Response to Reviewer 1

Dear Reviewer,

We sincerely thank you for your thoughtful and constructive comments and for recognising the value of evaluating rainfall-induced LEWS through the EW4All framework. In response, we have substantially strengthened the analytical interpretation of the review, clarified the methodology and operational classification, expanded the discussion of governance and implementation, and placed greater emphasis on Pillars 3 and 4. We also revised the figures, comparative analyses, and Conclusion to improve synthesis and reduce descriptive repetition.

Your suggestions have helped us improve the clarity, balance, and analytical focus of the review. Below, we respond to your major comments paragraph by paragraph, followed by a response to the minor comments.

Major Comments

Comment 1: The Introduction is informative but somewhat heavier than necessary. The transition toward the research gap is somewhat delayed. The manuscript would benefit from bringing forward more explicitly the limitations of existing LEWS reviews and the specific added value of adopting an EW4All-based analytical perspective. The main contribution is not the compilation of published LEWS studies, but rather their reinterpretation through operational and governance dimensions. This is an important point that deserves importance. The methodological framework based on PRISMA 2020 is appropriate and adds transparency to the review.

Response: We thank the reviewer for this helpful comment. We agree that the principal contribution of this review lies not simply in compiling published LEWS studies, but in interpreting them through the operational and governance dimensions of the EW4All framework. We have therefore clarified this contribution more explicitly in Section 1.4, where we explain that previous LEWS reviews have predominantly focused on technical dimensions, such as rainfall thresholds, spatial scale, monitoring approaches, and modelling methods, whereas the present review examines institutional responsibility, warning dissemination, preparedness, response capability, and implementation feasibility through the EW4All framework. We have retained the broader introductory discussion because this background is necessary for readers who may be unfamiliar with the development and structure of the EW4All framework, and it provides the context required to understand the subsequent analysis of LEWS through its four interconnected pillars. The PRISMA 2020-based methodology has also been retained and further clarified in Section 2 to ensure transparency in the identification, screening, and selection of the reviewed systems.

Comment 2: The Results and Discussion section contains a large amount of relevant material, but its presentation is often more descriptive. The literature is

well covered, yet many findings are reported rather than interpreted. For NHESS, a stronger effort to extract meaning from the observed patterns would be expected. Implications for operational reliability, scalability, and governance could be developed more systematically.

Response: We have strengthened interpretation throughout Sections 3.1–3.4**.** Rather than only listing characteristics, the revised manuscript now uses Table 1 and Appendix II to compare operational status, spatial scale, and major technical characteristics, and then interprets these patterns in relation to institutional responsibility, scalability, maintenance requirements, warning authority, and communication arrangements. For example, the revised analysis shows major differences in operational status across spatial scales and explicitly interprets these as an operational trade-off between local accuracy and wider transferability rather than as a hierarchy of system quality. Likewise, the Pillar 2 analysis concludes that no individual technology consistently explains operational status and that operational maturity appears more closely associated with institutional responsibility, routine maintenance, warning authority and established communication and response arrangements.

Comment 3: For instance, the discussion on susceptibility mapping could be strengthened by moving beyond the simple observation of its limited use. The more interesting point is what these reveals about the persistent dominance of rainfall-threshold-based approaches compared to more spatially distributed risk modelling strategies. Similarly, the distinction between local and broader scale systems would benefit from a more explicit reflection on the trade-offs between accuracy, transferability, and operational scalability.

Response: We have substantially strengthened this discussion in Section 3.1**.** The revised manuscript now explains that the uneven use of susceptibility maps reflects the continuing prominence of rainfall-threshold approaches, which are comparatively easier to develop and operationalise where data and institutional resources are constrained. It also explains the limitation of threshold-only warnings in representing spatial variations in susceptibility and risk. The revised text also explicitly discusses the scale trade-off. Local systems can provide more spatially specific warnings but require slope-specific monitoring, maintenance, expertise, and sustained resources, reducing transferability. Regional and National systems are comparatively more scalable but benefit from susceptibility or risk information to improve spatial targeting.

Comment 4: The section on artificial intelligence is relevant and up to date, but the framing is sometimes slightly unbalanced. While limitations are correctly identified, the discussion would be stronger if it more clearly acknowledged the parallel potential of AI-based approaches, particularly in data-scarce environments, alongside their well-known constraints in terms of interpretability.

Response: The AI/ML discussion in Section 3.2 has been revised to recognise both its opportunities and limitations. The manuscript now notes that AI/ML can support data-gap filling through satellite remote sensing, pattern recognition, data integration and

susceptibility mapping, and may therefore be particularly useful in data-sparse settings. At the same time, the text discusses training-data requirements, transferability, cloud-related limitations, local contextual differences, interpretability, uncertainty and human oversight. AI is consequently framed as a complementary component of a hybrid LEWS, combined with expert interpretation, field validation, and institutional decision-making.

Comment 5: In particular, the idea that only effective LEWS can reduce landslide impacts should be softened, as risk reduction is inherently multi-dimensional and depends on land use planning, also governance structures, exposure and vulnerability conditions.

Response: We have revised the relevant statement. The manuscript now states that an effective LEWS can contribute significantly to reducing potential loss and damage, but that its effectiveness also depends on broader risk-reduction measures, including land-use planning, governance structures, exposure reduction, vulnerability reduction and preparedness planning**.** This avoids implying that LEWS alone can reduce landslide risk.

Comment 6: One of the strongest contributions of the manuscript is the identification of the limited attention given to Pillars 3 and 4 of the EW4All framework. This is a particularly relevant finding and could be more strongly emphasized, as it highlights a clear structural imbalance in the current LEWS literature between technical forecasting components and communication.

Response: We agree that this is one of the most important findings of the review and have strengthened it throughout the manuscript. Section 3.3 is now dedicated jointly to Pillar 3 and Pillar 4, supported by Figure 9 on warning dissemination and Figure 10 on preparedness and response. Academic publications provided Pillar 3 evidence for approximately 22 of the 45 systems and Pillar 4 evidence for only 15, requiring supplementary official evidence. The gap analysis further develops last-mile communication in Section 3.4.3 and preparedness and response in Section 3.4.4**.** The synthesis at the end of Section 3.4 explicitly concludes that the principal weakness is not a single technology but the uneven transition from risk and forecasting information to authorised communication and feasible early action. This finding is also highlighted prominently in the Conclusion.

Comment 7: The discussion on operational systems is also valuable. The observation that only a small fraction of systems described in the literature are actually operational is an important point. However, the explanation of this phenomenon would benefit from a more integrated interpretation.

Response: The revised dataset and interpretation substantially change this discussion. We now identify 27 operational systems among 45 unique systems, rather than the previous 14 of 61 records, and explicitly distinguish LEWS from Forecasting-focused systems. Section 3.1 now explains that the transition from prototype to sustained operation requires considerably more than a forecasting algorithm. It depends on continuous data availability, maintenance funding, institutional responsibility, legal

authority to issue warnings, skilled personnel, communication and response protocols, and an appropriate mandate. This provides a more integrated explanation of why technically developed systems may remain non-operational.

Comment 8: The manuscript also appropriately highlights the gap between academic publications and operational reality, particularly regarding the lack of detailed implementation information in scientific articles. This is an important methodological limitation and could be further developed, as it directly affects the robustness of global comparisons**.**

Response: We have made this limitation explicit at the beginning of Section 3. The revised manuscript states that only information supported by the selected publications and supplementary official sources was recorded, while missing evidence was treated as not reported**.** It further explains that some studies provide detailed technical forecasting information but much less information on institutional mandates, dissemination, preparedness, operational status and community engagement. Consequently, international comparisons may partly reflect differences in reporting practices rather than differences in actual system maturity. The same point is now reiterated in the Conclusion as an important methodological and substantive finding.

Comment 9: For the conclusions section, in its current form, it would be preferable to focus more clearly on the main scientific messages, the key gaps identified, and the most relevant priorities for future LEWS development within the EW4All framework.

Response: The Conclusion has been substantially rewritten around the principal scientific findings and future priorities. It now synthesises the uneven operationalisation of LEWS, the particular difficulty of operationalising Local systems, wider institutional and financial constraints, the imbalance between Pillars 1–2 and Pillars 3–4, the academic-reporting gap, and the limitations of globally standardised approaches where local calibration is necessary. It concludes by identifying operational governance, risk- and impact-based information, last-mile communication, preparedness, and locally responsive scalability as priorities for future LEWS development.

Comment 10: In summary, the manuscript has strong potential as a review article for NHESS. The literature coverage is extensive and the EW4All perspective represents a clear added value. However, the manuscript would benefit from a more analytical structure, reduced redundancy, and a stronger effort to synthesize rather than describe.

Response: We have revised the manuscript throughout to move from descriptive compilation towards comparative interpretation. The main changes include the system-level classification into LEWS and Forecasting-focused systems, the operational-status criteria in Section 2, the comparative cross-tabulation in Table 1, the scale comparison in Figure 7, the revised geographical analysis in Figure 8, the Pillar 3 and 4 analyses in Figures 9 and 10, and the consolidated EW4All gap framework in Figure 11. These

revisions allow the Results and Discussion to focus more clearly on what the observed patterns imply for reliability, scalability, governance, and the transition from forecasting to actionable early warning.

Minor comments

We also addressed the minor comments as follows:

Lines 327–334**:** The clarification regarding the limitations of the reviewed literature is appreciated and improves the transparency of the study. However, this paragraph could be shortened slightly to avoid interrupting the transition into the Results and Discussion section.

Response: We shortened and refocused this material. The revised opening of Section 3 now provides one concise methodological caveat explaining the treatment of missing information and the implications of differing reporting practices for global comparison, without substantially interrupting the transition into the Results.

Lines 338–344**:** The discussion introducing Pillar 1 is clear and well contextualized. Nevertheless, some sentences are somewhat repetitive, particularly regarding the concept of “awareness” and “knowledge” of landslide risks.

Response: The introduction to Section 3.1 has been updated. The revised section proceeds directly to the system-level evidence, spatial scale, and operational status, avoiding the previous repeated explanation of awareness and knowledge.

Lines 345–352**:** The finding that only 14 out of 61 LEWS are operational is highly relevant. It would be useful to elaborate more on the reasons preventing the transition from prototype systems to operational implementation.

Response: This issue is now developed directly in Section 3.1**.** The revised manuscript explains that operationalisation requires continuous data, maintenance funding, institutional responsibility, warning authority, skilled personnel, and functioning communication and response protocols. The analysis also shows how these constraints are particularly important for Local systems.

Lines 366–374: The discussion on slope-specific LEWS is interesting and highlights an important operational limitation. However, the argument on cost–benefit analysis could be supported with a more critical perspective on scalability and long-term maintenance requirements.

Response: We expanded this discussion in Section 3.1. The revised manuscript now explicitly links Local systems to slope-specific instrumentation, continuous monitoring, calibration, maintenance, technical expertise and secure funding, and explains why these requirements can constrain wider scalability despite the potential for highly localised warning accuracy.

Lines 385–406: The section discussing susceptibility maps is very informative. In particular, the explanation of how susceptibility mapping may reduce false alarms is well presented. However, some parts could be reduced in order to improve readability.

Response: The susceptibility-mapping discussion has been updated and made more analytical. It now focuses on the contrast between rainfall-threshold dominance and spatially targeted warning, followed by a separate discussion of the trade-off between accuracy, transferability, and operational scalability.

Lines 407–417: The discussion on data scarcity is highly relevant, especially for data-sparse regions. Nonetheless, similar arguments appear repeatedly throughout the manuscript.

Response: We reduced repetition and concentrated the main critical discussion of data scarcity within Section 3.4.1.1, “Data scarcity”**,** where it is linked to cross-sectoral data collection, integration, and governance rather than repeatedly restating the same limitation throughout the Results.

Lines 432–439: The introduction to Pillar 2 is generally clear, although the paragraph would benefit from a more direct connection to the operational implications of monitoring strategies.

Response: The opening of Section 3.2 now explicitly connects monitoring choice with warning reliability, lead time, maintenance requirements, and scalability. Table 1 and Appendix II then provide the supporting comparative evidence.

Lines 473–478: The role of additional meteorological variables is mentioned appropriately; however, the statement that these variables are “less crucial” may be simplified, particularly in complex hydrometeorological environments.

Response: The previous categorical wording suggesting that other variables were “less crucial” has been removed. The revised text identifies rainfall as the primary hydrometeorological trigger within the reviewed rainfall-induced systems without dismissing the supporting relevance of other environmental and monitoring variables.

Lines 481–497: The discussion regarding piezometers and inclinometers is valuable and technically well explained. However, some sentences are long and could be divided to improve readability.

Response: We revised this discussion for readability and separated the explanation into shorter sequential statements. The revised text explains the functions of pore-water-pressure and displacement monitoring first, and then separately discusses their reliability benefits, maintenance costs, spatial limitations, and suitability for Local rather than broad-scale monitoring.

Lines 578–600: The manuscript correctly highlights the lack of information regarding Pillars 3 and 4 in the reviewed literature. This represents one of the most important findings of the study and deserves further emphasis in the Conclusions section.

Response: We have done so. The revised Conclusion now explicitly identifies the underreporting of Pillars 3 and 4 as a structural imbalance between technical LEWS development and the people-centred operational requirements of EW4All, and links this to the wider gap between academic publication and operational reality.

We sincerely thank the reviewer again for these constructive suggestions. They have helped us sharpen the distinction between technical forecasting and complete early warning, strengthen the analytical interpretation of the reviewed evidence, and better articulate the operational and governance implications of applying the EW4All framework to rainfall-induced LEWS.

Response to Reviewer 2

Dear Reviewer,

We sincerely thank you for your detailed and constructive assessment of our manuscript. Your comments prompted substantial methodological, analytical, structural, and presentational revisions. In particular, we clarified the distinction between complete LEWS and Forecasting-focused systems, reconstructed the review at the level of unique systems rather than individual publications, strengthened the evidence used to determine operational status, incorporated targeted evidence from LandAware and official government/agency sources, introduced descriptive cross-tabulation by system type, operational status, and spatial scale, replaced the previous radial diagrams, and substantially expanded the analysis of EW4All Pillars 3 and 4. The revised review now contains 45 unique systems, of which 33 are classified as LEWS and 12 as Forecasting-focused systems.

General comment

This review article evaluates rainfall-induced landslide early warning systems (LEWS) in the lens of the UN's Early Warnings for All (EW4All) framework. The authors reviewed 61 publications covering 23 countries looking at key gaps across the four EW4All pillars. The topic is relevant to NHESS. However, the manuscript in its current form has significant methodological, structural, and presentational weaknesses that must be addressed before it can be reconsidered for publication.

Response: We thank the reviewer for recognising the relevance of this study to NHESS and for highlighting the key areas requiring improvement. We have carefully revised the

manuscript to address the methodological, structural, and presentational concerns raised.

Specific comments

On the paper selection and analysis

Comment 1: My main concern regards the inclusions of forecasting systems in the analysis, which could be misleading and led to biased findings. Looking at Table 1, the vast majority of the 61 reviewed studies address only EW4All Pillars 1 and 2 (risk knowledge and detection/monitoring/forecasting). Very few address Pillars 3 and 4. This pattern is not incidental, indeed it directly reflects the inclusion of forecasting-only studies that, by the authors' own definition, are not EWS at all. As a matter of fact, the headline finding "14 of 61 LEWS are operational" is potentially misleading because it is unclear how many of the 61 are proper early warning systems versus forecasting tools that were included despite not meeting the paper's own definition of EWS. Moreover, the claim to evaluate LEWS "through the EW4All framework" is undermined because including forecasting-only systems guarantees that Pillars 3 and 4 will appear absent, not because they are genuinely missing from practice, but because the included studies were never designed to address them. Thus, I suggest to discard the forecasting systems from the review and focus only on proper LEWS, considering if necessary all LEWS already mentioned in the previous review articles (cited in the text). I think that including all LEWS in the review will allow a more detailed evaluation of all EW4All Pillars. As an example, Hong Kong, Rio de Janeiro, Japan LEWS are left out from the main discussion, despite being consolidated systems with rich peer-reviewed and grey literature. I would suggest having a look also on the LEWS catalogue produced by LandAware, the international network on LEWS (https://www.landaware.org/glossary-and-catalog-of-lews/).

Response: Thank you for raising this important concern. We have substantially revised both the terminology and analytical treatment of the selected systems. Section 2 now explicitly distinguishes a LEWS, for which evidence of the complete warning chain could be identified, from a Forecasting-focused system, for which evidence of a complete EWS chain was not available. Forecasting-focused systems are therefore no longer presented as equivalent to complete LEWS. Of the 45 unique systems, 33 are now classified as LEWS and 12 as Forecasting-focused systems.

We retained the Forecasting-focused category because it reveals an important reporting and terminology issue in the literature, namely that some studies use LEWS terminology while primarily describing forecasting or monitoring components. However, these systems are analytically separated throughout Table 1. More importantly, the analyses of warning dissemination, preparedness and response in Section 3.3, and the corresponding gap analyses for Pillars 3 and 4, are based on the 33 systems classified as LEWS, rather than on all 45 systems. Targeted information from LandAware and official government and agency websites was also incorporated to strengthen evidence on operational status and Pillars 3 and 4. We have also incorporated the suggested systems into the revised analysis.

The headline result has consequently changed from the previous “14 of 61 LEWS are operational” to 27 of 45 systems being operational, comprising 26 LEWS and one Forecasting-focused system, which is stated explicitly in the revised Abstract.

Comment 2: The 61 selected articles appear to include a wide range of publication types, from peer-reviewed empirical studies to conference proceedings and grey literature. The authors do not apply any quality assessment criteria to the included studies. Without this, high-quality national operational systems receive equal weight to conference papers describing prototype models.

Seven grey literature sources are included, but the selection criteria for these are vague. How were national websites identified? Was the search systematic or opportunistic? This needs clarification.

Response: We have strengthened the evidence-assessment procedure in Section 2 and Appendix I. Rather than assigning a single generic quality score to very different types of evidence, the revised review now records the source type, operational evidence and evidence strength separately for each system. Evidence is classified as High where direct evidence is available and Moderate where operational status has to be determined from more limited evidence. Appendix I also reports the source used for each EW4All pillar assignment.

The grey-literature search is also now explicitly defined as a targeted supplementary search**,** using the LandAware catalogue and official government and agency websites/portals. These sources were used principally to verify operational status, supplement evidence for Pillars 3 and 4, and identify operational LEWS not captured through the filtered academic literature. This makes the role of grey literature considerably more transparent than in the previous version.

Comment 3: Moreover, some papers are included in 61 selected papers (Table 1) even though they do not describe early warning systems or forecasting systems. As an example, the paper by Guzzetti et al. (2024) describes a validation of a deep-learning model for landslide prediction; moreover, the three papers from Zhang et al. (2024) – which are wrongly cited as 2024, 2024a and 2024b – describe criteria for analyzing landslide displacements with the aim of early warning, but they do not describe a forecasting system; the article by Thomas et al. (2023) describes the application of a slope stability model in some locations, but is far from the definition of a comprehensive forecasting model.

Response: We agree with the reviewer. The analytical dataset was re-screened and reconstructed. The specific methodological/model-development records identified in the comment are no longer treated as standalone LEWS in the revised analytical dataset. Section 2 now requires that retained systems either provide evidence of a complete LEWS or represent a forecasting-focused system that was explicitly presented in the source literature as an LEWS-related system. After screening, 57 records remained, six

were excluded, 51 system records were retained, and duplicate records describing the same system were merged to produce 45 unique systems.

Comment 4: The paper does not describe a structured data extraction protocol or inter-rater reliability process. Given that the review has a single primary analyst (RS), there is a risk of extraction bias, particularly for the EW4All pillar assignments in Table 1. Several pillar assignments appear to be inferred rather than explicitly reported in the source articles (as acknowledged in Section 3). This needs to be flagged more prominently as a limitation, and the basis for each assignment should be made transparent, perhaps via supplementary material.

Response: We agree that transparent coding is particularly important for this type of review. A formal post-hoc inter-rater reliability statistic was not introduced because the original extraction was undertaken by a primary analyst. Instead, we have substantially strengthened the auditability of the coding process. Section 2 now specifies a structured data-extraction protocol covering country, locality, areal coverage, scale, system type, operational evidence, evidence strength, individual P1–P4 assignment sources, source type, and references. Appendix I provides this information at the individual-system level. We have also adopted a more conservative treatment of missing evidence. At the beginning of Section 3, the manuscript now states explicitly that only information supported by the reviewed publications or supplementary sources was included, and where information could not be identified it was treated as "not reported", rather than being interpreted as evidence that the component was absent in practice. The manuscript also acknowledges that international comparisons may partly reflect differences in reporting practices rather than actual differences in system maturity.

Comment 5: The paper does not dedicate any structured analytical section specifically to local-scale LEWS, despite them constituting nearly a third of the reviewed systems (19 of 61). Indeed, a previous review on local-scale LEWS (https://link.springer.com/article/10.1007/s10346-018-1068-z) is not mentioned. The gap analysis in Section 4.5 discusses challenges generically across all LEWS types without disaggregating by scale. There is no comparative discussion of how the challenges and EW4All pillar coverage differ between local, regional, and national systems — even though Table 1 encodes this information. The community-based LEWS literature is particularly relevant to EW4All's people-centred mandate but receives no dedicated treatment.

Response: We have strengthened the treatment of Local systems throughout the analysis rather than creating a separate Local-only subsection, which would duplicate several scale-stratified analyses. Spatial scale is now a cross-cutting analytical variable in Section 3.1, Figure 7, Table 1, and Appendix II. The revised analysis shows that 15.4% of Local systems in the reviewed sample were operational, compared with 56.25% of Regional systems and 100% of National systems. The manuscript then interprets these differences in terms of institutional mandates, maintenance, funding, scalability and the trade-off between highly localised accuracy and wider transferability. Community-centred dimensions are also developed more explicitly in Sections 3.4.2.3, 3.4.3 and 3.4.4,

including community participation, locally appropriate warning channels, awareness, preparedness, evacuation and collaboration with local actors. This provides a more direct connection between Local LEWS and the people-centred requirements of EW4All. The Local LEWS discussion is now strengthened using the dedicated review by Pecoraro et al. (2019).

Comment 6: The novelty claimed in Section 1.4 is overstated. The authors assert that the distinct contribution lies in "reframing the field through the EW4All framework," yet the analytical application of the framework remains largely descriptive rather than evaluative. The paper identifies well-known gaps (data scarcity, lack of risk maps, limited community engagement) that have been extensively documented in prior literature. The authors do not demonstrate how the EW4All lens generates new insights beyond organising pre-existing knowledge under new headings. The theoretical contribution would be strengthened considerably if the authors more explicitly articulated what the EW4All framing reveals that prior frameworks did not. Section 1.4 should be improved to make a more defensible claim about novelty.

Response: Section 1.4, “Novelty and originality”**,** has been substantially rewritten to make the claim more modest and defensible. We now explicitly state that the novelty does not lie in identifying individual limitations such as data scarcity, limited mapping or weak community engagement for the first time. Instead, the contribution lies in examining how these established limitations interact across the complete EW4All warning chain and in interpreting LEWS through operational and governance dimensions including institutional responsibility, dissemination, preparedness, response capability, and implementation feasibility.

On data analysis

Comment 7: The core analytical tool is a series of radial diagrams (Figures 7, 8, 9) that have serious readability problems. The analysis they represent is largely descriptive and categorical. The paper does not attempt any cross-tabulation, correlation, or comparative analysis between LEWS characteristics and operational status, geographic region, or EW4All pillar coverage. For example: Are LEWS that use susceptibility maps more likely to be operational? Do national-scale systems address more EW4All pillars than local ones? These questions are implied but never tested.

Response: We have substantially revised the analytical presentation. The previous radial diagrams have been removed, and Table 1 now provides a structured cross-tabulation of operational status and spatial scale against system type and major characteristics, including susceptibility mapping, rainfall thresholds, sensor use, AI/ML, API use, IoT, and remote sensing. Appendix II provides the supporting data. Given the small, categorical, and review-derived nature of the dataset, we considered descriptive cross-tabulation more appropriate than presenting formal correlations as evidence of causal relationships. The manuscript explicitly states this limitation. For example, 19 of the 25 systems using susceptibility maps were operational compared with eight of the 20 systems without susceptibility maps, but the revised text clearly states that this does not demonstrate that

susceptibility mapping causes operationalisation. The revised discussion therefore uses the comparative patterns to interpret operational reliability, scale and institutional context without overstating causality.

Comment 8: The distinction between operational and non-operational systems is central to the paper's argument but is applied inconsistently. The authors note (Section 3) that some LEWS in the "validated" stage are recommended for implementation, and that operational status does not necessarily mean full areal coverage. These nuances are important but are not systematically incorporated into the analysis.

Response: The operational classification has been standardised in Section 2. A system is now classified as Operational only where current routine warning dissemination is demonstrated through published or supplementary official evidence. Systems described only as designed, prototyped, experimentally tested, validated, or recommended for future implementation are classified as Non-operational unless routine warning use is explicitly demonstrated. Operational status is also separated from spatial coverage. Appendix I contains distinct fields for locality, areal coverage, system scale, and operational evidence, avoiding the previous ambiguity between being operational and providing full geographic coverage.

Comment 9: Section 4.3 is, in my opinion, the weakest part of the paper. The authors essentially acknowledge that the literature review cannot address Pillars 3 and 4 because the academic publications do not cover them adequately. While this is an honest and valid observation, a paper claiming to evaluate LEWS "through the lens of the EW4All framework" cannot do so when two of the four pillars are almost entirely absent from the analysis. The authors should either supplement this section with a targeted review of grey literature, agency reports, and policy documents on warning dissemination and community preparedness, or clearly reframe the paper's scope in the title, abstract, and objectives to reflect that the analysis is primarily limited to Pillars 1 and 2.

Response: We have substantially reworked this part of the manuscript. Section 3.3 is now explicitly framed around warning dissemination and communication (Pillar 3) and preparedness and response capability (Pillar 4)**.** The revised analysis found that academic publications provided Pillar 3 evidence for approximately 22 of the 45 systems and Pillar 4 evidence for 15 systems, demonstrating a reporting gap. Supplementary official sources were therefore used to obtain additional information. Importantly, after supplementation, only the 33 systems meeting the LEWS definition are used for the detailed Pillar 3 and 4 analysis. Figure 9 now presents documented warning-dissemination modes, while Figure 10 presents preparedness and response activities. The text explicitly cautions that missing documentation should not be interpreted as proof that operational practices are absent. This issue is also elevated into one of the main conclusions of the paper, where the imbalance between the strong technical emphasis on Pillars 1 and 2 and the limited reporting of Pillars 3 and 4 is identified as a major structural finding.

Comment 10: The feasibility analysis in Section 4.6 is conceptually interesting but reads as opinion rather than evidence-based analysis. Several of the six feasibility concerns are presented without citation or empirical grounding. For instance, the claim that "ensuring complete inclusivity is practically impossible" is asserted without reference to any case studies or theoretical literature on emergency management and inclusivity. Similarly, the critique that the EW4All framework "emphasises the application of similar methods or models everywhere" is a characterisation that the authors do not substantiate with specific textual evidence from the EW4All documentation. These claims may be correct, but they must be supported.

Response: Section 4 has been comprehensively revised to make the feasibility discussion evidence-based. The previous general statements have been replaced by six specific subsections supported by recent literature and/or EW4All evidence:

4.1 Financing and sustained implementation capacity; 4.2 Global consistency and local adaptation; 4.3 Global forecasting products and local calibration; 4.4 Last-mile communication; 4.5 Inclusivity in operational implementation; and 4.6 Feasibility of universal coverage by 2027.

For example, the previous implication that EW4All requires the same model everywhere has been softened. Section 4.2 now discusses the tension between common standards and necessary local adaptation, supported by Rokhideh et al. (2025), while Section 4.3 discusses locally calibrated thresholds and the limitations of global meteorological products using Piciullo et al. (2017), Nocentini et al. (2024), and UNDRR and WMO (2025). Funding and the 2027 coverage target are likewise linked to recent UNDRR/WMO evidence rather than being presented as unsupported assertions.

On the presentation quality

Comment 11: The radial diagrams (Figures 7, 8, 9) represent a major presentational problem. Each diagram attempts to display three or four variables simultaneously for 61 LEWS using country codes as labels around a crowded circle. The result is essentially not readable without extreme magnification. Individual labels frequently overlap, and the legend abbreviations require readers to cross-reference constantly. These figures, in their current form, do not meet minimum readability standards for a journal article. The authors should replace or substantially redesign these figures. Heat maps, grouped bar charts, or structured tables would convey the same information far more clearly. If the authors wish to retain the radial format as a visual overview, they should provide supplementary tables containing the underlying data in accessible form.

Response: We agree, and the previous radial diagrams have been removed. The revised manuscript now uses simpler and more interpretable visualisations: Figure 7 shows operational status by spatial scale, Figure 8 shows the geographical distribution of systems and their operational status, Figure 9 presents warning-dissemination modes, Figure 10 presents preparedness and response activities, and Figure 11 synthesises

EW4All-related gaps. The underlying categorical information is also presented in Table 1 and Appendices I–II.

Comment 12: Table 1 is comprehensive and generally well-constructed, though it is very long and would benefit from a brief inline summary noting the distribution of studies by continent and EW4All pillar coverage. Table 2 is useful for contextualising the additional LEWS from prior reviews.

Response: The revised Section 3.1 now provides a narrative summary before and around Table 1, including the number of unique systems, LEWS versus Forecasting-focused systems, spatial-scale distribution, operational status, and geographic distribution. Table 1 itself has been redesigned as a comparative cross-tabulation rather than simply a long catalogue. The previous separate dataset of “additional LEWS from review papers” has also been removed as an independent analytical dataset. Relevant previous reviews and official sources are now used to support or contextualise the unified 45-system analysis, which removes the duplication identified by the reviewer.

Comment 13: The English writing is generally good. Given the authors' acknowledgement that AI tools were used for some paragraphs, the editors should be aware that several passages have a smoothed but imprecise quality that may have been introduced through AI assistance rather than corrected.

Response: The manuscript has undergone detailed language revision to improve specificity, reduce overgeneralisation, and ensure that interpretive statements are supported by the analysis. We have also clarified the role of AI assistance in the declaration. The revised manuscript states that the main text was originally written by the authors and that ChatGPT was used for sentence structure, readability, punctuation, spelling, and grammatical checking, after which all content was reviewed and edited by the authors.

Comment 14: The paper's structure is broadly logical, but the relationship between Sections 4.4 and 4.5 is confusing. Section 4.4 discusses "additional LEWS from review papers" using a different data source than the main 61 articles, while Section 4.5 analyses gaps in the 61 articles. The boundary between these sections is unclear, and the discussion of the additional 30 LEWS in Section 4.4 partially duplicates findings already made about the primary 61 in Sections 4.1–4.2. The authors should clarify how the findings from the two datasets are analytically distinguished and whether the additional 30 LEWS inform the gap analysis in Section 4.5.

Response: We have removed the previous two-dataset structure that created this ambiguity. The revised analysis is based on 45 unique systems**,** with academic publications and targeted supplementary official evidence incorporated within the same structured system-level dataset. The gap analysis is now consolidated in Section 3.4, rather than comparing a primary dataset against a separate set of additional systems from earlier reviews. Within Section 3.4, Pillars 1 and 2 are examined using the 45 systems,

whereas the analyses of Pillars 3 and 4 are restricted to the 33 systems classified as LEWS. This distinction is now stated explicitly.

Comment 15: I'd suggest to specify in the title that the review and analysis were done in the lens of EW4All framework.

Response: We agree and have revised the title accordingly. The revised title is:

“Rainfall-Induced Landslide Early Warning System through the Lens of Early Warnings for All Framework: Advances, Gaps, and Perspectives.”

Other minor comments

Comment 16: Section 1.3: The claim that "88% of landslides are rainfall-triggered" (citing Haque et al., 2019 and Froude & Petley, 2018) should be contextualised. This statistic relates to fatal landslides in a specific database and time period, not to landslides in general. The generalisation as stated is imprecise.

Response: We have corrected and contextualised this statement in Section 1.3. Rather than generalising the statistic to all landslides, the revised text now specifies that Froude and Petley (2018) found that 79% of non-seismic fatal landslide events in their inventory were triggered by rainfall, while Haque et al. (2019) reported that more than half of recorded deadly landslide events occurred in areas exposed to extreme rainfall. The relevant inventory periods are also introduced immediately beforehand.

Comment 17: Section 4.5.2.5: The claim that "there is no known standard methodology for developing LEWS" is an important finding that deserves more discussion. The authors could usefully reference the work of Calvello (2017) and Guzzetti et al. (2020) on performance evaluation frameworks, which represent partial steps toward standardisation.

Response: We have expanded Section 3.4.2.5, “Standardised methodology”**,** as suggested. The revised manuscript now explicitly discusses the contributions of Calvello (2017) and Guzzetti et al. (2020) as useful foundations for threshold validation, warning-level evaluation, and operational performance assessment, while distinguishing these evaluation frameworks from a universally applicable methodology for developing LEWS in different physical and institutional contexts.

Comment 18: Section 4.6: The six feasibility concerns should be structured and numbered consistently with the gap analysis in Section 4.5 for readability. Each concern should be supported by at least one citation or concrete example.

Response: We have reorganised the feasibility discussion into six explicitly numbered subsections, Sections 4.1–4.6, to make the progression much clearer. Rather than mechanically reproducing every internal subsection number from the gap analysis, the revised ordering follows the same broader analytical progression: enabling and

implementation capacity, methodological and local adaptation issues, forecasting and calibration, last-mile communication, inclusive implementation, and finally the overarching feasibility of universal coverage by 2027.

Each concern is now tied to published or institutional evidence. For example, financing is supported by UNDRR and WMO (2025) and Tupper and Fearnley (2023); local adaptation by Rokhideh et al. (2025); local calibration by Piciullo et al. (2017), Nocentini et al. (2024) and UNDRR and WMO (2025); communication and inclusivity by UNDRR and WMO (2025); and the 2027 implementation challenge by UNDRR and WMO (2025) and Rokhideh et al. (2025).

We sincerely thank the reviewer again for these detailed comments. They prompted a substantial restructuring of the manuscript and helped us distinguish more clearly between technical forecasting research, complete LEWS, documented operational practice, and the broader people-centred requirements of EW4All.

Kind Regards,

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On behalf of **Bayes Ahmed** and **Peter Sammonds**