

RC#4

R: The paper is presented in the format of a short communication or technical note aimed at providing insights into the added value associated with the use of volumetric soil water content as provided by ERA5-Land, as an additional proxy for event identification. I agree with the points raised by the other reviewers: I appreciate the clarity and simplicity of the approach. All steps are straightforward and easy to understand; nonetheless, I also share some concerns (and it would therefore be useful to provide further information regarding):

A: Thank you for your comment. While we understand that the structure of our manuscript may resemble a short communication, it does not meet the criteria defined by NHESS for that format, which is limited to 2–4 journal pages. Based on the constructive feedback received from all four reviewers, we are currently expanding the manuscript and integrating additional analyses to enhance its scientific depth and clarity.

R: What is the current early warning system used in Sicily for landslide forecasting, and what is the added value compared to this benchmark? (In this regard, if the system is based solely on triggering rainfall, it would be very interesting to understand the added value of using soil moisture as an event discriminator);

A: Currently there is no early warning system in Sicily specific for landslides. There is indeed an alert system for generic “hydro-geological risk” which is generic for floods and landslides and is based on comparing quantitative precipitation forecasts (QPF) with precipitation depth-duration-frequency curves of different rainfall return periods. Hence, it is based on intrinsic characteristics of rainfall, which is analyzed independently from the observed impacts produced by extreme rainfall. For instance, an alert level is activated when rainfall is predicted to exceed the IDF curve of 0.80 of non-exceedance probability, and this is not necessarily linked to observed floods/landslides in an area, as this depends on catchment/soil characteristics which are not taken into account by the system. Indeed, several theoretical inconsistencies of this approach have been highlighted in a recent brief communication under review in NHESS (Marra et al., 2025). Given this, inclusion of soil moisture and the increase of performance respect to precipitation-based thresholds shown in our analyses already prove the added value of using soil moisture. We will add a sentence to the discussion section of our revised manuscript.

REFERENCE: Marra F, Dallan E, Borga M, Greco R, Bogaard T Brief communication: Threshold not probability. The conceptual difference between ID thresholds for landslide initiation and IDF curves. <https://doi.org/10.5194/egusphere-2025-3378>

R: what are the characteristics of the movements in the area? It is obviously well known that the added value of using volumetric water content as a proxy depends on the characteristics of the event—events in finer-grained soils are more influenced by antecedent rainfall, while with thinner soil layers or higher permeability, the importance of triggering precipitation increases. With that in mind, is it possible to identify a sort of zonation to understand in which areas there might be added value in using reanalysis-based volumetric soil water content as a proxy? If possible, a spatial representation of the information could be very helpful.

A: We agree with the reviewer that the characteristics of landslide movements can strongly influence the added value of using soil moisture information. In principle, it would be meaningful to perform separate analyses based on the type of movement or according to the geographical alert zones used in Sicily’s civil protection system. However, as also noted in our response to Referee #1, the type of movement is unfortunately unknown for most of the 144 landslide events included in our dataset. Additionally, splitting the dataset by the 9 official alert zones would result in very small subsets, which would not be sufficient to support a robust statistical evaluation of model performance. For these reasons, we chose not to apply a spatial or typological stratification in the present analysis. Nonetheless, we acknowledge the potential value of this approach and consider it a promising direction for future work, particularly as more detailed and spatially distributed landslide information becomes available. A comment on this will be added to the revised manuscript.

R: while I understand the rationale for using information with up to a 15-day delay in the first part of the analysis, from the introduction of the ANN approaches onward, I find it less useful and would limit all representations to 5

days before the present time; it is likely that in upcoming releases (ERA6 is expected in December 2025 with 14 km resolution) the delay will decrease and not increase.

A: We understand the reviewer's concern regarding the limited operational relevance of testing latencies beyond 5 days, particularly in the context of ANN-based forecasting. However, we believe that exploring a wider latency window (up to 15 days) remains meaningful for two main reasons. First, while the current latency of ERA5-Land is about 5 days and future products such as ERA6 may further reduce this delay, temporary disruptions (e.g., due to maintenance or data access issues) cannot be excluded in operational contexts. Second, from a scientific standpoint, our aim was to investigate the sensitivity of model performance to soil moisture availability over time. This allows us to better understand the degradation of performance as information becomes less timely. We agree that, in practical terms, the most relevant scenarios are within the 1–5 days window, and this is reflected in our discussion of operational perspectives. We appreciate the reviewer's suggestion and will make this clearer in the revised manuscript.

R: although it is well known to most, for completeness I would include a brief description of the ERA5-Land reanalysis (it would also be helpful to emphasize that 9 km is the resolution of the land module only, while the atmospheric part is a statistical interpolation from the parent model "ERA5"). For accuracy, I would avoid referring to ERA5-Land as "products" or "dataset" and instead use the term "reanalysis outputs."

A: We thank the reviewer for the helpful suggestion. In the revised manuscript, we will include a brief description of the ERA5-Land reanalysis to improve completeness and clarity and to emphasize its relationship with ERA5. Thanks for your suggestion about the use of correct terminology. However, we have chosen to use the terms “dataset” in accordance with the official terminology adopted by the Copernicus Climate Data Store (CDS), which distributes ERA5-Land (see <https://cds.climate.copernicus.eu/datasets/reanalysis-era5-land?tab=overview>). Also “reanalysis product” is consistent with the data provider and broader scientific usage (see <https://link.springer.com/article/10.1007/s00382-023-06803-w>). Thus, we prefer to maintain this terminology in our manuscript.

R: Additionally, I note: In the abstract, avoid or explain any acronyms used.

A: *Will be done*

R: there's a typo in Figure 1.

A: *Will be fixed*