); Not specified at all (Cancer, Bark); Skin and subcutaneous tissue (Basket - Nishicacano, Trunk and exhudate; Haemorrhage, Bark); UTEN&TOOL: Domestic utensils (Basket - Chichabëcasa, Bark; Basket - Coquita, Bark; Basket - Nishicacano, Bark; Basket - Nishicacano, Trunk; Man basket, Bark; Tacú - Arusa timatí, Trunk); Labour tools (Hoe, Trunk)".

impossible to figure out how prominent the different medical uses of the various plant parts are. This lack of quantitative primary data hampers the decision making for further studies and actions.

Many researchers adopting indices are apparently convinced that pharmacologists or phytochemists would consider ethnobotanical indices when choosing which medicinal plant to work with. This is a logical corollary from Friedman et al. (1986) who suggested to use the FL as a proxy for efficacy. Today, authors extend this alleged power also to other indices. However, no proof of concept exists that would show that indices hold more information than the primary data and that they serve as a tool for drug discovery or for assessing the efficacy of therapeutic treatments. History of drug discovery from natural sources, on the contrary, shows that ethnopharmacological discoveries of important pharmaceutical drugs started with accurate field observations and the collection of primary data, followed by *in vitro*, *in vivo* and clinical studies (Bruneton, 1999; Heinrich et al., 2004; Dewick, 2002; Gertsch, 2009). Today, pharmacologists working with plant extracts base their decision on existing pharmacological and chemical literature about the whole taxon as well as therapeutic primary data from field studies or therapeutic descriptions present in herbal pharmacopoeias and historical books (e.g., Vásquez-Ocmín et al., 2018; Gupta et al., 2018; Pompermaier et al., 2018; Tomani et al., 2018; Riondato et. al., 2019; Roumy et al., 2020a; 2020b; Carabajal et al., 2020; Baldé et al., 2020; Schultz et al., 2020).

A further problem with ethnobotanical indices is that their calculation inevitably leads to a discussion section where indices are compared with each other within and across studies and the rather uninteresting insight that numbers are always either higher or lower, in line with the primary data. However, comparing indices across studies and cultures is even more problematic as sample sizes as well as emic use-categories differ. Especially unexperienced and young researchers may be ensnared by ethnobotanical indices and instead of thinking further and trying to understand the relevance of traditional medicines and the data collected for community healthcare or drug discovery some ready to calculate indices are presented and discussed. All this appears like a bureaucratic exercise and leads to a discussion about indices instead of ethnopharmacology. Therefore, such indices distract from the journal scope and prevent researchers from digging the literature and further educating themselves in the attempt to understand the data they've gathered pharmacologically and medically. The same can be said for ethnobotanical uses in general as the gain in knowledge about plant use by transforming primary data into indices is not clear. Also, the quality of feedback potentially given to the community members, where field work has taken place will inevitably suffer.

Conclusions

For simple percentage calculations (e.g., RFC) no indices are needed. The reviewed ethnobotanical indices (FL, RI, UV/CI, CV), are statistically insufficient because neither the effect of sample size on data dispersion nor the differential probability of use-report allocation to categories of use are accounted for. Also, important covariates such as the availability of pharmaceutical drugs, which has an impact on the use of traditional resources as well as the severity of health issues covered by the various use-categories, are not taken care of.

Importantly, the various indices do not provide any surplus of information or insight into plant use with respect to the primary data but reduce a part of the information into simple numbers. More specifically, history shows that these indices have no power as a starting point for drug discovery or efficacy assessments, while primary data has. Interdisciplinarity demands that we apply methods that comply with the standards of the respective disciplines. Therefore, we should follow the standards of statistics whenever manipulating primary data. Simple percentage calculations should be named for what they are (percentage of X or Y) and not be turned into indices with fantastic names. Also, for pinpointing species for conservation measures indices seem not be the appropriate tool. Currently, such indices are applied in a far too uncritical and superficial manner. While it cannot be excluded that corrected ethnobotanical indices applied in a reasonable way may contribute to ethnopharmacological or ethnobotanical research questions, so far, their relevance for resolving research questions in both fields is lacking. I conclude that contextualized primary data provides more information about the cultural value and importance of plants than simple numbers and I argue that if one doesn't understand the primary data, one doesn't understand indices and if one does understand the primary data, one doesn't need indices.

References

Baldé, M.A., Tuenter, E., Traoré, M.S., Matheeussen, A., Cos, P., Maes, L., Camara, A., Haba, N.L., Gomou, K., Diallo, M.S.T., Baldé, E.S., Pieters, L., Balde, A.M., Foubert, K., 2020. Antimicrobial investigation of ethnobotanically selected guinean plant species. J Ethnopharmacol. 263:113232. doi: 10.1016/j.jep.2020.113232.

Barnes, J., Anderson, L.A., Phillipson, J.D., 2002. Herbal medicines. A guide for healthcare professionals. Pharmaceutical Press, Chicago.

Bennett, B.C., Prance, G.T., 2000. Introduced plants in the indigenous pharmacopoeia of northern South America. Econ. Bot. 54, 90–102. doi.org/10.1007/BF02866603.

Bernard, H.R., 2011. Research Methods in Anthropology – Qualitative and Quantitative Approaches. Fifth Edition. UK: Altamira Press.

Bruhn, J.G., Rivier, L., 2019. Ethnopharmacology - A journal, a definition and a society. J Ethnopharmacol. 242:112005. doi: 10.1016/j.jep.2019.112005.

Bruneton, J., 1999. Pharmacognosy, phytochemistry, medicinal plants, 2nd edn. Lavoisier publishing, Hampshire.

Carabajal, A.M.P., Perea, M.C., Isla, M.I., Zampini, I.C., 2020. The use of jarilla native plants in a Diaguita-Calchaquí indigenous community from northwestern Argentina: An ethnobotanical, phytochemical and biological approach. J Ethnopharmacol. 247:112258. doi: 10.1016/j.jep.2019.112258.

Dewick, P., 2002. Medicinal natural products. A biosynthetic approach. Wiley, Chichester.

Dudney, K., Warren, S., Sills, E., Jacka, J., 2015. How study design influences the ranking of medicinal plant importance: a case study from Ghana, West Africa. Econ. Bot. 69, 306–317.

ethnobotanyR: Calculate Quantitative Ethnobotany Indices. https://rdrr.io/cran/ethnobotanyR/ (accessed, 24.11.2021).

Friedman, J., Yaniv, Z., Dafni, A., Palewitch. D., 1986. A Preliminary Classification of the Healing Potential of Medicinal Plants, Based on a Rational Analysis of an Ethnopharmacological Field Survey Among Bedouins in the Negev Desert, Israel. J. Ethnopharmacol. 16, 275–287. doi: 10.1016/0378-8741(86)90094-2.

Gertsch, J., 2009. How scientific is the science in ethnopharmacology? Historical perspectives and epistemological problems. J. Ethnopharmacol. 122, 177–183.

Giovannini, P., Heinrich, M., 2009. Xkiyoma (ourmedicine) and xkitienda (patent medicine) - Interface between traditional and modern medicine among the Mazatecs of Oaxaca, Mexico. J. Ethnopharmacol. 121, 383–399. doi: 10.1016/j.jep.2008.11.003.

Gupta, V.K., Kaushik, A., Chauhan, D.S., Ahirwar, R.K., Sharma, S., Bisht, D., 2018. Anti-mycobacterial activity of some medicinal plants used traditionally by tribes from Madhya Pradesh, India for treating tuberculosis related symptoms. J Ethnopharmacol. 227, 113–120. doi: 10.1016/j.jep.2018.08.031.

Heinrich, M., Barnes, J., Gibbons, S., Williamson, E.M., (Edtrs.). 2004. Fundamentals of Pharmacognosy and Phytotherapy. Churchill Livingstone, London.

Heinrich, M., Jäger, A.K., 2015. Ethnopharmacology. Chichester: JohnWiley & Sons.

Lach, D., 2014. Challenges of Interdisciplinary Research: Reconciling Qualitative and Quantitative Methods for Understanding Human¬Landscape Systems. Environmental Management 53, 88–93. doi:10.1007/s00267-013-0115-8.

Le Fanu, J., 2011. The Rise and Fall of Modern Medicine. Hachette Digital, London.

Leonti, M., Weckerle, C.S., 2015. Quantitative and comparative methods. In: Ethnopharmacology. Heinrich, M., Jäger, A.K. (Eds.), Ethnopharmacology. Ltd. Published by John Wiley & Sons, Chichester, UK.

Leonti, M., Casu, L., de Oliveira Martins, D.T., Rodrigues, E., Benítez, G., 2020. Ecological Theories and Major Hypotheses in Ethnobotany: Their Relevance for Ethnopharmacology and Pharmacognosy in the Context of Historical Data. Rev. Bras. Farmacogn. 30, 451–466. https://doi.org/10.1007/s43450-020-00074-w

McLeod, M., 2018. What makes interdisciplinarity difficult? Some consequences of domain specificity in interdisciplinary practice. Synthese 195, 697–720. doi.org/10.1007/s11229-016-1236-4

Mann, R.D., 1984. Modern Drug Use: An Enquiry on Historical Principles. MTP Press Limited, Lancaster, UK.

Paniagua Zambrana, N.Y., Bussmann, R.W., Hart, R.E., Moya Huanca, A.L., Ortiz Soria, G., Ortiz Vaca, M., Ortiz Álvarez, D., Soria Morán, J., Soria Morán, M., Chávez, S., Chávez Moreno, B., Chávez Moreno, G., Roca, O., Siripi, E., 2017. Traditional knowledge hiding in plain sight - twenty-first century ethnobotany of the Chácobo in Beni, Bolivia. J Ethnobiol Ethnomed. 13(1):57. doi: 10.1186/s13002-017-0179-2.

Phillips, O., Gentry. A., 1993. The useful Plants of Tambopata Peru: II Additional Hypothesis Testing in Quantitative Ethnobotany. Econ. Bot. 47, 33–43.

Pompermaier, L., Marzocco, S., Adesso, S., Monizi, M., Schwaiger, S., Neinhuis, C., Stuppner, H., Lautenschläger, T., 2018. Medicinal plants of northern Angola and their anti-inflammatory properties. J Ethnopharmacol. 216, 26–36. doi: 10.1016/j.jep.2018.01.019.

Reyes-García, V., Huanca, T.,Vadez, V., Leonard, W., Wilkie, D., 2006. Cultural, Practical, and Economic Value of Wild Plants: A Quantitative Study in the Bolivian Amazon. Econ. Bot. 60, 62–74.

Riondato, I., Donno, D., Roman, A., Razafintsalama, V.E., Petit, T., Mellano, M.G., Torti, V., De Biaggi, M., Rakotoniaina, E.N., Giacoma, C., Beccaro, G.L., 2019. First ethnobotanical inventory and phytochemical analysis of plant species used by indigenous people living in the Maromizaha forest, Madagascar. J Ethnopharmacol. 232, 73–89. doi: 10.1016/j.jep.2018.12.002.

Roumy, V., Ruiz, L., Ruiz Macedo, J.C., Gutierrez-Choquevilca, A.L., Samaillie, J., Encinas, L.A., Mesia, W.R., Ricopa Cotrina, H.E., Rivière, C., Sahpaz, S., Bordage, S., Garçon, G., Dubuisson, J., Anthérieu, S., Seron, K., Hennebelle, T., 2020a. Viral hepatitis in the Peruvian Amazon: Ethnomedical context and phytomedical resource. J Ethnopharmacol. 255:112735. doi: 10.1016/j.jep.2020.112735.

Roumy, V., Ruiz Macedo, J.C., Bonneau, N., Samaillie, J., Azaroual, N., Encinas, L.A., Rivière, C., Hennebelle, T., Sahpaz, S., Antherieu, S., Pinçon, C., Neut, C., Siah, A., Gutierrez-Choquevilca, A.L., Ruiz, L., 2020b. Plant therapy in the Peruvian Amazon (Loreto) in case of infectious diseases and its antimicrobial evaluation. J Ethnopharmacol. 249:112411. doi: 10.1016/j.jep.2019.112411.

Schultz, F., Anywar, G., Wack, B., Quave, C.L., Garbe, L.A., 2020. Ethnobotanical study of selected medicinal plants traditionally used in the rural Greater Mpigi region of Uganda. J Ethnopharmacol. 256:112742. doi: 10.1016/j.jep.2020.112742.

Tardío, J., Pardo-de-Santayana, M., 2008. Cultural Importance Indices: A Comparative Analysis Based on the Useful Wild Plants of Southern Cantabria (Northern Spain). Econ. Bot. 62, 24–39. doi:10.1007/s12231-007-9004-5

Tomani, J.C.D., Gainkam, L.O.T., Nshutiyayesu, S., Mukazayire, M.J., Ribeiro, S.O., Stevigny, C., Frederich, M., Muganga, R., Souopgui, J., 2018. An ethnobotanical survey and inhibitory effects on NLRP3 inflammasomes/Caspase-1 of herbal recipes' extracts traditionally used in Rwanda for asthma treatment. J Ethnopharmacol. 227, 29–40. doi: 10.1016/j.jep.2018.08.016.

Trotter, R., Logan, M., 1986. Informant consensus, a new approach for identifying potentially effective medicinal plants, in Plants in Indigenous Medicine and Diet, Biobehavioural Approaches (ed. N.L. Etkin), Redgrave Publishers, Bedford Hills, NY, pp. 91–112.

Vásquez-Ocmín, P., Cojean, S., Rengifo, E., Suyyagh-Albouz, S., Amasifuen Guerra, C.A., Pomel, S., Cabanillas, B., Mejía, K., Loiseau, P.M., Figadère, B., Maciuk, A., 2018. Antiprotozoal activity of medicinal plants used by Iquitos-Nauta road communities in Loreto (Peru). J Ethnopharmacol. 210, 372–385. doi: 10.1016/j.jep.2017.08.039.

Verpoorte, R., 2012. Primary data are the basis of all science! J. Ethnopharmacol. 139, 683– 684.

Watt, T.A., McCleery, R.H., Hart, T., 2007. Introduction to Statistics for Biology third ed.. Chapman & Hall / CRC, New York.

Waugh, M.A., 1982. Role played by Italy in the history of syphilis. Br J Vener Dis. 58, 92–95.

Weckerle, C.S., de Boer, H.J., Puri, R.K., van Andel, T., Bussmann, R.W., Leonti, M., 2018. Recommended standards for conducting and reporting ethnopharmacological field studies. J Ethnopharmacol. 210, 125–132. doi: 10.1016/j.jep.2017.08.018.

Wichtl, M., 2002. Teedrogen und Phytopharmaka: Ein Handbuch für die Praxis auf wissenschaftlicher Grundlage, 4. Aufl. Wissenschaftliche Verlagsgesellschaft, Stuttgart.