



From research to reality: utilising grey literature to document and track climate change adaptation



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While some large-scale and government-led adaptation is recorded, small-scale adaptations (e.g., in homes or businesses) are unreported, giving a partial view of national adaptation. Knowing how people adapt enables governments to incentivise and harness individual and bottom-up adaptation to support resilience. Grey literature (e.g. community-group and private sector reports) offers a rich source of adaptation information. Mining this using AI-tools and expert review would support evidence-based adaptation policy and evaluation

Bridging the adaptation data gap

The ability to precisely quantify greenhouse gas emissions is indisputable, providing a foundation for monitoring and evaluating progress against common baselines and driving policy towards international climate goals. In contrast, our capacity to determine *if, where, when, and how* adaptation is being implemented by different population cohorts, business sectors and social groups is exceptionally limited. The processes that countries use to define, identify or evaluate various components of adaptation action are often unclear, with no universal approaches, standards, or criteria for recording adaptation at the individual or small scale^{1,2}.

Fragmentation of adaptation information across different websites, reports and knowledge platforms also limits accessibility and useability for evidence-based decision-making and translation into action³. Adaptation databases do exist at the global scale (e.g. through knowledge hubs that often rely on users uploading case studies and reports, such as WeADAPT³ and the UNFCCC Adaptation Knowledge Portal⁴, as well as the Private Sector Initiative database⁵) and national scale^{1,2,6}. Whilst these databases typically collate adaptation exemplars, they do not capture the spectrum and prevalence of small-scale, autonomous and daily adaptations.

Furthermore, existing indices of adaptation identify elements of risk or vulnerability, often drawing on pre-existing global indicators such as the Human Development Index⁷. These indicators reveal progress towards adaptation or highlight specific risks, but none comprehensively depict the full array of adaptations undertaken by actors across scales, limiting the potential to evaluate the extent, quality and impact of non-state adaptation.

The lack of understanding of who is undertaking which adaptation, when, where and how remains a serious shortcoming given the need for all parts of society to adapt to climate-related impacts now and in the future. Even if Paris Agreement targets are met, and warming is kept below 2 °C, the

need for adaptation implementation remains vast to avoid significant risks to humanity⁸. However, the gap between existing adaptation effort and adaptation need is widening nationally and internationally, yet we do not fully understand the size or nature of this gap at the national, regional, local and individual level due to the reasons already outlined.

The UNFCCC has generally emphasised frameworks, capacity-building, and forward-looking planning over detailed inventories and tangible evidence of adaptation action^{9,10}. The Paris Agreement, through the global stocktake on adaptation, now seeks evidence of the practical process of implementation to enable evaluation of adaptation outcomes.

There is, however, a significant disparity in what academic literature covers when evaluating adaptation and what is being implemented in practice^{1,11–14}. In contrast, grey literature—defined here following Schöpfel¹⁵ as literature being of sufficient quality to be preserved in libraries or institutions and not being commercially published, including reports by inter-governmental and government organisations, adaptation funders, technical and project reports from NGOs and academic dissertations, etc.—contain critical yet underutilised evidence of adaptation in practice across all scales^{12,13}. The potential scope of grey literature is therefore vast and largely untapped. However, unlocking this information will require methodological innovations to process the large volume of material involved, including the use of Artificial Intelligence (AI), as well as a shift in how the curation of adaptation information and data is valued^{16,17}.

Existing methods to evaluate adaptation and what's missing

Small scale sector and risk specific systematic reviews increasingly use peer-reviewed articles to assess the theory, tracking and evaluation of adaptation, as opposed to practical implementation e.g. in health systems¹⁸ and

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housing¹⁹. The largest systematic study to assess adaptation implementation across all scales, the Global Adaptation Mapping Initiative (GAMI), analysed over 48,000 peer-reviewed articles. From this sample, 1,682 articles (or 3.5% of the reviewed articles) provided empirical evidence of adaptation action globally¹⁴ revealing a scarcity of evidence in peer-reviewed literature. The assessment authors have themselves highlighted the importance of expanding adaptation evidence synthesis beyond peer-reviewed literature, including the need to consider multilateral governance institutions, statistical data, legal documents, government reports, policy documents, NGO reports, working papers and company publications as important sources for understanding adaptation in practice¹¹.

Other approaches have employed structured expert judgment to identify and evaluate existing adaptation actions. One benefit is that the expert panel can quantitatively score adaptation to provide a globally comparative evaluation, overcoming the lack of consistent data on which to evaluate metrics of adaptation success²⁰. Systematic surveys have been used to evaluate, for example, business level adaptation planning. These surveys could be extended to specifically capture information on implemented adaptation²¹.

Importantly, given the drivers behind researchers writing and publishing academic articles, and need for originality, they do not often cover the type of material or report the granular, place-based nature of real-world adaptation¹². Practise is poorly reported in academic literature and practitioners are not usually incentivised or rewarded to document their adaptation activities in this format. This creates a disparity where the academic evidence base may lag behind practice and be biased, covering only a subset of implemented actions and potentially painting a misleading picture of implementation.

In contrast, broader, but still robust grey literature sources often contain detailed documentation of such actions. Resources to assess could include: the private sector's climate-related financial risk disclosures (TCFD); corporate sustainability and Environmental, Social, and Governance (ESG) reports; operational reports produced by NGOs and development agencies¹⁷ (e.g. global governance institutions research²²); local government adaptation reports (e.g. London Climate Resilience Review²³); or case studies and technical guidance produced by practitioner organisations and professional networks (e.g. the practitioner led report on global leading practices for coastal resilience²⁴). Evaluating such material for evidence of implemented adaptation would provide a step-change in capturing a wider and more representative spectrum of adaptation actors and provide vital and deeper insights into the current state of adaptation across scales and sectors.

When evaluating grey literature, it is also important to consider the breath of sources. Where non-academic articles have been considered, adaptation research has predominantly focused on evidence derived from public-sector reports and assessments, for which a range of documentation methods exist (e.g.^{25,26}). This emphasis leaves a substantial evidence gap regarding how adaptation is occurring beyond more formal governance processes and reporting. In particular, there is limited understanding of adaptation actions taken by business and other private-sector organisations²², community actors, households and individuals. This gap constrains our ability to assess the full scale, distribution and effectiveness of adaptation and how we might incentivise future adaptation actions at scale.

Mining grey literature at scale

A key challenge is that grey literature resources are dispersed, inconsistently catalogued, and difficult to access systematically (i.e., there is no Web of Science, Scopus or PubMed equivalent). Methods to overcome this barrier include identifying existing repositories of cross-sectoral adaptation reports, such as the UK's Adaptation Reporting Power reports^{1,27}, exploring key organisational websites such as Australia's 566 local government areas⁶, individually utilising webpage free-text search functions to identify sub-sets of reports; emailing organisations and community groups to request project documents; snowball sampling from academic articles; drawing on insight from experts in the field through discussions and surveys⁶; or utilising grey

literature databases^{12,13} (such as OpenGrey (<https://opengrey.eu>) or Overton (<http://www.overton.io>)).

The long length and inconsistent structure of grey literature documents can be a barrier. A further challenge is therefore how to identify and convert relevant, but potentially inconsistency reported and formatted, evidence on implemented adaptation into usable datasets and information for expert review. For example, from billions of business level ESG disclosures. Here, data mining algorithms can be explicitly programmed to overcome this challenge. For example, dictionary-based approaches that provide transparent first-pass screening of large document collections²⁸. More specifically, content analysis studies now utilise text mining to retain a document's original structure and identify segments as text units (TUs), consisting of sentences, table rows, or images²⁹.

A further challenge to comprehensively identifying, evaluating and cataloguing evidence from grey literature is scale. Manual reviews are resource intensive, particularly when considering larger areas and multiple sectors. Additionally, adaptation terminology is inconsistently applied across sectors and contexts, limiting the effectiveness of keyword searches and making reproducibility difficult¹. To address this issue, thematic classification could differentiate whether the information included in a TU refers to climate hazards, organisational risks and/or adaptation responses (A.S., D.M. & K.J., unpublished presentation at FRBC'26, University of Glasgow). This classification would also serve as a coding basis, where numerical information which supports comparison and narrative information are tagged. Expert review of the derived output can be considered a process of developing new knowledge, because it is a basis to validate best practice and identify weaknesses/inconsistency in adaptation reporting. Knowledge-synthesis guidance for climate assessments now places particular weight on evidence that is transparent, reproducible, inclusive and timely³⁰.

Consequently, AI offers promising solutions as already highlighted through supporting systematic reviews of academic literature³¹. Natural language processing techniques—namely Machine Learning (ML) and Deep Learning (DL)—can be adapted to extract relevant information from unstructured texts. In addition to the examples above, named entity recognition can identify organisations, geographies, and adaptation activities, while context-aware models could be utilised to specifically distinguish between descriptions of theoretical versus actual implementation (e.g., “flood assessment” vs. “flood barriers constructed in 2022”).

Applying a logical pathway approach that could map from ‘hazard’ to ‘risk’ to ‘adaptation’ provides a tractable framework for linking and interpreting evidence. This will be key given that previous inventory and evidence-synthesis studies have shown that implemented adaptation remains difficult to distinguish from broader planning or capacity-building activities^{1,14}. If utilising large-scale text-related AI methods it is therefore important that they not only reduce the manual burden, but that they remain sensitive to context, subtle distinctions and construct validity¹⁶. A logical pathway approach as alluded to above would therefore move automated analysis beyond simple keyword prevalence by identifying meaningful relationships between terms. For example, it is postulated that a document section that links flood risk to critical infrastructure disruption and subsequent flood-protection investment would provide stronger evidence of adaptation than the mention of flood-protection terms alone.

More advanced language models trained on large collections of specialist adaptation-related documents, such as ClimateBERT and the potential for adaptation-specific derivatives (e.g., an AdaptationBERT) would support more nuanced classification tasks by interpreting words in their wider context in this way. Benchmark datasets developed for climate-related corporate disclosures have already demonstrated how AI-assisted searches can be evaluated for accuracy, traceability and source coverage³², including the systematic identification of adaptation and resilience information from sustainability reports from S&P 500 companies³³.

Existing annotated corpora therefore provide useful starting points, but adaptation tracking requires labels that preserve the relationship between exposure (hazard), consequence (risk) and response (adaptation). This

would enable the identification of subtle distinctions between implemented action, planned action, capacity building and general climate-risk reporting overcoming many of the issues associated with keyword-based approaches^{33,34}. Developing such AI approaches targeted specifically to adaptation grey literature resources, that would be applicable to reporting across scales and beyond the public sector, could therefore yield significant gains.

Implications for global assessments and models

More rigorous integration of grey literature into adaptation tracking holds direct relevance for global reporting and assessment processes. The global adaptation stocktake will only be as robust as the level of information and data inventories that feed it. As countries prepare for the second stocktake cycle running from 2026–2028 (covering the period of 2024–2028), inclusion of evidence from wider grey literature sources could help build national inventories of implemented adaptation action more efficiently and inclusively. Advances here could not come soon enough given the shift in focus from theoretical and technical guidelines on adaptation to supporting meaningful impact and implementation for COP30 in Brazil. Likewise, the Intergovernmental Panel on Climate Change (IPCC) has also flagged limited empirical evidence of adaptation, especially from outside the academic domain³⁵, with such resources providing additional evidence that could be evaluated as part of the review and writing process. Acknowledging this, GAMI, which was developed specifically to inform the IPCC Sixth Assessment process is being revisited. GAMI 2.0 will support the IPCC Seventh Assessment process and adaptation tracking linked to the global goal on adaptation and global stocktake processes. To do so the initiative recognises the need to address concerns raised here, including to further automate the use of ML and NLP to handle the volume of information and improve the representation of grey literature which could help to enhance knowledge for underrepresented sectors and regions¹¹.

Accessible and clearly structured inventories based on high-quality grey literature could offer a more comprehensive picture of adaptation in practice across the public and private sector as well as small-scale adaptations at the business, household or individual level. Assessment bodies need evidence not only on whether adaptation is mentioned, but also on which hazards are addressed, which sectors report action, which responses have been implemented, and where disclosures on adaptation remain aspirational or incomplete.

New and enhanced inventories of implemented adaptation action would provide a stronger baseline on which to evaluate and compare the value and strength of evidence from grey literature against peer-reviewed literature and provide a more comprehensive baseline from which to support future adaptation monitoring, evaluation and learning. Evidence can be used to support sharing of best practice and examples of adaptation that are politically, technically and economically feasible (e.g., the use of the UK Adaptation Inventory as a resource in the UK governments Green Book supplementary guidance on climate change and environmental valuation); help to identify adaptation gaps; and support more targeted and just responses.

Such efforts could also enhance integrated assessment models (IAMs) and climate risk modelling, which is a further research priority¹⁴. Both rely on currently limited or simplified assumptions about the extent and type of adaptation actions that are, or could be, implemented. Access to real-world evidence could improve the parametrisation of adaptation actions and integration of specific approaches into local, regional and national climate risk assessment frameworks. This would facilitate more robust assessments of future risks and testing and prioritisation of both individual and suites of adaptation actions.

Building a stronger adaptation evidence base

Grey literature is not a panacea. Documents vary in quality, accessibility, and reproducibility. In utilising AI, quality control must remain a design principle rather than an end-stage correction. Automated coding should not replace assessment expertise, given variation in purpose, review status and

incentives. A credible multi-method evidence base would collate and evaluate evidence from machine screening, sample-based human validation¹⁷, expert review of uncertain classifications and transparent reporting of false positives and false negatives. Grey literature will only strengthen adaptation assessment when inclusion is matched by clear validation standards giving the evidence credibility and weight alongside academic, or more formally peer reviewed, information.

Nevertheless, continuing to overlook this vast resource limits our understanding of adaptation on the ground. AI methods, as discussed above, provide an opportunity to mine this information at scale, capturing public and private information on implemented adaptation to provide a more complete understanding of what adaptation is happening today. If systematically catalogued in inventories this information can be combined with evidence from other important sources within this reporting framework¹⁷, cutting across scales, and derived through other approaches, such as academic systematic reviews^{1,14}, expert elicitation²⁰, structured surveys²¹, evidence from lived experience and measures influenced by local and indigenous knowledge^{36,37}. There are also needs to enhance the inclusion of non-English literature¹⁴, which can result in published literature remaining inaccessible but highlights another area where AI translation could provide a solution³⁸.

This broader evidence base would not only strengthen adaptation science but would provide a richer foundation for evidence-based adaptation policy and evaluation. Open access inventories can help equip practitioners, policymakers, and communities with the information they need to help support decision-making. Ensuring decisions are grounded in robust evidence, from which a foundation for monitoring and evaluating progress can be achieved will be imperative to accelerating climate adaptation policy and action in the decades ahead.

While the computational process of mining grey literature and cataloguing information may not be considered ‘blue sky’ research to many academics, the value of more comprehensive adaptation inventories to support national and the Global Goal on Adaptation cannot be emphasised enough and is essential to push the frontiers of climate change adaptation research, policy and practice.

Data availability

No datasets were generated or analysed during the current study.

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References

- Jenkins, K., Ford, A., Robson, C. & Nicholls, R. J. Identifying adaptation ‘on the ground’: Development of a UK adaptation Inventory. *Clim. Risk Manag.* **36**, 100430 <https://doi.org/10.1016/j.crm.2022.100430> (2022).
- Tompkins, E. L., Vincent, K., Nicholls, R. J. & Suckall, N. Documenting the state of adaptation for the global stocktake of the Paris Agreement. *WIREs Clim. Change* **9**, e545 <https://doi.org/10.1002/wcc.545> (2018).
- Bharwani, S., Williamson, K. & Butterfield, R. Measuring what matters: Building impact pathways to actionable information for the weADAPT platform. *Clim. Serv.* **38**, 100574 <https://doi.org/10.1016/j.cliser.2025.100574> (2025).
- UNFCCC. *United Nations Climate Change: Adaptation Knowledge Portal*, (2026).
- UNFCCC. *United Nations Climate Change: Adaptation Private Sector Initiative (PSI)*, (2026).
- Brullo, T., Barnett, J., Waters, E. & Boulter, S. A method for tracking national progress towards climate change adaptation. *Clim. Risk Manag.* **51**, 100800 <https://doi.org/10.1016/j.crm.2026.100800> (2026).
- Biesbroek, R., Mirbach, C., Sietsma, A. & Garschagen, M. Assessment of existing datasets for tracking progress towards the

- Global Goal on Adaptation (and beyond). *Clim. Policy* **26**, 535–549 <https://doi.org/10.1080/14693062.2025.2517644> (2026).
8. Fuldauer, L. I. et al. Targeting climate adaptation to safeguard and advance the Sustainable Development Goals. *Nat. Commun.* **13**, 3579 <https://doi.org/10.1038/s41467-022-31202-w> (2022).
9. Biesbroek, R., Wright, S. J., Eguren, S. K., Bonotto, A. & Athanasiadis, I. N. Policy attention to climate change impacts, adaptation and vulnerability: a global assessment of National Communications (1994–2019). *Clim. Policy* **22**, 97–111 <https://doi.org/10.1080/14693062.2021.2018986> (2022).
10. Mizuno, O. & Okano, N. Reconsidering National Adaptation Plans (NAPs) as a Policy Framework under the UNFCCC. *Clim. Policy* **24**, 1309–1321 <https://doi.org/10.1080/14693062.2024.2378194> (2024).
11. Petzold, J. et al. Ways forward for global adaptation evidence synthesis building on the Global Adaptation Mapping Initiative. *Commun. Sustain.* **1**, 62 <https://doi.org/10.1038/s44458-026-00071-5> (2026).
12. Piggott-McKellar, A. E., McNamara, K. E., Nunn, P. D. & Watson, J. E. M. What are the barriers to successful community-based climate change adaptation? A review of grey literature. *Local Environ.* **24**, 374–390 <https://doi.org/10.1080/13549839.2019.1580688> (2019).
13. Martinez, G. S., Williams, E. & Yu, S. S. The Economics of Health Damage and Adaptation to Climate Change in Europe: A Review of the Conventional and Grey Literature. *Clim* **3**, 522–541 (2015).
14. Berrang-Ford, L. et al. A systematic global stocktake of evidence on human adaptation to climate change. *Nat. Clim. Change* **11**, 989–1000 <https://doi.org/10.1038/s41558-021-01170-y> (2021).
15. Schöpfel, J. Towards a Prague definition of grey literature. In *Proceedings of Twelfth International Conference on Grey Literature*, Prague, Czech Republic, 6–7 December 2010. (2010).
16. Sietsma, A. J., Ford, J. D. & Minx, J. C. The next generation of machine learning for tracking adaptation texts. *Nat. Clim. Change* **14**, 31–39 <https://doi.org/10.1038/s41558-023-01890-3> (2024).
17. Wilby, R. L. Evaluating the Potential of ChatGPT to Support Climate Risk and Adaptation Assessment. *Clim. Resil. Sustain.* **4**, e70013 <https://doi.org/10.1002/cli2.70013> (2025).
18. Ansah, E. W., Amoah, M., Obeng, P. & Sarfo, J. O. Health systems response to climate change adaptation: a scoping review of global evidence. *BMC Public Health* **24**, 2015 <https://doi.org/10.1186/s12889-024-19459-w> (2024).
19. Cabana, D., Röfler, L., Evadzi, P. & Celliers, L. Enabling Climate Change Adaptation in Coastal Systems: A Systematic Literature Review. *Earth's Futur.* **11**, e2023EF003713 <https://doi.org/10.1029/2023EF003713> (2023).
20. Magnan, A. K. et al. Status of global coastal adaptation. *Nat. Clim. Change* **13**, 1213–1221 <https://doi.org/10.1038/s41558-023-01834-x> (2023).
21. Dookie, D. S., Conway, D., Dessai, S. & Olinier, E. Organisational perceptions of adapting to a changing climate. *Clim. Risk Manag.* **45**, 100637 <https://doi.org/10.1016/j.crm.2024.100637> (2024).
22. Rexer, J. M. & Sharma, S. Climate Change Adaptation: What Does the Evidence Say?;36. PLANET World Bank Group., Washington, D.C. (2024).
23. Greater London Authority. The London Climate Resilience Review. Greater London Authority. https://www.london.gov.uk/sites/default/files/2024-07/The_London_Climate_Resilience_Review_July_2024_FA.pdf, London, (2024).
24. PEERS. Global Leading Practices for Coastal Resilience: A Report of the Practitioner Exchange for Effective Response to Sea Level Rise (PEERS). peerscoastal.org/wp-content/uploads/2026/03/PEERS-Global-Leading-Practices-2026.pdf (2026).
25. Berrang-Ford, L. et al. Tracking global climate change adaptation among governments. *Nat. Clim. Change* **9**, 440–449 <https://doi.org/10.1038/s41558-019-0490-0> (2019).
26. Olazabal, M., Ruiz de Gopegui, M., Tompkins, E. L., Venner, K. & Smith, R. A cross-scale worldwide analysis of coastal adaptation planning. *Environ. Res. Lett.* **14**, 124056 <https://doi.org/10.1088/1748-9326/ab5532> (2019).
27. Jenkins, K., Nicholls, R. J. & Sayers, P. Climate Change Adaptation in the Port Industry: Evaluating Evidence of Implemented Adaptation Using a National Adaptation Inventory. *Earth's Futur.* **13**, e2024EF005841 <https://doi.org/10.1029/2024EF005841> (2025).
28. Loughran, T. & McDonald, B. The Use of Word Lists in Textual Analysis. *J. Behav. Financ.* **16**, 1–11 <https://doi.org/10.1080/15427560.2015.1000335> (2015).
29. Pfitzmann, B., Auer, C., Dolfi, M., Nassar, A. S. & Staar, P. in *Proceedings of the 28th ACM SIGKDD Conference on Knowledge Discovery and Data Mining* 3743–3751. Association for Computing Machinery, Washington DC, USA. (2022).
30. Ford, J. D. et al. Recommendations for producing knowledge syntheses to inform climate change assessments. *Nat. Clim. Change* **15**, 698–708 <https://doi.org/10.1038/s41558-025-02354-6> (2025).
31. Sietsma, A. J. et al. Machine learning evidence map reveals global differences in adaptation action. *One Earth* **7**, 280–292 <https://doi.org/10.1016/j.oneear.2023.12.011> (2024).
32. Schimanski, T., Ni, J., Martín, R. S., Ranger, N. & Leippold, M. ClimRetrieve: A Benchmarking Dataset for Information Retrieval from Corporate Climate Disclosures. 17509–17524. Association for Computational Linguistics (2024).
33. Spacey Martin, R., Ranger, N., Schimanski, T. & Leippold, M. Empirically assessing corporate adaptation and resilience disclosure using AI. *npj Clim. Action* **5**, 22 <https://doi.org/10.1038/s44168-025-00321-7> (2026).
34. Webersinke, N., Kraus, M., Bingler, J. A. & Leippold, M. ClimateBert: A pretrained language model for climate-related text. In *Proceedings of the AAAI 2022 Fall Symposium: The Role of AI in Responding to Climate Challenges*. *Climate Change AI*. <https://www.climatechange.ai/papers/aaai-fs2022/12> (2022).
35. Nalau, J., Gilmore, E. & Howden, M. Improving adaptation assessment in the IPCC. *npj Clim. Action* **3**, 76 <https://doi.org/10.1038/s44168-024-00155-9> (2024).
36. Iocca, L. & Fidélis, T. Is There a Place for Indigenous Peoples and Local Communities in Climate Change Policy and Governance? Learnings from a Brazilian Case. *Land* **12**, 1647 (2023).
37. Zvobgo, L. et al. The role of indigenous knowledge and local knowledge in water sector adaptation to climate change in Africa: a structured assessment. *Sustain. Sci.* **17**, 2077–2092 <https://doi.org/10.1007/s11625-022-01118-x> (2022).
38. Robakiewicz, E., Alvarez, W., Chan, L. S. & Alemu, T. Lost in non-translation: AI translation could bring non-English literature into modern geoscience research. *GSA Today* **36**, 4–9 <https://doi.org/10.1130/GSATG642A.1> (2026).

Author contributions

K.J. contributed to the conception of the work and wrote the first submission of the text. All authors contributed to the significant revision and expansion of the paper. K.J., E.T. and R.N. brought expertise and led contributions related to national and global adaptation. A.S. and D.M. brought expertise and led contributions related to mining grey literature and AI approaches. All authors contributed to the final review of the manuscript and approved the final version.

Competing interests

The authors declare no competing interests.

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