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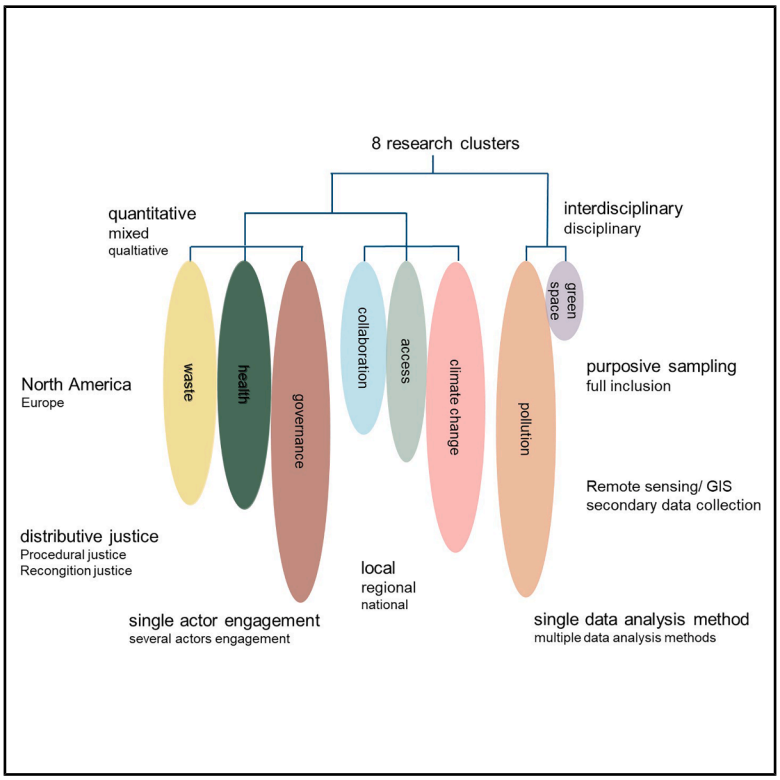
Measuring environmental (in)justices: Insights from a systematic literature review on methodological approaches

Graphical abstract



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In brief

Earth sciences; Environmental science; Social sciences

Highlights

- Environmental (in)justice research is expanding, yet methodologically fragmented
- Review of 421 studies shows dominance of quantitative, GIS, and secondary-data methods
- Participatory and qualitative, procedural, and recognition justice are underused
- Research skews toward North America; future work should center on marginalized voices

Loos et al., 2025, iScience *28*, 113889
December 19, 2025
https://doi.org/10.1016/j.isci.2025.113889

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Measuring environmental (in)justices: Insights from a systematic literature review on methodological approaches

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https://doi.org/10.1016/j.isci.2025.113889

SUMMARY

Environmental (in)justice research uses various conceptual frameworks and methodological approaches, leading to fragmentation across contexts and disciplines. Our systematic review provides a methodological overview of how environmental (in)justice has been studied in 421 English-language scientific articles. Most studies approach environmental (in)justice from a quantitative and interdisciplinary perspective, primarily using purposive sampling, secondary data, and GIS/remote sensing tools with an emphasis on distributive justice. Although there is a notable diversification over time in data collection and analysis, there is a strong geographic bias with short-term, locally focused, and limited actor involvement, though actor diversity is growing over time. We identified eight thematic clusters with distinct methodological patterns: health, pollution, governance, climate change, collaboration, access, and green space. The lack of broadly adopted methodological approaches for evaluating environmental (in)justices largely stems from the context-specific, multi-scalar nature of cases and the philosophical and normative diversity embedded in the EJ concept itself.

INTRODUCTION

Environmental justice (EJ) refers to removing the barriers that cause disparities and inequalities in a given reality.[1,2] Although it started as a civil rights movement in response to disproportionate pollution and health issues beared by marginalized people, such as black communities,[3,4] over the past decades, EJ has significantly expanded its focus to a global, multifaceted matter that addresses environmental governance, pollution, land use, health, biodiversity, sustainability transitions, and climate change.[5–8] EJ has been increasingly backed up by scientific data and evidence since its origin, often through community-led science,[9] thereby unraveling systemic disadvantages of marginalized people. These disadvantages are expressed either in disproportionate exposure to environmental hazards or health risks, or in reduced access and availability of benefits that are related to environmental assets. Currently, EJ represents both a broad range of grassroot social movements and an interdisciplinary field of academic research, engaging with diverse academic traditions and disciplines (e.g., geography, sociology, environmental sciences) and activist communities around the world.[10–12]

The conceptual expansion of EJ is well documented.[13,14] Existing reviews synthesize important advances and debates in relation to its conceptualization to frame and study inequality issues in climate vulnerability, green spaces, pollution, health, and governance, as well as to investigate how to support all members of society in proportion to what they initially have or what they need to tackle inequality and reach justice; a concept known as equity.[15,16] EJ is a multidimensional concept, encompassing various notions and frameworks. It is commonly understood to include distributive, procedural, recognitional, and contextual elements,[17–19] but has also been expanded to incorporate additional dimensions such as restorative or multispecies justice.[5,20–22]

In addition, EJ has become an important principle in many public programs and policies in different geographies and at different scales, from local to national and global. Thus, there is a growing need for reviews and toolkits that capture and address how EJ can be studied empirically in diverse geographies and contexts. Existing reviews focus on specific analytical tools (e.g., spatial analysis, participatory mapping) or domains (e.g., health, pollution),[23–25] but there is often a lack of clear understanding and guidance on how to empirically measure EJ. Tarrant and Cordell (1999)[26] already stated early that data collection and analysis techniques in environmental justice research may lead to conflicting results. However, to our knowledge, a comprehensive methodological overview of the field is yet to come.

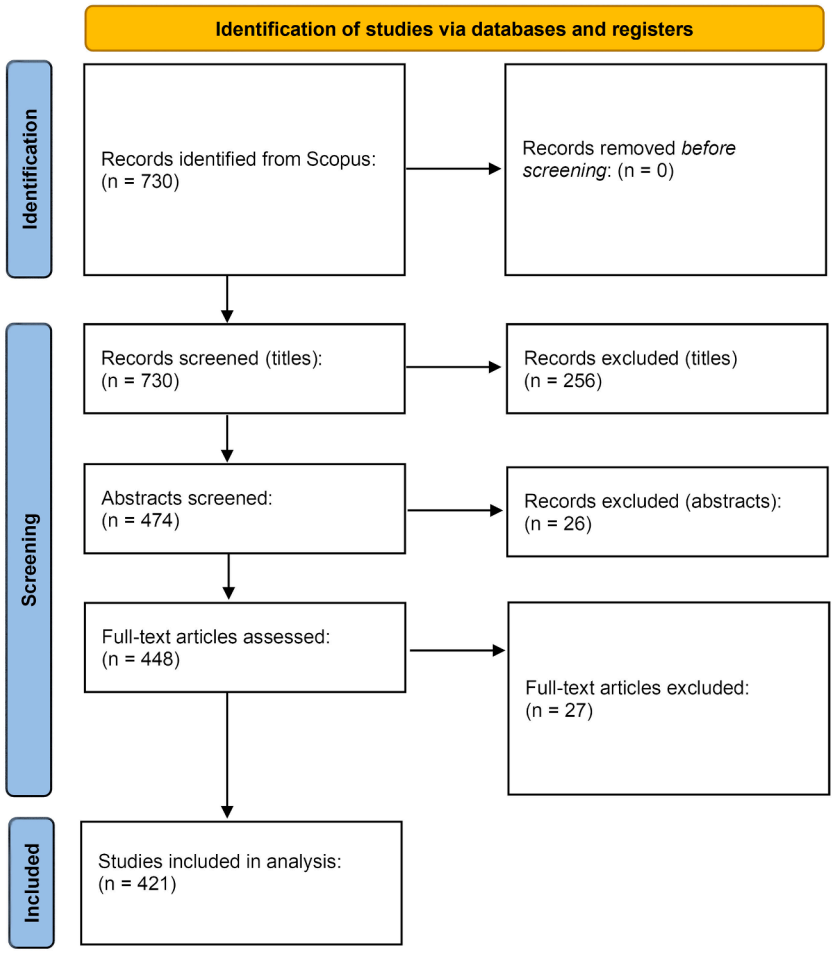

Figure 1. PRISMA 2020 flow diagram of the literature screening and selection process

Adapted from Page MJ et al. (2021), BMJ, 372:n71, under the CC BY 4.0 license (https://creativecommons.org/licenses/by/4.0/).

Empirical research on EJ is fragmented across disciplines such as geography, sociology, political ecology, and planning, with different methodological traditions, employing quantitative, qualitative, and mixed methods.[25,27] Each brings distinct theories and epistemological assumptions, shaping how injustices are identified, measured, and addressed. This fragmentation produces challenges such as how to identify suitable methods and measurements aligned with the justice dimensions studied, how methods can be both context-sensitive and comparable across scales and to what extent they make visible hidden or structural forms of harm, and how they reflect underlying values, norms, and power dynamics.[28,29] The way EJ issues are constructed is deeply connected to the methods used to reveal multiple dimensions of harm across time and space.[17,30] It also depends on the capacity to critically reflect on the assumptions, limitations, and potential of these methods to make conscious decisions when using them and working with data.

Likewise with the multitude of interpretations and conceptualizations of what can be considered ''just,'' there is no methodological unity in how to assess, measure, and communicate environmental (in)justice issues.[31] To our knowledge, there is also no systematic and comparative synthesis of empirical methods used to study and assess EJ across multiple dimensions and disciplines, nor how these methods have evolved alongside conceptual developments. Such an overview could provide a clearer mapping of methodological diversity, revealing dominant approaches as well as underutilized or emerging ones. This synthesis would help identify implicit biases, neglected aspects, for example, tendencies toward certain geographic regions or methodological approaches, thereby highlighting opportunities to broaden methodological pluralism. Moreover, by tracking how methods have developed, this work could guide the integration of quantitative, qualitative, and mixed approaches, fostering more holistic and context-sensitive research. In doing so, it would support interdisciplinary collaboration, enrich future research agendas by identifying knowledge gaps and innovation spaces, and enhance the policy relevance and communication of environmental (in)justice scholarship. Ultimately, this contributes to a more inclusive and nuanced understanding of environmental (in)justice, better equipped to address plurality in environmental (in)justice research.[32]

To this end, we conducted a systematic literature review of English academic publications (Figure 1) to characterize the main empirical approaches used to study environmental (in)justice across disciplines, geographies, justice dimensions, and scales. In particular we 1- identified which empirical methods have been used to study environmental justice in published case studies; 2- characterized which justice dimensions (e.g., contextual, distributive, procedural, recognitional, restorative, intergenerational, multispecies) they address; 3- explored how these methods evolved over time and across geographies and 4- which actors were considered and how they were related to which sampling, data collection and analysis methods. Overall, by providing an overview of existing methods, their uses and limitations, and how they relate to different justice claims, we aimed to support both academic research and policy applications.

RESULTS

Descriptive overview of methods used in environmental justice

A log-linear regression model revealed a significant increase in the number of published studies over time, with an estimated annual growth rate of approximately 13% per year ($\beta = 0.123$,

$p < 0.001$, $R^2 = 0.81$). Articles were published in 190 different journals, with the International Journal of Environmental Research and Public Health ($n = 24$), Environmental Justice ($n = 23$), Sustainability ($n = 13$), Urban Planning ($n = 12$) and Geography ($n = 10$) being the five most frequented ones. Most of the studies ($n = 248$) were quantitative investigations, followed by mixed approaches ($n = 101$) and qualitative studies ($n = 72$). The proportion of quantitative and mixed-methods articles decreased significantly over time ($p < 0.05$), while the share of qualitative studies remained stable. Our set of articles entails 210 interdisciplinary and 155 disciplinary studies, with multi- and transdisciplinary studies only having found their way into environmental justice research in the year 2005. Since then, however, the proportional share of transdisciplinary studies has significantly declined (estimate (-0.132, $p < 0.001$).

Sampling strategy

Almost 50% of all articles used purposive sampling ($n = 213$), followed by 161 studies employing full inclusion/census sampling. While purposive sampling was associated with qualitative and mixed inter- & transdisciplinary studies, full inclusion/census was typically related to quantitative, disciplinary studies. Stratified sampling ($n = 42$) and convenience sampling ($n = 40$) were less common, with random ($n = 16$), multi-stage ($n = 15$), and snowball sampling ($n = 9$) used even less frequently. Full inclusion/census was most commonly combined with purposive sampling ($n = 34$), and convenience sampling was also frequently paired with purposive sampling ($n = 11$). Overall, purposive sampling was the method most often combined with others ($n = 76$), followed by full inclusion/census ($n = 44$). After accounting for the increasing annual number of articles, there was no significant trend in the use of single versus multiple sampling strategies over time. However, snowball sampling showed the strongest significant decline over time (estimate = -0.233, $p = 0.034$), accompanied by notable decreases in basic random (estimate = -0.104, $p = 0.007$) and multi-stage sampling (estimate = -0.103, $p = 0.033$), while convenience sampling remained stable.

Data collection techniques

A total of 138 articles applied GIS and remote sensing for data collection, and 133 utilized secondary data sources, most frequently associated with a disciplinary, quantitative context. Surveys, censuses, or questionnaires were used in 119 studies, while 68 articles conducted interviews. These were mainly employed in qualitative studies. Participatory methods were applied to 41 transdisciplinary, qualitative, and mixed studies. There was a significant increase in the diversity of data collection methods over time ($\beta = 0.47$, SE = 0.04, t = 10.91, $p < 0.001$), with the model explaining 82% of the variance ($R^2 = 0.82$). Most articles (58%) relied on a single data collection method, predominantly secondary data ($n = 69$), GIS/remote sensing ($n = 60$), or surveys/census/questionnaires ($n = 57$). Over time, the relative use of single methods slightly decreased while the use of multiple data collection techniques increased. Among the methods analyzed, only surveys/census/questionnaires showed a significant decline (estimate = -0.056, $p = 0.003$). The most frequent combinations were GIS/remote sensing with secondary data ($n = 34$) and GIS/remote sensing with surveys/census/questionnaires ($n = 26$).

Data analysis methods

A total of 249 articles applied only one data analysis method at a time, out of which 76 disciplinary articles solely applied univariate statistics, 69 applied spatial analysis, 23 articles used qualitative coding, and 21 used descriptive statistics, out of which a large share were of an interdisciplinary nature. 146 articles used several data analysis methods, with most of them ($n = 62$) combining spatial analysis with univariate statistics, while 26 combined spatial analysis with descriptive statistics. Another relatively large fraction of paired analyses methods were combined descriptive and univariate statistics ($n = 21$), as well as descriptive and multivariate statistics ($n = 15$). We detected a small but statistically significant increasing trend in the number of different methods applied over time (Kendall's tau = 0.11, $p = 0.006$), indicating a gradual rise in the use of multiple data analysis methods across articles. Normalized by the increasing number of publications over time, generalized linear models revealed a significant decline in the relative use of machine learning and modeling methods ($p < 0.005$). Univariate statistical methods also showed a decreasing trend, though this was marginally non-significant ($p = 0.0076$). No other methods demonstrated significant changes in relative usage over time.

Linkage between sampling, data collection, and analysis methods

Pearson's chi-squared tests revealed highly significant associations between sampling strategies and data collection methods ($\chi^2 = 540.49$, df = 220, $p < 0.001$), sampling strategies and data analysis methods ($\chi^2 = 198.87$, df = 66, $p < 0.001$), as well as between data collection and data analysis methods ($\chi^2 = 386.26$, df = 120, $p < 0.001$), indicating strong interdependencies among these methodological choices. The results reveal clear interdependencies among sampling strategies, data collection methods, and analytical approaches. Purposive sampling was closely associated with qualitative techniques such as interviews and qualitative or mixed methods analysis. Full inclusion or census-based sampling often co-occurred with secondary data and GIS/remote sensing collection, linking further to spatial and statistical analyses. Basic random sampling was tied to structured instruments such as surveys and was frequently analyzed using machine learning or statistical techniques. Across data collection and analysis, qualitative methods such as interviews, focus groups, participatory techniques, and ethnographic approaches were strongly linked to qualitative and mixed methods analysis. In contrast, secondary data and GIS/remote sensing were associated more with statistical and spatial analyses (Figure 2).

Justice dimensions addressed across studies

Of the coded articles, 68% ($n = 287$) explicitly engaged with distributive justice, 35 articles with procedural justice, and 19 with recognition justice; 91 articles did not clearly specify a justice dimension. Other dimensions addressed included social ($n = 13$), epistemic ($n = 6$), and spatial justice ($n = 6$). A total of 32 articles engaged with more than one justice dimension.

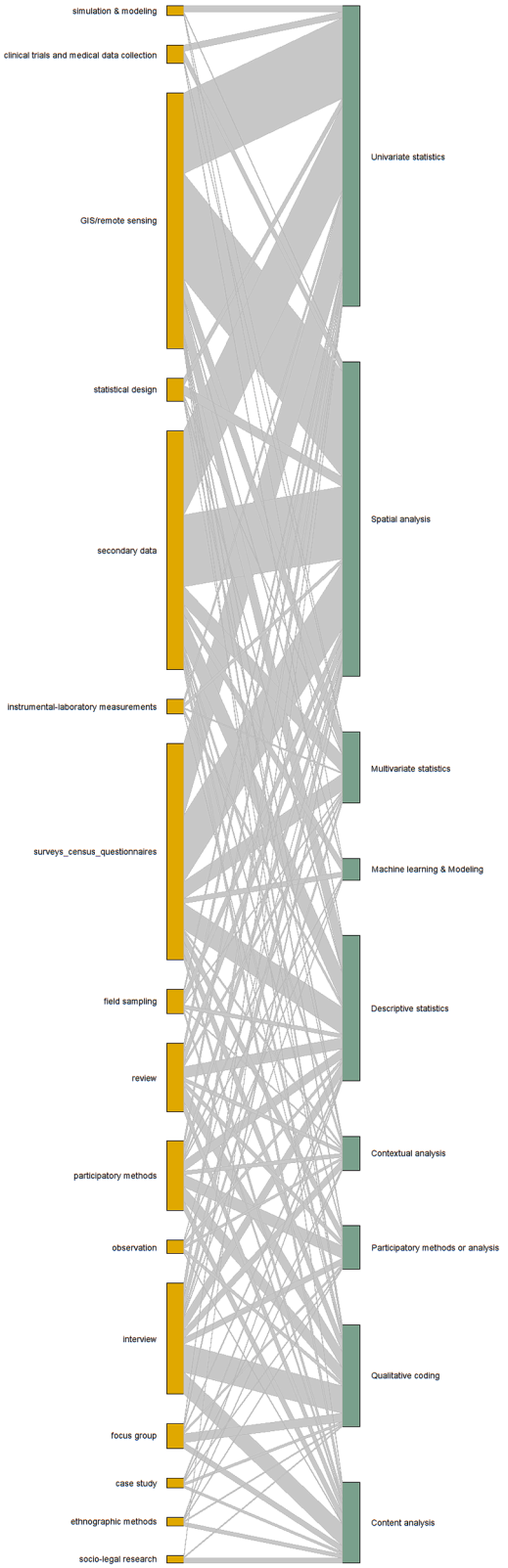

Figure 2. Sankey diagram showing 927 connections between data collection and analysis methods across 421 articles, reflecting multiple methods per article

Notably, all articles published before 2005 engaged only in a single justice dimension. In 2005, one-third of the studies incorporated more than one justice dimension. Since then, the number of multidimensional justice studies has increased significantly, with an average annual rise of 0.2 articles, comprising 1–12% of annual publications.

Justice dimensions are highly significantly associated with the methodological approaches employed in the studies, including sampling strategies ($\chi^2 = 254.26$, df = 96, $p < 0.001$), data collection methods ($\chi^2 = 703.38$, df = 176, $p < 0.001$), and data analysis techniques ($\chi^2 = 437.83$, df = 88, $p < 0.001$), indicating that the choice of methods varies systematically depending on the justice focus of the research. Articles that considered distributive justice mostly used purposive sampling ($n = 141$) or full inclusion/census ($n = 119$) as a sampling strategy. In articles looking into procedural and recognition justice, purposive sampling dominated ($n = 23$; $n = 15$, respectively). Data collection in distributive justice studies was mostly related to GIS/remote sensing ($n = 109$) or secondary data collection ($n = 100$), whereas studies with a procedural and recognition focus used interviews ($n = 17$; $n = 14$, respectively). Data analysis in distributive justice studies predominantly employed spatial analysis ($n = 127$) and univariate statistics ($n = 122$), both showing strong positive associations (std. residuals >5). Descriptive statistics ($n = 58$) and multivariate statistics ($n = 33$) were also commonly used in these studies. In contrast, procedural and recognition justice studies primarily utilized qualitative coding (procedural $n = 8$, recognition $n = 6$) and content analysis (procedural $n = 6$, recognition $n = 6$), with significant positive associations indicated by residuals above 5 and 6, respectively. Recognition studies further featured contextual analysis and machine learning/modeling methods, suggesting a broader methodological diversity within this category. Participatory methods or analyses were used in 25 articles, out of which 14 engaged with distributive justice, 6 on procedural, 2 on epistemic, and 1 on climate, recognition, and/or social justice.

The conceptualization of EJ has evolved from focus on disparities to a deeper engagement toward assessing equity concerns and broadly the root causes of (in)justice. There was a significant increase over time in the use of equality-related terminology ($p = 0.03$), while other terminologies, such as equity, fairness, disparity, and unevenness, showed no significant change. The use of justice-related terms showed a positive but marginally non-significant upward trend ($p = 0.096$).

Geographic and spatiotemporal patterns across studies

The majority of the $n = 421$ reviewed articles explored environmental (in)justice cases in North America ($n = 245$, Figure 3A), embracing the USA ($n = 227$) and Canada ($n = 18$). Studies from Europe ($n = 65$) entailed cases from Spain ($n = 10$), Germany ($n = 9$), France ($n = 8$), and the UK ($n = 8$). Most studies from Asia ($n = 53$) came from China ($n = 36$). Remarkably few studies represent Oceania ($n = 3$), and Africa ($n = 14$), and 17 studies employed cases on various continents. Although relatively underrepresented, literature from South America and Africa often focuses on issues around governance, recognition, participation, livelihood, and conservation. African studies had the highest share of interdisciplinary research approaches (71%), whereas studies

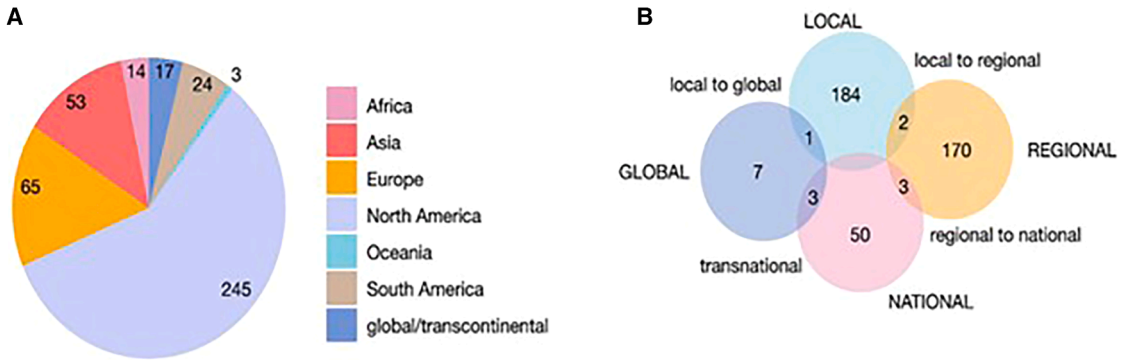

Figure 3. Detrended Correspondence Analysis Ordination showing indicator word clusters

(A) Share of articles per continent, based on the 421 investigated articles.

(B) Counts of published articles sorted by their spatial focus, ranging from local to global investigations.

from South America were mostly disciplinary (61%). In the case of South America, EJ research include tourism in protected area management,[33] extractivism,[34] food insecurity in indigenous communities[35] and human rights violations.[36] Methods range from geospatial tools and surveys to ethnographic and participatory methods. In the case of Africa, the focus is set on exclusion from environmental decision-making of poor and marginalized people, who remain excluded from environmental decision-making,[37] PAs impact on environmental justice and human well-being[38] and women's vulnerability to climate change.[39] Regarding methods, Africa-based studies present in our database focus more on structured data collection and less on immersive qualitative fieldwork.

Most studies investigated environmental justice issues on a local (n = 184), regional (n = 170), or national (n = 50) scale (Figure 3B). Over time, the proportion of studies conducted at local and regional scales increased slightly, while the relative share of global-scale studies declined significantly ($p < 0.001$). Regarding temporal coverage, the majority of studies (n = 177) focused on periods of one year or less. A total of 91 studies examined durations of 1–5 years, 95 studies focused on 5–25 years, and 34 studies addressed periods exceeding 25 years. An ordinal logistic regression showed that over time, studies tended to have shorter durations (estimate = −0.001, $p < 0.001$). The temporal scale of analysis was significantly associated with the spatial scale (χ^2 = 37.90, df = 16, p = 0.0016). Short-term studies (≤1 year) primarily focused on local scales (∼50%), whereas long-term studies (>25 years) were more evenly distributed across local (41%) and broader regional to national scales (44%).

Actor engagement and epistemic prioritization

Most studies (n = 282) engaged with a single actor, while 139 studies engaged with several actors. Most frequently, community actors (n = 315) and vulnerable communities (n = 178) were subject to the study, with markedly less focus on institutional actors (n = 37) and governance actors (n = 28). Although there was a trend toward more actor groups being involved per study over the years, this trend was non-significant. While community actors and vulnerable people have been involved throughout the entire investigated period (1997–2025), other actors were only considered later, starting with institutional actors in 2002, experts and governance actors in 2006, and policy shapers and actors from the private sector in 2010. While the number of actors considered in studies increased overall, the proportional share of each individual actor group declined except for external actors, and this was significant for governance actors (estimate −0.016, $p < 0.005$), institutional actors (estimate −0.008, $p < 0.01$), and policy shapers (estimate −0.011, $p < 0.01$). Studies including community actors mostly engaged at the local (n = 147) and at the regional (n = 122) scale, which is a pattern that was also visible for vulnerable community groups (with n = 76 studies at the local and n = 71 at the regional scale). In contrast, institutional actors were associated with studies covering the local to global scale. Actor inclusion showed to be scale-sensitive in the scientific literature (χ^2 = 60.99, df = 32, $p < 0.005$). The actors investigated in the studies were as well highly significantly associated to the choices of sampling (χ^2 = 381.86, df = 104, $p < 0.005$), data collection (χ^2 = 431.76, df = 144, $p < 0.005$) and analysis methods (χ^2 = 556.86, df = 72, $p < 0.005$), suggesting epistemic prioritization in these studies: While experts were typically involved through purposive sampling, community actors most frequently were investigated by stratified sampling, and vulnerable actors through full inclusion/census and governance actors through snowball sampling. In terms of data collection, information from external influencers was associated with qualitative coding, whereas experts were investigated mostly through case studies and interviews, vulnerable community members mostly through surveys, census, and questionnaires, and rarely through participatory approaches. Instead, participatory data collection methods mostly occurred in relation to governance actors. Data analysis in studies that included institutional actors was primarily through content analysis, while studies considering experts, governance actors, and/or policy shapers employed contextual analysis. Actors from the private sector were included in studies using qualitative coding. Actor groups differed significantly across the considered justice dimensions (χ^2 = 162.43, df = 64, $p < 0.001$). Articles including community and vulnerable actors mainly addressed distributive justice,

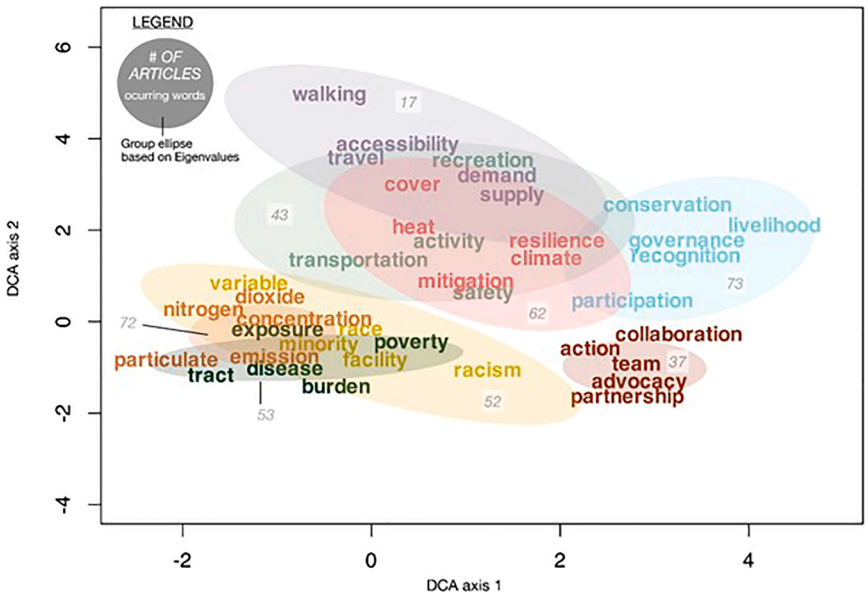

Figure 4. Eight research clusters derived from 409 empirical articles on environmental justice (12 excluded due to overlength)

Colored nouns indicate cluster membership. "Accessibility" is prominent both in the light green and violet clusters. Proximity between clusters reflects thematic similarity.

while those featuring governance and institutional actors engaged more evenly with procedural and recognition dimensions.

Clusters/semantic map of environmental justice clusters and claims

Our cluster analysis (Figure S1) and the multivariate analysis of the 409 articles used in the word analysis suggested eight different research clusters present in the environmental justice literature that we reviewed (Figure 4). Given their most abundant terms, we named these research clusters *governance*, *pollution*, *climate change*, *health*, *waste*, *access*, *collaboration* and *green space* (Table 1). The cluster comprising the largest number of articles in this review is the *governance* cluster (n = 73) which shows a distinct word usage profile compared to the closely overlapping clusters on *pollution* (n = 72), *waste* (n = 52), and *health* (n = 53); the overlapping clusters of *climate change* (n = 62), *access* (n = 43), and *green space* (n = 52); and the separate cluster on *collaboration* (n = 73) (see Figure 4). These clusters are distributed along the two DCA axes in ways that reflect broader thematic distinctions. The clusters on *pollution*, *waste,* and *health* center on environmental harms and the disproportionate exposure of socially disadvantaged people, often defined by race, ethnicity, or income. These articles primarily aim to identify, describe, and measure environmental injustices, emphasizing diagnosis and problem characterization. In contrast, the *governance* and *collaboration* clusters are more oriented toward institutional responses, participatory strategies, and solutions for addressing injustices. Based on this contrast, the first DCA axis can be interpreted as capturing a gradient from diagnosing harms to developing strategies for improvement. A second thematic distinction emerges between clusters focusing on environmental harms (*pollution*, *waste*) and those addressing the distribution of environmental goods and opportunities (*access, green space*). While the former highlights disproportionate burdens and vulnerabilities, the latter emphasize just access to environmental benefits and adaptation strategies. Accordingly, the second DCA axis may be interpreted as representing a continuum from exposure to environmental harms to access to environmental benefits.

Before 2000, there were mainly studies belonging to the clusters of *waste* and *pollution* (Figure 5A). In the year 2000, access formed a new cluster in EJ research, with collaboration following in 2002, health in 2004 and governance in 2005. The *climate change* cluster occurred for the first time in 2012, and *green space* literature emerged in 2018. Studies in the cluster *waste* peaked in 2013 with 6 publications, and *pollution* studies peaked in 2024 with 12 studies. 2024 was also the year with the highest number of publications for all other clusters, except for *access,* which reached the highest number of 7 publications in 2023. Over time, the *waste* cluster showed a significant declining trend (estimate = −0.119, $p < 0.001$), indicating reduced relative focus despite increasing total publications. The *pollution*, *access*, *governance*, and *collaboration* clusters also exhibited decreasing but statistically non-significant trends. Conversely, *climate change* and *green space* clusters showed positive yet non-significant increases, suggesting emerging interest. The *health* cluster remained relatively stable over time. Across all continents, research in Africa is mainly related to the *governance* cluster (n = 9), in Asia to green space (n = 16), in Europe to *pollution* (n = 28), and in North America to *health* (n = 50). The *governance* cluster also dominated in studies in Oceania, South America, and global or multiple geographic foci. There was no research on *health* or *waste* in Africa, Oceania, or South America, although these were the dominating clusters in North America. Another stark contrast is in the number of studies in the *green space* cluster, which dominated in Asia but was only present with 1 publication in North America, and not present in any other region.

A Pearson's Chi-Square test revealed significant associations between clusters and methodological choices, with sampling methods (χ^2 = 126.87, df = 77, p = 0.0003), data collection methods (χ^2 = 375.00, df = 147, $p < 2.2e\text{-}16$), and analysis methods (χ^2 = 257.52, df = 70, $p < 2.2e\text{-}16$) all showing non-random distributions across clusters. The dominating data collection and analysis methods per group are displayed in Table 1. In the *governance* and *collaboration* clusters, studies predominantly used qualitative and participatory data collection methods such as interviews and community engagement, emphasizing procedural justice and advocacy. Studies from the governance clusters were also less likely to use multiple

Table 1. Group characteristics ordered by size, showing article counts and the top 75% most frequent data collection and analysis methods per group by cumulative occurrence

Group	# Articles	Five most abundant words	Description	Data collection method	Data analysis methods
3-Governance	73	recognition, governance, livelihood, participation, conservation	Most studies conducted in North America (*n* = 16). Cluster with the most global studies (*n* = 5). Most studies use a qualitative or mixed approach and interviews focusing on procedural and recognitive (in)justice. Topics evolve around conservation, capacity building, ecosystem services, and land rights.	Interviews (26%); Participatory methods (12%); review (11%); GIS/remote sensing (10%); surveys, census, and questionnaires (10%)	Qualitative coding (21%); Content analysis (39%); Descriptive statistics (55%); Spatial analysis (70%)
7-Pollution	72	dioxide, emission, nitrogen, concentration, particulate	Most studies conducted in Europe (*n* = 28). The majority of articles in this cluster focus on urban areas and connect air pollution from traffic to the socio-economic status of residents. Other articles evaluate health effects of proximity to industrial sites. Most studies use a quantitative approach and spatial analysis tools focusing on distributional (in)justice.	Secondary data (33%); GIS/remote sensing (23%); surveys, census, and questionnaires (18%)	Univariate analysis (39%); Spatial analysis (74%)
6-Climate change	62	heat, mitigation, climate, cover, resilience	Most studies were conducted in North America (*n* = 38). Articles in this cluster cover extreme weather events in urban and rural areas, such as heat, floods, and droughts, seismic risks. Articles develop decision support systems to reduce harm through environmental hazards via risk indices to improve community resilience.	GIS/remote sensing (36%); Secondary data (25%)	Spatial analysis (42%)
2-Health	53	burden, disease, exposure, poverty, tract	Most studies were conducted in North America (*n* = 50), and three studies were from Asia. Most studies use a quantitative approach using databases and census tract information, focusing on distributional (in)justice. The analyses evolve around health risks, primarily cancer, asthma, and heart diseases, and through air pollution and soil contamination related to socio-economic status.	Secondary data (30%); surveys, census, and questionnaires (20%); GIS/remote sensing (16%); clinical trials and medical data collection (7%)	Univariate statistics (55%)
1-Waste	52	minority, race, variable, facility, racism	Most studies were conducted in North America (*n* = 45). Articles in this cluster analyze spatial inequalities from hazardous waste dump facilities, brownfields, and air toxics. Most studies use a quantitative approach and spatial analysis tools focusing on distributional (in)justice.	Surveys, census, and questionnaires (29%); GIS/remote sensing (26%)	Univariate statistics (46%)

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Table 1. ***Continued***

Group	# Articles	Five most abundant words	Description	Data collection method	Data analysis methods
5-Access	43	accessibility, recreation, safety, activity, transportation	Most studies were conducted in North America (n = 26). Studies focus on safety in urban environments, access to green spaces, and the effects of highway constructions. Most studies use a quantitative or mixed approach and spatial analysis tools focusing on distributional (in)justice.	GIS/remote sensing (30%); surveys, census, and questionnaires (28%)	Spatial analysis (37%); Univariate statistics (64%)
4-Collaboration	37	partnership, advocacy, action, collaboration, team	Most studies were conducted in North America (n = 36). Most studies use a qualitative approach and interviews focusing on distributive and procedural (in)justice. Articles in this cluster work with research approaches to enhance capacity building using citizen science participation, participatory research, and community-engaged research methods.	Interviews (17%); participatory methods (14%); surveys, census, and questionnaires (14%); review (10%); secondary data (8%); focus groups (7%)	Content analysis (24%); Spatial analysis 44%); Descriptive statistics (62%)
8-Green space	17	walking, accessibility, travel, supply, demand	Most studies were conducted in Asia (n = 16), and one study was from the US. Most articles focus on accessibility to green spaces in urban areas. They use a quantitative approach and spatial analysis tools focusing on distributional (in)justice.	GIS/remote sensing (40%); Secondary data (20%)	Spatial analysis (39%); Univariate statistics (59%); Multivariate statistics (75%)

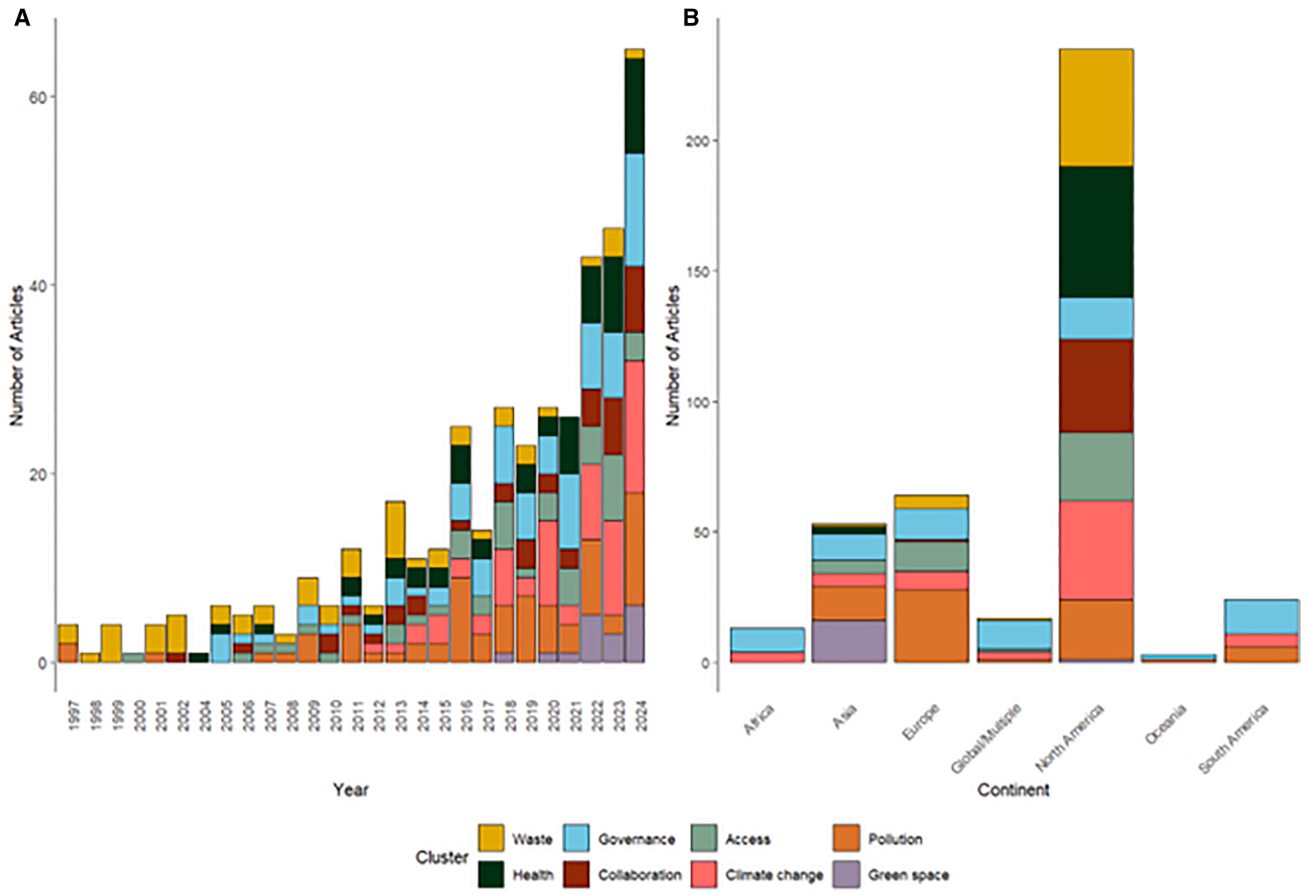

Figure 5. Stacked barplot of investigated actors per research cluster

(A) Counts of articles per cluster over time (total n = 409).

(B) Shares of articles per group and continent.

analysis methods ($\beta = -1.29$, $p = 0.002$), suggesting a more focused analytical approach. In contrast, the *pollution*, *health*, *waste*, *access*, and *green space* clusters rely mainly on quantitative methods, with extensive use of GIS and spatial analysis to examine distributive justice and spatial inequalities. The *climate change* cluster is characterized by an abundant utilization of remote sensing and secondary data, addressing environmental hazards and community resilience through spatial tools. Notably, *green space* studies utilize multivariate statistical techniques, highlighting the complexity of factors influencing accessibility. These methodological patterns underscore the varied analytical strategies aligned with each cluster's research objectives.

Our investigation into links between clusters and actor types showed that community actors and vulnerable communities appeared in 18–75% of studies overall. Governance and collaboration clusters involved the widest variety of actors, including institutional, governance, researchers, and experts, while green space studies engaged with at most two actor types (Figure 6).A Pearson's Chi-squared test revealed a significant association between actor group representation and clusters ($\chi^2 = 151.6$, df = 56, $p < 0.0001$). Follow-up logistic regressions with a logit link function showed that articles in the *governance* cluster (Group 3) were significantly more likely to engage institutional actors ($\beta = 1.44$, $p = 0.014$) and governance actors ($\beta = 1.69$, $p = 0.031$), while being less likely to include vulnerable communities ($\beta = -0.85$, $p = 0.023$), highlighting a tendency to foreground formal institutions over marginalized groups. Community actors and vulnerable community groups were investigated in all studies, composing, respectively, between 18 and 75% of the actors represented. Additionally, governance studies also included institutional and governance actors, and collaboration studies engaged also researchers and experts. These two study fields were the ones that engaged the most with different actors, whereas studies on green spaces maximally engaged with two types of actors (Figure 6).

Methodological limitations

About half of the studies (n = 190) noted methodological limitations. The most abundantly reported shortcoming was related to sampling, referring to a general lack of data (n = 29), unrepresentative samples (n = 12), specific contextual problems concerning the sample (n = 10), or a systematic sampling bias or artifacts that were known but could not be overcome (n = 40).

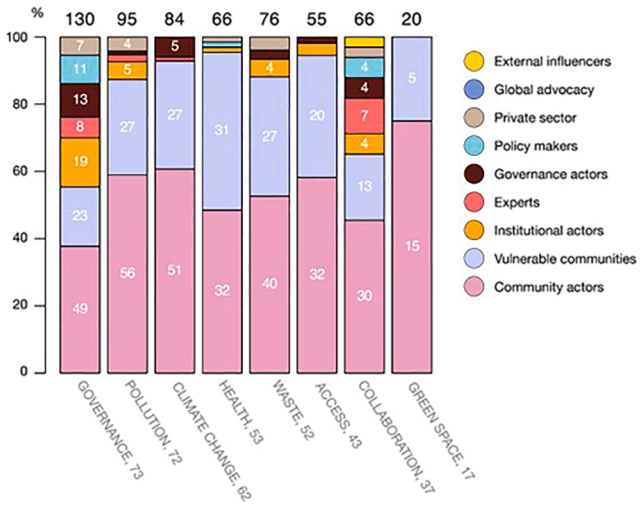

Figure 6. Share of actor types per identified group (*n* = 409)
Numbers of articles per group are indicated on the x axis. Numbers within the bar indicate the absolute number of articles per group for each actor type. Counts below 4 are not shown. Multiple actors indicate more than one actor type and consist of two or more of the other six actor types.

Specifically noted sample bias elements are a lack of samples representing certain groups (*n* = 14), spatial issues (*n* = 54), or temporal issues concerning sampling (*n* = 13), questions of data ethics (*n* = 4), or a lack in explanatory factors that were not a proper part of the sample design (*n* = 39). Other factors mentioned related to the validity (*n* = 17) or transferability of the results (*n* = 9), or general problems in the design of the respective study, such as data being sampled for other purposes (*n* = 8) or of low explanatory power (*n* = 3). Few studies mentioned relying on proxies that do not represent the causal relation (*n* = 14), or noted that the utilized methodological approaches may be improper or limited to generate valid results (*n* = 22). Taken together, the majority of the methodological limitations were rather generic, as most issues and biases that were noted are rather universal and hard to overcome or compensate for. Most notably, hardly any study offered a critical research perspective that highlights the limitations of the perspective of the researchers. Most studies mentioned one (*n* = 112) or two limitations (*n* = 61), and a few studies (*n* = 17) mentioned more limitations.

DISCUSSION

To our knowledge, our investigation into methods being used in the ''theoretically weak and dispersed'' EJ literature[40] is the first systematic scrutinization of how EJ scientific knowledge is created, and with what tools and techniques it is revealed. Despite early criticism of the overemphasis on local case studies,[41] we still found few investigations that created more generalizable studies, thereby deeply engaging with more global crucial processes and relations. Although the share of interdisciplinary studies was high, we were surprised to find that quantitative studies with disciplinary approaches dominated over time, and that only a relatively small proportion of articles employed participatory methods. This is particularly striking since EJ is a grass-root movement that originated to uphold vulnerable and marginalized communities, and since EJ's scientific literature has long been calling for participatory approaches, taking into consideration situated knowledge and intersectionality.[42] Instead, as Temper et al. (2016)[43] highlight, local communities are subjected to research, not (co-)producers of knowledge. Although evidence on the exposures to environmental threats and limited access to environmental goods for parts of the population is critical information to avert environmental injustices, the expected solution-orientation of the EJ literature lacked behind in much of the currently available scientific literature, although exceptions do exist (e.g.,[44,45]). At the same time, the observation that methods have diversified and transdisciplinary approaches have increasingly been reflected in our results shows that calls for alternative approaches to knowledge generation and the recognition of plural values and worldviews slowly find their way into science. Thus, based on our review of empirical case studies, we cannot confirm a methodological evolution in EJ research, although tendencies toward diversification are visible.

Both the methods employed in environmental justice research, as well as its conceptualization, have gone mostly hand in hand over time.[27] Early EJ studies, particularly those from the 1980s, primarily employed statistical analysis to quantify the disproportionate establishment of hazardous waste facilities and polluting industries near vulnerable communities in the United States. These studies were instrumental in describing unequal environmental pollution and hazards borne by already marginalized groups, thereby politicizing the issue and contributing to the establishment of environmental inequality as a field of academic inquiry. These methods aligned with the emergence and evolution of the EJ social movement and its claims regarding the disproportionate environmental burdens affecting vulnerable or marginalized communities. Although effective in identifying patterns of injustice, these approaches often lacked deeper community engagement in research processes.[43] In the 1990s, as the EJ movement matured, research began to expand to include health studies and risk assessments that quantified the negative health impacts of environmental pollution on affected communities. During this time, the concept of equity began to be more widely used, shifting attention toward the distribution of environmental burdens to benefits.[46] This divide in the literature from problem description to solution and from environmental threat to benefits is also reflected in our DCA ordination. Methodologically, this period also saw the first integration of Geographic Information Systems (GIS) and some attempts to incorporate community perspectives, although participatory and qualitative approaches remained marginal.

In more recent years (2000s to present), more sophisticated techniques, such as detailed spatial mapping and modeling to study access to green spaces, health, or climate change, have been used to identify and assess injustices related to green space access or urban heat exposure, and statistical tools have been applied to visualize cumulative impacts, especially in urban environments.[47] At the same time, the focus of the research moved to understanding the causes of such environmentally borne disparities, making it necessary to engage with

actors' perspectives and knowledge in EJ research. It has led to an increasing use of participatory and co-produced approaches in environmental research generally.[48] Though not exempt from caveats, the processes of co-generating knowledge have been identified as central to bringing a plurality of knowledge,[49] as researchers and actors have started to collaborate in the generation of research results. The engagement of actors has been manifested in the growing use of surveys, interviews, focus groups, and participatory mapping, but still our results show that GIS-based approaches based on census data and disciplinary approaches are prevalent. Both the methodological and conceptual framing of EJ have become increasingly diverse, as reflected in our review. The concept of justice has gained prominence as more inclusive than earlier framings based solely on inequality or inequity.

As the participation of a diversity of actors in research spreads, EJ demands methods that combine diverse knowledge systems from academia, grassroot movements, decision makers, and communities[50] to co-create more grounded and actionable responses to the EJ challenges to be addressed. Moreover, the need for transdisciplinary and collaborative research expanded, particularly in studies focusing on governance. These studies have adopted qualitative methods such as content and contextual analyses, and mixed methods including participatory mapping. These approaches increasingly aim to decipher and address the root causes of inequalities, such as racism, colonial legacies, and power imbalances, and contribute to a broader and more inclusive practice of EJ research.[51]

Our results show that distributional inequalities have been studied the most. Yet, as actors are invited to participate in research, the distributional character of EJ went forward to issues of how to combine diverse knowledge systems (credibility, salience and legitimacy,[52] epistemic justice[53]), how the processes of co-generating knowledge and results should be (procedural justice[54]), and who should be engaged in the research and decisions taken (recognition[55]), especially in global studies and governance challenges. Although EJ research has gradually moved toward broader dimensions and more collaborative, participatory, and co-generated methods, our results indicate that actors in these studies often continue to be treated as research subjects rather than active participants. A striking finding is the limited use of participatory methods despite the frequent research focus on community members and vulnerable groups. This suggests that while such communities are central to EJ discourse, there remains a persistent gap in epistemic inclusion and participatory practice within the field.

Despite the promotion of knowledge co-generation and transdisciplinary approaches, if they are treated merely as technical solutions without intentionally including diverse ways of knowing, addressing power imbalances, or ensuring legitimacy from the start, then they can unintentionally reinforce existing inequalities and conflicts instead of resolving them. Thus, most recently, EJ research has started to embrace post-colonial and decolonial perspectives, which critically examine how colonial legacies shape environmental injustices and perpetuate power imbalances within participatory and knowledge co-generation approaches themselves, turning the focus of EJ on issues of contextual,[56] restorative[57,58] and intergenerational[59] justice. Structural approaches to power presume that an actor's space to exercise power is constrained by political, cultural, and economic structures, such as entrenched social classes, gender roles, economic relations, or colonial legacies.[60] In some cases, the structural power at work does not consider relevant ways of knowing belonging to vulnerable or marginalized actors and does not give them a voice. Decolonial approaches aim to dismantle power structures within research and facilitate dialogue between diverse worldviews.[61] This ensures that methods are not only rigorous but also ethically grounded, fostering epistemic justice and directly contributing to more transformative EJ research.[62] The transformative potential of EJ methods is still understudied, and our results also did not capture empirical studies that adopt more transdisciplinary and decolonial/postcolonial perspectives or more recent approaches to emerging EJ areas of attention, such as multispecies justice.[22] This suggests that the empirical, data-generative works published using these lenses remain limited, with most contributions focusing on theoretical advances, essays, and topical debates.[63,64]

In line with previous findings, our review confirms that empirical environmental justice research remains geographically uneven,[65] over-representing studies from the Global North, although Temper et al. (2016)[43] state that political ecology scholars have mainly studied environmental injustices in the Global South. Over half of the studies reviewed were conducted in North America, particularly in the United States. This dominance reflects not only the historical and academic origins of the field but also structural factors such as the availability of high resolution datasets (e.g., EJSCREEN, census data,[66,67] the prevalence of English-language scholarship,[68,69] and the salience of structural injustices in urban and racialized environments[70,71]). While this body of work has significantly shaped EJ research and supported activist movements, recent scholarship increasingly critiques the Western-centered epistemologies that dominate the field.[43,72,73] From an epistemic justice perspective, future research must engage with ways of knowing and being that have been historically marginalized or silenced.[29,70,74] This requires not only broader geographical inclusion but also methodological approaches grounded in situated, plural, and decolonial frameworks that reflect diverse conceptualizations of justice and the environment.[70]

The increasing focus on local and regional scales in EJ research reflects a growing emphasis on grounded, context-specific inquiry. Environmental injustices often manifest most visibly at these levels, where local knowledge, community engagement, and place-based dynamics shape both problems and solutions. In contrast, the declining attention to global-scale analyses suggests a move away from abstract framings toward more situated understandings of justice. While this shift enhances relevance and responsiveness, it raises concerns about under-examining global drivers of injustice, such as transnational governance or global trade dynamics. Although EJ struggles often emerge from local exposures to environmental harms, they are embedded in translocal systems including global markets, climate regimes, and extractive infrastructures that transcend place.[75–77] To adequately engage these dynamics,

methods must make an effort to move beyond the local scale and capture multi-scalar and relational dimensions of injustice.[7,78,79] Likewise, the proximity-based and distribution-based approaches used in many of those spatial investigations on EJ come along with a too broad resolution, leading to concerns about their suitability even for local analysis.[80] Recent attention to translocal case studies,[81] multi-sited ethnography,[82] and community-based participatory research,[83] allow studies to trace how interconnected injustices manifest across sites with different social-ecological histories and governance regimes.[84–86] These approaches reveal structural patterns and the transnational alliances that support resistance to injustices. Methodologically, they require balancing local contexts with global interconnections, providing tools to analyze how actors navigate, resist, and reimagine systems of environmental inequality across space and scale.[85] Advancing such approaches calls for relational, flexible, and transformative methods that respond to lived experience while remaining attentive to broader systemic structures.

The spatial trend found in our review is accompanied by a modest but notable increase in mid- and long-term studies, suggesting the growing recognition of the value of sustained temporal engagement. Although short-term studies ($\leq$1 year) continue to dominate (likely due to funding cycles, project constraints, and data availability) longer-duration research (>25 years) offers rare but important insights into structural change, policy impact, and the cumulative nature of environmental burdens. These extended time frames, though still underrepresented, reflect an emerging commitment to understanding the durability and resilience of EJ interventions over time.

Contemporary EJ research increasingly requires deep multi-actor engagement and methodological innovation to account for the evolving complexity of injustices, shaped by intertwined ecological, social, and political forces, whether global capital,[77] climate change,[87,88] or spatialized power.[89] Both academics and social movements call for approaches that foreground power, colonial histories, and non-human agencies.[22,87,90] In this sense, our review emphasizes the growing importance of engaging with methodological pluralism in EJ research, integrating qualitative, quantitative, participatory, and community-based approaches to better reflect diverse contexts and forms of knowledge.[32,91,92] This also requires contributions across the natural and social sciences, the humanities, and social movements to uncover the social and political conditions enabling and constraining actions to address environmental injustices. In particular, methods that center situated knowledge, address epistemic injustices, and operate across spatial and institutional scales are critical for confronting the uneven geographies of environmental (in)justice. In light of recent political changes affecting funding priorities and the orientation of higher education, addressing environmental injustices has become increasingly challenging, highlighting the urgent need for scientific research that is both rigorous and responsive to social and ecological realities.

Conclusion

Environmental justice research has many different facets, which we synthesized in the context of a systematic review of empirical academic literature. Although the number of articles and the diversity of methods increased over time, we noted a continued disintegration of different thematic foci as well as methodological divides. Despite the notion of environmental justice as a community-led societal movement and research field and manifold acknowledgment of the need to consider value plurality and people's lived experiences, our review revealed little development of actor engagement, be it through participatory research approaches or through transdisciplinary research modes. Most attempts within the sciences continue to stick to quantitative, descriptive studies, highlighting the risks and problems rather than focusing on collaboration and solutions, hence, ways to overcome environmental injustices. Thus, we were unable to note the evolution of the research field as such. Instead, new themes emerged as research foci, such as climate justice and green space accessibility, further nuancing the different facets of environmental justice from problem description to future adaptation thinking and from exposure to threats toward access to benefits. Notwithstanding, such approaches exist in the environmental justice literature, and are conceptualized and promoted in environmental justice literature that was not captured in our review. In sum, to advance also empirical research on environmental (in)justices demands a pluralistic, cross-disciplinary, and power-conscious methodological approach that centers upon situated knowledge and challenges the structural conditions sustaining environmental injustices.

Limitations of the study

This study has several limitations. First, the search was limited to publications in English, which may have excluded relevant studies published in other languages. Second, despite the careful construction of the search string, it may not have captured all existing or ongoing works, particularly as many studies in this field are still in progress or not yet published. Third, the analysis relied on accessible scientific publications, meaning that insights from gray literature or unpublished materials could not be included. Additionally, the extraction of metadata and the deductive coding approach may have overlooked nuances not explicitly described in the reviewed articles—for example, participatory assessments that were conducted but were not reported in detail. We thus acknowledge that more literature exists, yet we restricted the scope of our review to empirical articles only. Finally, coding and evaluation were performed without in-depth knowledge of each individual case, which may have limited contextual interpretation.

RESOURCE AVAILABILITY

Lead contact

For further information and requests for data or materials, please contact Jacqueline Loos, jacqueline.loos@univie.ac.at.

Materials availability

This study did not generate new material.

Data and code availability

Any additional information required to reanalyze the data reported in this article is available from the lead contact upon request.

ACKNOWLEDGMENTS

We express our gratitude to Prof. Hooman Latifi for the encouragement to conduct this review. JL received funding from the University of Vienna and thanks the Biodiversity Dynamics and Conservation Division at the Institute of Botany and Biodiversity Research for their support, as well as Franz Essl and Karl Reiter for sharing their offices. NZ-C is supported by the María de Maeztu Excellence Unit 2023-2027 Ref. CEX 2021-001201-M, funded by MCIN/AEI/10.13039/501100011033. GC-C is grateful to the Alexander von Humboldt Stiftung for their support through Postdoctoral Research Fellowships.

AUTHOR CONTRIBUTIONS

J.L., Hv.W., N.Z.C., C.G., and G.C.C. conceived the ideas and designed the methodology; all authors collected the data; C.G. and J.L. and Hv.W. analyzed the data; J.L., G.C.C., N.Z.C., and C.G. led the writing of the article. All authors contributed critically to the drafts and gave final approval for publication.

DECLARATION OF INTERESTS

The authors declare no conflict of interest.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the authors used ChatGPT to help us fix coding in R for our analysis. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the publication.

STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

- KEY RESOURCES TABLE
- METHOD DETAILS
- EXPERIMENTAL MODEL AND STUDY PARTICIPANT DETAIL
- QUANTIFICATION AND STATISTICAL ANALYSIS

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.isci.2025.113889.

Received: July 10, 2025
Revised: October 14, 2025
Accepted: October 24, 2025
Published: October 28, 2025

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STAR★METHODS

KEY RESOURCES TABLE

REAGENT or RESOURCE	SOURCE	IDENTIFIER
Software and algorithms		
Python (v3.12)	Python Software Foundation	https://python.org
R (v4.4.2)	R project	https://www.r-project.org
Other		
Literature database for systematic review	Scopus	https://www.scopus.com
Analytical procedures: Chi-square, GLM, log-linear models, Fisher's exact test, Kendall's tau, hierarchical cluster analysis, indicator species analysis, DCA	Analytical procedures	Abson et al.[93]; This paper
Systematic review reporting guideline	PRISMA 2020	https://prisma-statement.org

METHOD DETAILS

We conducted a systematic literature review using the Scopus database on November 29, 2024, applying the following search string:

(TITLE-ABS("environmental equity" OR "environmental inequity" OR "environmental justice" OR "environmental injustice" OR "environmental disparities" OR "environmental inequality" OR "environmental equality") AND TITLE-ABS("case study" OR "area" OR "study region") AND TITLE-ABS("method" OR "assessment" OR "tool*")).*

We limited the search to English-language, peer-reviewed articles, resulting in 730 initial records. Screening occurred in three stages: 1. Title screening excluded 256 articles that were clearly unrelated to environmental (in)justice or lacked an empirical focus. 2. Abstract screening removed an additional 26 articles that did not meet our inclusion criteria: empirical focus and engagement with environmental (in)justice. 3. Full-text screening excluded 27 more articles due to insufficient relevance or lack of methodological detail.

EXPERIMENTAL MODEL AND STUDY PARTICIPANT DETAIL

The final dataset included 421 articles for full analysis (Figure 1).

We classified data collection temporal scales into five categories: short (<1 year), medium (1–5 years), long (>5 years), and very long (>30 years). Studies lacking temporal information were coded as missing. Data types were categorized as quantitative, mixed, or qualitative. Sampling strategies were classified as probability-based (e.g., simple random, stratified, cluster, systematic, multi-stage) or non-probability-based (e.g., quota, snowball, purposive, convenience) following Ahmed (2024).[93] Full inclusion or census approaches were also noted when entire datasets were analyzed.

Data collection methods were grouped into the following broad categories based on methodological traits: Interviews, surveys/census/questionnaires, GIS/remote sensing, clinical trials or medial data collection, simulation & modelling, statistical designs, instrumental or laboratory measurements, field sampling, reviews, participatory methods, observation, focus groups, case studies, ethnographic methods, socio-legal sources or secondary data sources. Data analysis methods were coded into univariate statistics, multivariate statistics, descriptive statistics, spatial analysis, machine learning & modelling, contextual analysis, participatory methods or analysis, qualitative coding or content analysis. Finally, we classified studies by their disciplinary orientation (disciplinary, interdisciplinary, multidisciplinary or transdisciplinary), and the dimensions of justice addressed.

We conducted two rounds of intercoder reliability checks during the title and abstract screening phases to ensure consistency. For full-text coding, variable definitions were collaboratively developed and refined through team discussions. Each article was coded by one researcher and reviewed or supplemented by a second. Although we did not calculate formal intercoder agreement scores, collaborative review aimed to minimize inconsistencies.

QUANTIFICATION AND STATISTICAL ANALYSIS

We analyzed our dataset at two levels. We performed descriptive statistical analysis on all 421 articles. This included univariate analyses to explore associations between variables using Chi-square tests, generalized linear models (GLMs), log-linear models to investigate proportions, Fisher's exact tests, and Kendall's tau rank correlations, depending on the type and distribution of the data. Following Abson et al. (2014),[94] we conducted a multivariate full-text word analysis based on nouns extracted from the 409

article pdfs. Assuming that research communities tend to use distinct vocabularies, we applied hierarchical cluster analysis to group articles by similarity in word use. Clustering was based on minimizing within-group variance and maximizing between-group differences in word frequency distributions. To characterize each cluster, we applied an indicator species analysis,[95] treating words as ''species'' and clusters as ''habitats''. This allowed us to identify statistically significant indicator words, i.e., terms that are disproportionately associated with specific clusters, forming the semantic core of each research cluster. Finally, we employed a detrended correspondence analysis (DCA) to reduce dimensionality and visualize the primary axes of variation in word use across articles. The resulting ordination plot shows indicator words along two primary axes, enabling interpretation of the relationships between thematic clusters in the environmental justice literature. All analyses were conducted in R,Version 4.4.2 (R Core Team 2021).