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PERSPECTIVE

Stakeholder engagement for inclusive climate impact attribution studies

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Abstract

Since its emergence in the 1990s, the science of attributing observed phenomena to human-induced and natural climate drivers has made remarkable progress. To ensure the relevance and uptake of climate impact attribution studies, scientists must effectively engage with stakeholders. This engagement allows stakeholders to pose key questions, which scientists can then substantiate with evidence evaluating the existence of causal links. Although significant advancements have been made in climate impact attribution science, much work remains to understand the varied requirements of different stakeholders for impact attribution findings. This perspective explores the usefulness of stakeholder engagement in climate impact attribution, the challenges it presents, and how it can be made more relevant for addressing societal questions. It advocates for prioritizing stakeholder involvement to achieve greater transparency, legitimacy, and practical application of findings. Such involvement can enhance the societal impact of attribution studies and support informed decision-making in the face of climate change.

1. Introduction

Amidst successive years of shattering climate records and severe global impacts, stakeholders' interest in climate impact attribution is steadily increasing. Attribution studies in the context of climate change evaluate the contribution of one or more causal factors to changes or to individual events of climate-related impacts on natural and human systems (Hope *et al* 2022). For example, climate attribution studies may examine how

anthropogenic climate forcing contributes to observed trends such as drier summers or specific events like heatwaves or droughts. Similarly, impacts such as decreasing crop yield trends or a specific crop yield failure may also be attributed to climate change, either to observed long-term changes in climate or specifically to anthropogenic climate change. While strides have been made in the science of climate impact attribution (O'Neill *et al* 2022), there remains a considerable amount of work in understanding the varied requirements of different stakeholders for such information.

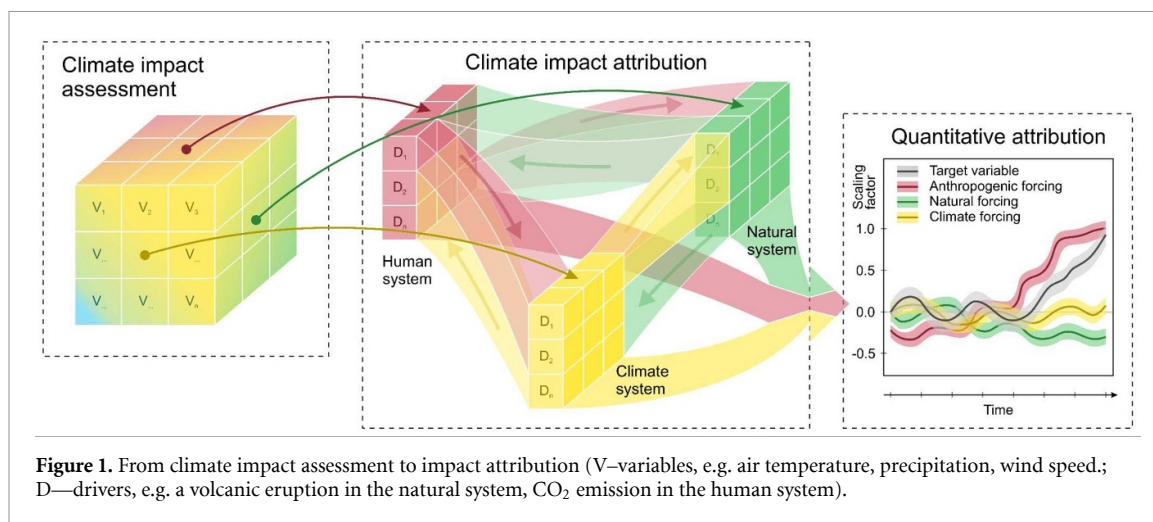
Stakeholder engagement has long been recognized as a key component of successful climate impact analyses (O'Connor *et al* 2000, Sippel *et al* 2015, Mkonda 2022). Yet, the potential and need for engaging stakeholders in climate impact attribution analyses is not yet well understood and practical mechanisms for effective dialogue and collaboration remain underexplored (Sippel *et al* 2015). Climate impact attribution findings are used by various stakeholders, including those working to strengthen resilience following extreme events (Birkmann *et al* 2023) and those aiming to raise awareness about climate change, such as media professionals and science communicators (Osaka *et al* 2020). Climate impact attribution is also a tool to debunk climate sceptics and call for urgent climate action. With advances in attribution science, the range of stakeholders interested in its findings has broadened to include those involved in regulatory, legal, and management frameworks. Yet, the ways in which climate impact attribution research can inform and engage diverse stakeholders to address societal questions remain largely unclear. For example, studies have shown that while stakeholders are interested in climate attribution, they are often uncertain about its relevance and practical utility for their work (Young *et al* 2019, Osaka and Bellamy 2020). A better understanding of stakeholder engagement processes in impact attribution studies and the potential for such processes is needed to inform future attribution studies and the use of attribution findings.

Stakeholder actions have considerable influence on societal development by improving decision-making quality, promoting broader policy acceptance, enhancing understanding of climate change issues, and safeguarding the democratic legitimacy of decision-making processes (Luís *et al* 2018, Lee *et al* 2023). The need to engage stakeholders in scientific projects dealing with societally relevant problems is widely recognised. Such engagement can be achieved through a variety of methods ranging from advisory functions to co-development processes to ensure projects' outputs meet stakeholder needs (Daniels *et al* 2020). Who exactly is a stakeholder depends on the scientific question being asked and the area of interest. In this paper, we use the word 'stakeholder' as a collective term for policy makers, scientists, administrators, natural resource managers, communities, companies, the legal sector, civil society organisations, ranging all the way to the wider public. However, we recognize that while the term 'stakeholder' is widely used in processes that seek to inform, consult, engage, co-produce, and collaborate on decisions and actions, the term includes inherent ambiguities, normative biases, and potential for exclusion (Reed *et al* 2024). Stakeholders may take an interest in scientific questions linked to climate impact attribution for various reasons, such as awareness raising in society, improved risk assessments, identifying climate change adaptation measures, legal actions against polluters or inclusion of scientific findings in policy making and operational management, among others.

In this perspective paper, we reflect on how stakeholder engagement in climate impact attribution can be beneficial, the challenges it presents, and how such engagement can shape attribution studies to address societal questions more effectively.

2. Cross-learning: benefits of stakeholder engagement in climate impact attribution studies

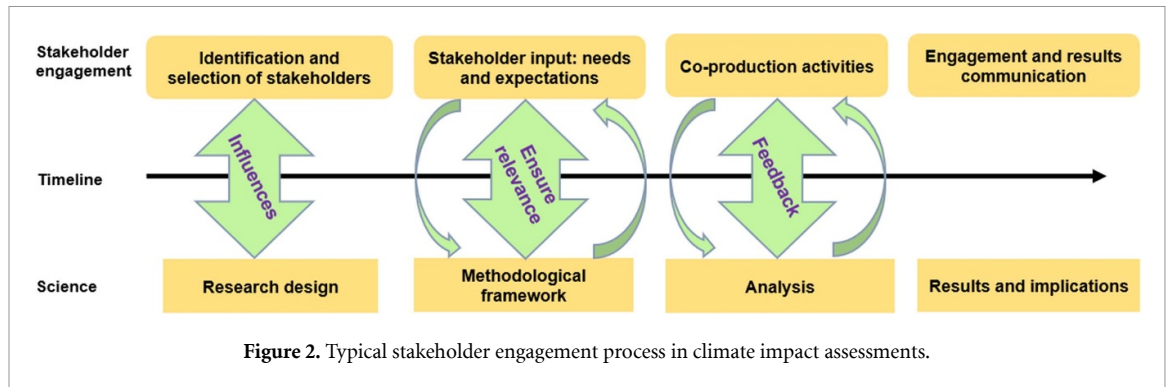
In this first section, we draw on expertise from stakeholder engagement processes in climate impact science. Climate impact attribution studies form part of the broader category of climate impact assessments, involving the systematic evaluation of potential effects of climate change on the environment, society, and the economy. Numerous studies have identified anthropogenic climate change impacts on the biosphere (Rosenzweig and Neofotis 2013, Seager *et al* 2014, National Academies of Sciences 2020). These findings, as well as extreme event attribution and attribution of long-term changes, are crucial for policymakers and the public to comprehend the critical need for effective mitigation and adaptation measures, to avoid otherwise resulting loss and damage. However, asking the right research questions, implementing these measures and evaluating outcomes necessitates the active involvement of stakeholders across various societal, scientific, and governance levels. This inclusive approach not only enhances decision-making, but also advocates for fairness and fosters social cohesion (Mkonda 2022). There has been significant progress in incorporating stakeholders into various climate impact assessments, such as climate adaptation evaluations and climate risk assessments. However, stakeholder involvement in climate impact attribution studies is neither well defined nor frequently implemented. Stakeholders exhibit limited awareness of attribution, which is a crucial drawback in policy adoption of this issue (Parker *et al* 2016).



The concept of impact attribution can be expressed as a separate effect of climate, natural and human dynamics on a change or event of a variable of interest (Stott *et al* 2013). Unlike climate impact assessments, which represent a more generalized view to a potential change of a target variable from baseline conditions, climate impact attribution studies define not only related systems but also attempt to disentangle the interaction between their drivers (figure 1). As climate impact attribution science aims to understand the anthropogenic part of the impact, it needs to separate anthropogenic forcings from other drivers. Figure 1 illustrates different forces that may all contribute to a climate impact; namely the human system, the climate system, and the natural system. The climate system includes drivers of natural variability such as la Niña or el Niño phenomena. Natural forcings are external factors that influence the climate but do not arise from the climate system itself, such as volcanic eruptions. The primary focus of an attribution study is the human system, which is responsible for CO₂ and other GHG emissions. This approach allows to quantify the drivers by linking the magnitude of the impact to specific systems. This correspondence provides a solid foundation for discussions with policy-makers, offering a clearer understanding of how human activities influence climate outcomes and helping guide future actions.

Against this background, valuable insights can be gathered from stakeholder engagement processes in existing climate impact assessments, allowing us to extrapolate these lessons for stakeholder engagement in climate impact attribution assessments. Stakeholder engagement yields common benefits across climate impact assessments, including: (1) ensuring the assessment addresses questions of interest to stakeholders, (2) enhancing technical assessment quality, e.g. by integrating diverse sources of knowledge, (3) providing a platform for stakeholders with diverse constituencies to share ideas and network, (4) facilitating the dissemination of climate assessment findings, (5) sensitizing stakeholders to potential impacts and adaptation strategies, and (6) legitimizing the process to third parties (O'Connor *et al* 2000). Furthermore, stakeholder engagement fosters a sense of ownership and collaboration among stakeholders, leading to better acceptance and implementation of actions (Bamzai-Dodson *et al* 2021). However, a successful stakeholder engagement process does not only look at stakeholders' needs, but equally takes their scientific interests into consideration. When co-developing research agendas or framing concrete research questions, a balance between stakeholder and researcher needs has to be found. This balance is hard to strike and often comes with additional challenges such as differences in timeline, time availability and budget for the process itself. Stakeholders may also have needs or questions that current attribution science cannot yet fully address, which may constrain the extent to which their expectations are met.

A typical stakeholder engagement process involves the identification and selection of stakeholders, identifying needs and expectations, engaging in co-production activities, and following up on engagement and communicating outcomes. Figure 2 outlines what such a process might look like within the timeframe of, e.g. a research project. The green arrows represent the interdependencies between the scientific analysis process and stakeholder engagement. The identification of stakeholders is often influenced by the field of research, with selected stakeholders helping shape the research questions to ensure relevance to their work. Methodological frameworks can be adapted to account for the needs and expectations of different stakeholders. Depending on the engagement's purpose and scope, co-production exercises can be designed differently, to meet specific needs. Usually, such exercises involve multiple interactions to ensure stakeholders' input is fully understood and accurately incorporated into the analysis. Only a thorough stakeholder engagement process will lead to a satisfying result for both stakeholders and scientists.



The design of each stakeholder process varies depending on the scientists, the type of stakeholders and their availability, the timeline and the joint needs. Table 1 illustrates examples of key elements and considerations in a stakeholder mapping process relevant for climate impact attribution, though it does not represent an exhaustive set of possibilities. While methodologies and outputs should not be rigidly standardized, it is crucial to acknowledge that engagement approaches successfully applied in climate impact assessments can be adapted for climate impact attribution studies. In essence, cross-learning through stakeholder engagement in broader climate impact assessments can strengthen the scientific relevance of the findings, thereby increasing their acceptance and application by different groups of stakeholders.

3. Challenges of stakeholder engagement in climate impact attribution

Having established the potential benefits of engaging stakeholders in climate impact attribution studies, we now highlight the challenges that may arise in this process. For the purposes of our discussion, we assume a willingness among scientists to establish a meaningful stakeholder engagement process and focus on challenges inherent to this process. While acknowledging the benefits, involving stakeholders extensively in such studies could face difficulties in consensus-building and potential delays due to the need to reconcile diverse interests (André *et al* 2023). In addition, engaging stakeholders in climate impact attribution studies requires substantial time, financial resources, and commitment for a successful engagement process. These may represent limiting factors for stakeholders' engagement as the time and resources needed may go beyond the requirements for conventional climate impact studies, as climate impact attribution studies are usually more complex and challenging to explain to a lay audience (Stott and Walton 2013).

The complexity of impact attribution research makes knowledge gaps regarding climate change more apparent and problematic as compared to climate impact assessments. Attribution studies add another layer of complexity to already complicated climate impact assessments with their respective uncertainties. For example, attribution research works with counterfactual scenarios and impact attribution connects causal impact chains, both of which are difficult to comprehend for non-scientists. Misinterpretation of uncertainties or attribution studies themselves may lead to misattribution posing another challenge for stakeholders. Most climate impact attribution research is conducted by researchers in high income countries and limited resources are invested in low- and middle-income countries, despite the latter being more vulnerable to impacts of climate change (Otto *et al* 2020). This leads to uneven knowledge distribution and a certain distance between scientists implementing study protocols and relevant stakeholder groups.

When engaging with stakeholders, scientists may encounter ethical challenges, particularly when advocacy is involved. They need to carefully balance their responsibility to advocate for evidence-based recommendations with the need to maintain scientific integrity and objectivity, while also managing potential conflicts between their research interests and stakeholder interests to avoid biased outcomes. Furthermore, climate impact attribution studies may have particular political and socioeconomic implications with often more specific action and liability claims attached as compared to conventional climate impact studies. For example, a climate impact attribution study quantifying the anthropogenic footprint of a specific flood or drought and the resulting damages and losses may raise claims and blame on behalf of affected stakeholder groups. In such a context, engaging stakeholders who have vested interests or conflicting agendas can be particularly challenging, especially when findings may influence policy decisions or resource allocations.

Table 1. Categorization of relevant possible stakeholder groups for climate impact attribution.

Type of organization/sector	Interest and needs (stakeholders)	Purpose of engagement (scientists)	Aspects to consider when choosing level of engagement
Policy makers (international, national, regional, local)	Could use the information of attribution studies to set more regulations on identified attributors and to demand the attributors for money for adaptation and mitigation actions	Ensure relevance of the scientific work, raises awareness for policy gaps, feed into on-going policy development	Different timelines for scientific output and need for input into policy processes
Civil society organizations	Capacity building around climate impacts and the climate change influence, use of information to further inform the wider public	Ensure relevance of the scientific work for society	Availability to engage may vary depending on funding, time needed, and capacities for engagement and managing expectations
Litigation community	Capacity building in scientific arguments around attribution for climate litigation, concrete attribution studies as input into climate litigation cases	Ensure usability of the scientific work for litigation cases	Time for capacity building around studies is needed (can also be provided by third parties such as civil society organisations), expectations around needs that cannot be met by science, yet need to be managed
Communication/ Media/ Education	Relevant scientific input for actual changes and events	Create public awareness, relevance and interest in available information	The timing and advertisement of studies matter
Academia	Understanding and streamlining between different areas of expertise	Understanding and streamlining between different areas of expertise	Capacity for engagement in non-key areas of expertise may vary
Private sector	Concrete questions around climate risks, responsibility and liability	Ensure relevance of scientific work for the private sector, understanding of gaps in the current scientific outputs	Often interest in high-resolution information and need for different timeline, realistic expectations help to ensure successful engagement
Community/religious/ cultural bodies	Capacity building around climate impacts and the climate change influence, use of information to further inform the wider public with a specific focus on minorities, use of information in litigation cases	Ensure relevance of scientific work for specific groups in societies	Availability to engage may vary depending on funding and time needed, power asymmetries, capacities for engagement, and managing expectations

4. Proactive stakeholder engagement in climate impact attribution: pathways to impact

From the opportunities and challenges inherent in actively involving stakeholders in climate impact attribution studies, several suggestions emerge to foster meaningful impact. Stakeholder engagement in climate studies is crucial for ensuring that the decisions and actions taken to address climate change are not only scientifically sound but also responsive to the unique needs and perspectives of the communities affected (Kloprogge and Sluijs 2006). This is also relevant for climate impact attribution studies. Therefore, in the pursuit of practical climate impact attribution studies, we advocate for the formulation of joint learning objectives and expected outcomes. We contend that early engagement with stakeholders is important to incorporate their perspectives and needs throughout the process, steering clear of the pitfalls of producing studies solely driven by research outputs.

To meaningfully integrate stakeholder engagement in attribution study processes, it is necessary to allocate sufficient time and resources for engagement, consultation and validation. Engaging stakeholders in climate impact attribution studies may require integrating them early into the research and may take longer

than conventional study processes, but may be more cost-effective in the long term when factoring in actual uptake and impact of scientific results. For stakeholder engagement in climate impact attribution studies, it is particularly important to identify the relevant stakeholders, as they may differ from stakeholders typically involved in climate impact studies. For instance, courts and lawyers are typically less interested in climate impact studies, but attribution studies can be highly relevant for them. For the specific case of climate litigation, continued exchange between legal experts as stakeholders and attribution scientists has the potential to increase the usability and relevance of attribution results for climate litigation cases. Both communities can learn from each other, and the more attribution scientists understand evidence requirements in courts, the better they can tailor their analyses and indicators studied to be relevant for legal proceedings while being scientifically sound.

Another key avenue for successful stakeholder engagement in climate impact attribution is adequate scientific evidence and uncertainty communication. Translating different scientific models, methodologies and dealing with scientific uncertainty takes time and may be challenging when working with different stakeholders. Making climate impact attribution science more usable is, however, not only about the content and quality of the research, but also about how the results are presented and communicated. Uncertainties in attribution results should be clearly communicated to stakeholders and the risks of misattribution or misuse of attribution results need to be considered and discussed.

Furthermore, engaging communities who are affected by specific climate impacts in respective impact attribution studies can support scientists in better understanding and contextualizing their results. Not engaging with local stakeholders runs the risk of focusing on metrics that are not relevant, or the misinterpretation of relevant metrics. For example, in agricultural settings, farmers often take particular pride in specific crops or livestock that they cultivate or hold. Losing these assets following a climate event or in response to an unfolding unsuitable mean climate may be considered much more detrimental than the loss of less-valued agricultural products, and this valuation may not be visible in monetary metrics. For effective detection of important non-monetary Loss and Damage components, engaging with stakeholders is crucial as stakeholder perspectives offer invaluable insights into the intangible costs of climate-related adversities. If affected stakeholders are effectively integrated in the climate impact attribution study process, they can ensure that complexities are adequately considered, by e.g. providing indigenous knowledge, identifying relevant factors, supporting equity and fairness in the attribution process, etc. This integration not only enhances the scientific rigour but also boosts both scientific and public interest and participation, especially when the co-participated attribution cases clearly show the direct link between actual climate events and research findings that incorporate the perspectives and input of affected stakeholders.

Additionally, expertise in climate impact attribution has predominantly been concentrated in high-income countries. However, it is crucial to involve scientists from low and middle-income countries in climate impact attribution projects as these countries experience the largest damages and socio-economic losses, arguably requiring a factual assessment of the role of climate change the most (Otto *et al* 2020). This highlights a broader need for greater inclusivity as involving researchers from low- and middle-income countries is crucial for ensuring that the scientific community working on climate impact attribution is diverse and globally representative. Thus, there is a pressing need for capacity building, data, model and code sharing to integrate scientists from low and middle-income countries into the climate impact attribution field.

Another aspect worth considering, which could link stakeholders and attribution studies, is the potential of citizen science. This emerging field holds promise for broadening the inclusivity of attribution studies across both high-income and low to middle-income countries. Citizen science, a research practice that relies on public contributions of data, is driven by citizens' desire for active intervention in issues directly impacting their lives, and whose decisions are often based and restricted to expert opinion (Albagli and Iwama 2022). Primarily constituted by voluntary non-scientist collaboration, citizen science is increasingly recognized for its role in promoting science dissemination and social participation. Through citizen science, there is also potential to build trust and establish critical communication channels that are essential for a deeper understanding of attribution science such as the link between greenhouse gas emissions and losses incurred during an event, enabling the communities to pose key evidentiary questions, while scientists can subsequently evaluate the existence of these causal links. Considering that citizen science has been applied in several climate change studies from participatory approaches (Albagli and Iwama 2022) to utilization of databases of citizen science observations (Hurlbert and Liang 2012), the same approaches can be adopted in climate impact attribution science. While a comprehensive exploration of citizen science's possibilities extends beyond this perspective, we contend that it can bridge the divide between attribution science and its significance within local communities.

5. Conclusion

Incorporating stakeholders at various societal, scientific, and governance levels in climate impact attribution science is pivotal to producing policy and stakeholder relevant outputs. Shifting the climate impact attribution research agenda from a scientist-centric approach to one that involves public participation, with various levels including not only stakeholder consultation, but also active involvement in shaping scientific research questions, is imperative. Sustained dialogue between attribution scientists and stakeholders is essential to ensuring the development of attribution studies that are both comprehensible and informative to the real world, particularly in legal contexts or loss and damage assessments where attribution science holds particular relevance.

A pressing need exists for researchers to incorporate stakeholder processes carefully into climate impact attribution projects and to report practices comprehensively. Understanding the contextual details of how, where, and by whom climate impact attribution information is utilized is crucial for refining research outputs to ensure appropriateness and effectiveness in decision-making. Engaging stakeholders in attribution research production processes enhances transparency and legitimacy, fostering a sense of ownership over the outcomes. Such collaborative, co-produced knowledge stands a better chance of being integrated into decision-making frameworks and of having actual impact, ensuring that climate impact attribution science effectively addresses stakeholder needs and contributes meaningfully to decision-making processes.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).

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