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GC Insights: On The Definition of Aridity in Geoscience Research

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Abstract. Aridity is a fundamental concept used across geoscience to describe water-limited environments, yet the scientific community currently uses multiple contradictory approaches to communicate aridity science. Here, we present the scope of aridity definition divergence, showing that out of 1000+ assessed studies aridity, A, is commonly defined as both the ratio of precipitation, P, to evaporative potential, E_P, as $A = P/E_P$ (32% of papers) and as its mathematical reciprocal $A = E_P/P$ (23% of papers), or is not defined at all (29% of papers). Based on this split between opposing definitions, we suggest standardization of the meaning of aridity for more effective interdisciplinary communication, accurate modeling, and metanalyses pertaining to water scarce regions.

Short Summary. Geoscience research exploring how study subjects are influenced by how much water is available on the earth's surface often uses the word 'aridity'. This work reviews the history of aridity and how geoscientist define it, including the two most common and opposite definitions. We advise researchers to use the more intuitive meaning of aridity, where a high aridity is used to describe a dry place, in order to clearly communicate research findings.

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1. Introduction

Investigations spanning a wide diversity of geoscience subjects often characterize the response of their subjects to 'aridity.' Example aridity studies include topics such as continental scaling patterns in evapotranspiration (Hunt et al., 2025), wildfire burn extents (Kampf et al., 2025), paleosol-based CO_2 reconstructions (Da et al., 2025), nitrogen isotope ratios in vegetation (Yang et al., 2025), root water uptake modeling (Bernhard et al., 2025), and summertime precipitation patterns (Wu et al., 2025). This wide range of geoscience subjects highlights the importance of aridity as a widespread driver of environmental organization across disciplines.

Fundamentally, aridity represents a biome scale multiyear balance between the supply of water via precipitation, P, and the evaporative potential, E_P, of the atmosphere to remove water from the surface. However, the definition of aridity as $A = P/E_P$ used by (Kampf et al., 2025; Wu et al., 2025) in their wildfire and precipitation studies is the mathematical reciprocal of that used by (Bernhard et al., 2025; Hunt et al., 2025) of aridity as $A = E_P/P$ in their investigation of root water uptake and evapotranspiration. While these example studies provide important context of how aridity relates to the environment and its changes, they also highlight the lack of consensus across quantitative sciences as to how to define aridity, where one common definition is the literal opposite meaning of another. The objective of this study is to present the wide, often contradictory, scope of how the geoscience community communicates the aridity research and begin a dialogue towards a consensus across disciplines. We briefly summarize the history of aridity definitions, examine their use in contemporary geoscience, and discuss implications arising from disparate definitions.

2. History of Aridity Definitions

Quantitative measures of aridity date at least to the early 20^{th} century. The precipitation to evaporation ratio was introduced (Transeau, 1905) as a metric of forest viability though it was not specifically termed aridity in this work. Difficulties in obtaining reliable estimates of evaporation lead others such as Lang (1915) and later De Martonne (1926) to define aridity type metrics based on mean annual precipitation and temperature, T (Gorczyński, 1943; Stadler, 2005; Wallen, 1967). These temperature-based indices are of the form of $A = P/T$ and $A = P/(T+10)$, for Lang and De Martonne respectively.

Contemporarily, Oldekop in 1911 proposed the ratio E_P/P as the governing quantity that determines the fraction of precipitation that leaves a catchment as either runoff or actual evaporation (Andréassian et al., 2016; Andréassian & Perrin, 2012). Importantly, moving away from temperature and precipitation metrics to metrics based on ratios using E_P and P (with both expressed as lengths per time) provides beneficial non-dimensionality properties. (Thornthwaite, 1948) in 1948 defined "a moisture ratio that expresses the relative humidity or aridity" of a location as $P/E_P - 1$. Building off prior collaborations with Oldekop, (Budyko, 1974) in 1974 defined E_P/P as a "radiative index of dryness" and used this ratio to determine the water and heat balance of locations on Earth.

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In 1979 The United Nations Educational, Scientific and Cultural Organization (UNESCO) Man in the Biosphere Program (Unesco, 1979) published a series of maps showing geographic patterns in P/E_P. This was later adopted for the 1992 United Nations Environment Programs (UNEP) World Atlas on Desertification (*World atlas of desertification*, 1992) which included specific categorizations of hyper-arid (P/E_P<0.05), arid (0.05< P/E_P <0.2), semi-arid (0.2< P/E_P <0.5), and dry sub-humid (0.5< P/E_P <0.65) drylands. Within this century, (Trabucco & Zomer, 2008; Zomer et al., 2022) have published high-resolution datasets of P/E_P following the UNESCO/UNEP definitions.

3. Patterns of Aridity Definition Usage

A historical review reveals that aridity definition popularity has evolved over the last century, with definition usage varying through time, by discipline, and by impact (Figure 1). The paleoclimate focused review of (Quan et al., 2013) found that over 50 different definitions have been used to quantify aridity, and we direct the reader to (Stadler, 2005) for a summary of many of the less commonly used definitions. We classified 1099 published studies indexed by Web of Science (WOS) that contain 'aridity', 'precipitation', and 'evap*' (where * indicates wildcard; all studies and their aridity definition can be found in Supplementary Table 1 for WOS index papers and their classifications) based on their definition of aridity: 'E_P/P', 'P/E_P', '1-P/E_P', 'other', or 'undefined.' We also categorized research areas using the WOS 'Categories' labels as 'Biology & Ecology' (Bio/Eco), 'Geology & Geography' (Geo), 'Atmospheric Sciences' (Atmo), 'Water Resources' (Wat Res), 'Engineering & Technology' (Eng/Tech), 'Managed Ecosystems' (Agro Sys), and 'Social Sciences' (Soc Sci).

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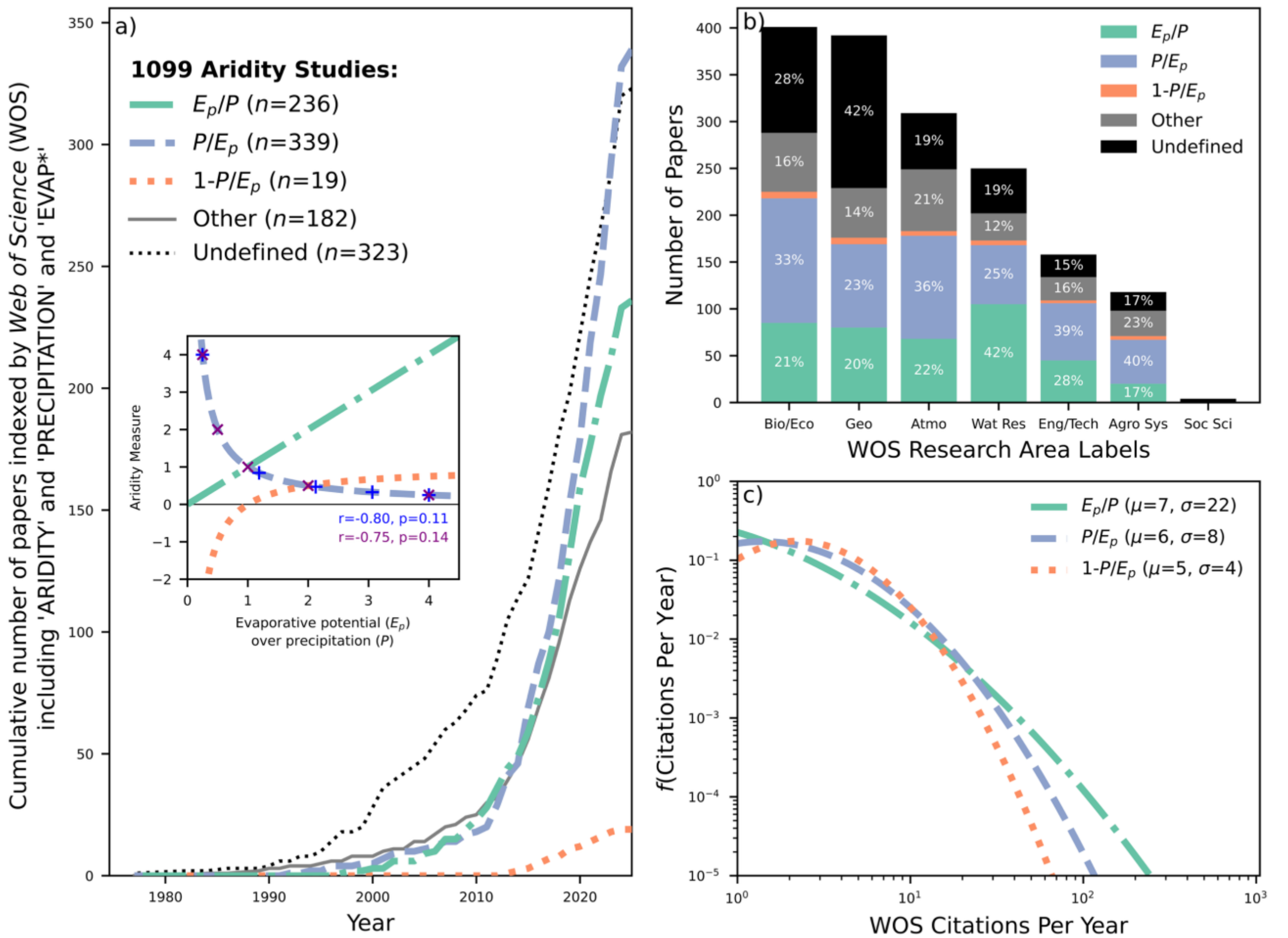

Figure 1: Assessment of aridity studies based on peer-reviewed articles indexed by Web of Science (WOS). The usage of different aridity metrics defined with some combination of precipitation, P, and evaporation potential, E_p, varies a) through time and b) by research area. The inset in a) shows the relationship between the different aridity metrics and E_P/P. The marks in the inset show five linearly (blue +'s) and logarithmically (purple ×'s) spaced data markers and their associated Pearson correlation (r) and significance (p) values. c) log-normal probability distributions of WOS citations per year for each study for three definitions of aridity fit based on the mean, μ, and standard deviation, σ.

Despite the long-standing recognition of the importance of aridity as a metric to climate, ecological, and water resource studies, no dominant standard has yet emerged with both P/E_P and E_P/P are commonly used, constituting over half (32% and 23% respectively) of reviewed studies. There are many studies that do not explicitly define aridity (29%) or use other definitions (16%), with these often based on Lang or De Martonne's metrics. While 1-P/E_P as used by (Pichon et al., 2025) has not been commonly used, its popularity in the last decade is increasing. Most studies we reviewed only presented one definition of

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aridity, and very few acknowledged multiple conflicting approaches, suggesting that authors may be unaware of definitions beyond what they are familiar with.

There is some preferential use of differing aridity definitions within certain fields, with biologic, atmospheric, engineering, and agronomic studies slightly preferring P/E_P. In contrast, water resources studies more often use E_P/P, while geologic studies frequently do not define the term and refer to aridity in more of a qualitative sense to describe the paleoclimatic conditions. Importantly, while P/E_P is more commonly used, publications defining aridity with E_P/P have a higher average number of citations per year and exhibit many more cases of being extremely highly cited studies (creating a heavy tail in the distribution of citations per year).

4. Forming A Community Consensus About Aridity

We welcome a dialogue about defining aridity and suggest here the formulation of aridity as E_P/P should be adopted as the standard meaning of aridity. Following the Budyko definition of E_P/P, more arid locations are those with higher values of E_P/P as it may be counter-intuitive if highly water-limited locations have a low aridity or aridity index value (as occurs when P/E_P). While the use of 1-P/E_P is monotonically consistent with E_P/P (see inset in Fig 1a) the introduction of another definition is unnecessary, as expressing E_P/P on a log scale, i.e. $\log_{10}(E_P/P)$, will differ by only ~3% from 1-P/E_P when $E_P/P = 8$. Based on our analysis the E_P/P definition also leads to more impactful geoscience based on the greater average number of citations per year.

Beyond intuitiveness, reported relationships between one metric of aridity may not necessarily translate to statistically significant relationships when converted to another metric of aridity, especially when sample sizes may be small. For instance, if a studied subject is perfectly correlated with E_P/P, the Pearson correlation and statistical significance levels between measurements of that subject and P/E_P will be lower, with differences also influenced by the distribution of data (see inset showing linearly and logarithmically distributed samples of P/E_P and their associated Pearson correlation and significance values with E_P/P). Also, defining an 'aridity index' with a different meaning than 'aridity' itself causes unnecessary linguistic complexity. Many studies used aridity and aridity index interchangeable, while others defined these as distinct, sometimes inverted, quantities.

Different definitions of aridity - or a lack of a definition altogether - will also lead to issues with predictions and interpretations in cases when models are trained on datasets where the underlying definition of aridity varies. The multitude of aridity definitions used across geoscience disciplines requires that researchers continue to be vigilant about how any referenced studies use aridity, the lack of a current consensus is not, in itself, a reason to not attempt to improve the clarity of how geoscientist quantify water limited environments in the future. Not only do humans benefit from a consistent definition, but large language models, e.g. (Miao et al., 2024), require training data without multiple, conflicting definitions. As AI-driven synthesis becomes

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more prevalent, such contradictory definitions may lead to severe errors in automated meta-analyses, as current models often fail to recognize that identical terminology can represent mathematically reciprocal quantities across different studies.

The geosciences community has a long history of discussing important terms and how they are calculated. The etymology of *geologia, geognosy, geogony, oryctognosy, geology,* and *geophysics* from the 1700's to present reveals significant shifts in the prevalence of chosen words used to describe Earths physical environment and demonstrate the ability of the community to adjust its vernacular (Howarth, 2020). Analogous arguments about other water related terms such as "evapotranspiration" and "non-perennial rivers" reveal the importance of consistent terminology for the clear exchange and advance of ideas (Ahmad et al., 2025; Asce Environmental And Water Resources Institute, Evapotrans, 2025; Busch et al., 2020; Miralles et al., 2020). This study continues these efforts to quantify and formalize the linguistic choices the geoscience community makes and welcomes ongoing dialogue about how aridity should be defined.

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Code and data availability

All published studies evaluated here are listed in Supplementary Table 1.

Supplement link

The link to the supplement will be included by Copernicus, if applicable.

Author contributions

All co-authors evaluated the published studies for their aridity definition. S.P.G preformed the data analysis and drafted the initial manuscript. All co-authors contributed to data analysis, reviewed and edited the manuscript.

Ethics Statement

No human subjects or sensitive data were involved in this research; thus, no ethical approval or informed consent was sought.

Competing interests

The authors declare there are no conflicts of interest for this manuscript.

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