
Referee #2 Comments:

1. General comments:

This manuscript presents a Human Social Sensing (HSS) framework combining manual coding and text-mining methods to examine long-term changes in water-related newspaper discourse in South Korea. The interdisciplinary topic is interesting and potentially relevant to sociohydrology.

However, the manuscript currently provides mainly a descriptive analysis of media discourse. The derived indicators are not directly linked to observed hydrological conditions, water-management responses, human behaviour, or practical applications in sociohydrological modelling. The main contribution therefore appears to be the HSS framework itself. Substantial revision is needed to clarify the hydrological contribution, strengthen its connection to sociohydrological modelling, and demonstrate the relevance of the proposed framework to HESS.

Response: We sincerely thank the reviewer for the thoughtful and constructive evaluation. We agree that the original manuscript presented a stronger descriptive analysis of newspaper discourse than operational demonstration of its relevance to sociohydrology.

The revised manuscript now defines the sociohydrological measurement problem more explicitly, distinguishes the HSS framework from its individual text-analysis techniques, and includes a quantitative demonstration showing how a discourse-derived indicator can provide information about a latent environmental-awareness state. We have also substantially narrowed claims that previously implied direct observation of public perception.

Accordingly, the revised Introduction now states:

“HSS is intended to address an observational limitation in sociohydrology rather than to replace or constitute a coupled hydrological model. Its purpose is to transform long-term human-generated records into quantitative observations that may help constrain otherwise poorly observed social components of human–water systems. The present study evaluates this role using newspaper-derived discourse indicators and includes a quantitative demonstration showing how a discourse-derived indicator can provide empirical information potentially relevant to a latent environmental-awareness state.”

2. Specific comments:

- 1) The central concern is that the connection to sociohydrology remains largely conceptual. The use of socioeconomic indicators alone is insufficient to establish a clear contribution to hydrological science.

Response: We agree with the reviewer that this was the central limitation of the original manuscript. We have therefore moved the sociohydrological application from a purely conceptual discussion to an explicit quantitative demonstration in the Methods and Results.

The revised manuscript constructs A_t^{HSS} from the classified newspaper articles and uses its temporal evolution as an empirical discourse-level reference potentially informative of a latent environmental-awareness state. Importantly, the indicator is not equated with environmental awareness itself. This distinction makes explicit what is measured by HSS and how the resulting information may be used in relation to a sociohydrological social-state representation.

Accordingly, the revised manuscript now reads:

“The sociohydrological use of HSS requires separating an observable discourse signal from the latent social process that the signal may help inform. In the present demonstration, the relative prevalence of environmental-sustainability and economic-development framing is used to define A_t^{HSS} . This indicator is not interpreted as environmental awareness itself; rather, its temporal evolution provides empirical discourse-level information potentially relevant to evaluating or constraining the representation of an environmental-awareness state.”

- 1-a) The manuscript mentions sociohydrological models and their limitations several times (Lines 18–20, 40–41, 44–47, and 381–383), but the proposed framework is not implemented within or evaluated alongside such a model. The authors should demonstrate how an HSS indicator could be incorporated into, used to constrain, or evaluated alongside a sociohydrological model. Preferably, this should include a modelling application showing how the identified discourse trends could be linked to specific model variables or parameters.

Response: Thank you for this suggestion. We agree that the implementation pathway should be explicit.

We have revised Section 4.3 to distinguish among three conceptually different operations: using an empirical discourse indicator to inform or evaluate a latent social state, estimating parameters controlling the temporal dynamics of that state, and coupling the social state dynamically with a physical hydrological model. The present study demonstrates the first operation. We no longer describe the present application as parameter calibration because no parameters of the latent social state are estimated from the HSS indicator.

Accordingly, Section 4.3 now reads:

“HSS information can contribute to sociohydrological models at different levels, which should not be conflated. First, a discourse-derived indicator may provide empirical information relevant to evaluating or constraining the temporal representation of a latent social state, such as environmental awareness. Second, repeated empirical indicators may support estimation of parameters controlling the dynamics of that state, provided that an appropriate relationship between the observed indicator and latent construct can be established. Third, the resulting social-state representation may be coupled dynamically with hydrological variables through feedback relationships. The demonstration presented here addresses the first level; subsequent parameter estimation and fully coupled simulation require additional observations and are beyond the scope of the present analysis.”

- 1-b) The discourse indicators should also be compared with corresponding historical meteorological, hydrological, and water-management data, such as precipitation, discharge, drought and flood records, water-quality observations, reservoir operations, or policy changes. A more in-depth attribution analysis is needed to determine whether changes in media discourse correspond to actual hydrological events or management responses.

Response: We appreciate this important suggestion. We agree that independent hydrological or water-management observations would provide a stronger basis for evaluating the sociohydrological meaning of the HSS indicators.

At the same time, the newspaper dataset was designed to characterize long-term discourse trajectories rather than event-by-event responses. We therefore avoid correlations between individual hydrological events and newspaper observations when the events may fall outside the sampled weeks.

In the revised manuscript, major hydrological, water-quality, institutional, and policy developments are used as independent historical context for the observed long-term discourse transitions, while temporal correspondence is explicitly distinguished from causal attribution.

Accordingly, the revised Discussion now reads:

“The major discourse transitions were additionally examined in relation to independently documented hydrological, water-quality, institutional, and policy developments. These comparisons are used to provide historical context and to assess temporal correspondence rather than establish causation. Because newspaper coverage was sampled during four weeks per year, the dataset is not suitable for event-by-event attribution of media response to individual floods, droughts, or pollution incidents. Accordingly, coincidence between a discourse transition and a documented management or hydrological change is interpreted as contextual evidence of possible human–water-system linkage, not as proof that one caused the other.”

Where the manuscript discusses specific events, the wording has also been revised from causal language to wording such as:

“The increase in sustainability-oriented framing during this period coincided with major water-quality incidents and subsequent institutional changes.”

rather than:

“These events caused the increase in environmental awareness.”

2) The novelty and robustness of the HSS framework require further justification.

Response: Thank you for this constructive comment. We agree that the methodological contribution and robustness of the proposed framework required clearer definition.

The revised manuscript now explicitly defines the information produced by HSS, reports intercoder reliability, evaluates sampling sensitivity, examines transition-model sensitivity, and distinguishes the direct outputs of discourse analysis from higher-level social proxies.

Accordingly, Section 4.2 now reads:

“The principal methodological contribution of HSS is the integration of contextual manual interpretation and scalable computational analysis into a workflow that produces explicitly defined, temporally resolved discourse indicators. Its robustness does not derive from any single analytical technique. Rather, it is evaluated through convergence among complementary analyses, intercoder agreement, sensitivity to the sampling design, and sensitivity of transition estimates to alternative nonlinear formulations. Importantly, HSS outputs are separated into directly observed discourse quantities and derived proxies so that uncertainty introduced during interpretation is not obscured.”

2-a) The manuscript should more clearly distinguish the proposed framework from previous studies combining manual coding, TF-IDF, semantic analysis, and topic modelling. Its methodological novelty should be stated explicitly. The authors should also define the quantitative indicators generated by the framework, explain their uncertainty and temporal resolution, and show how they could be used reproducibly in hydrological or sociohydrological applications.

Response: We appreciate this important suggestion. We agree that the original manuscript used the term “indicator” too broadly without defining exactly which quantities were directly observed and which represented higher-level interpretations.

We now distinguish three information levels: direct discourse indicators, derived discourse proxies, and latent social states. Their temporal resolution and major uncertainty sources are also explicitly described.

Accordingly, Section 2.1 now reads:

“HSS produces two distinct levels of quantitative output. Direct discourse indicators are quantities calculated from the newspaper corpus, including theme prevalence, framing prevalence, TF-IDF-based keyword importance, semantic-change measures, and topic prevalence. Derived discourse proxies are constructed from one or more of these direct indicators to provide empirical information relevant to a latent social construct. The environmental-framing indicator used in the sociohydrological demonstration is one such proxy. Latent constructs themselves, including environmental awareness or collective memory, are not directly measured by HSS.

The temporal resolution of each indicator is determined by the aggregation interval and the density of sampled articles. Uncertainty arises from article sampling, classification, source selection, editorial processes, and the mapping of observable discourse onto a latent social construct. These sources of uncertainty are treated separately where possible rather than being subsumed into a single measure.”

2-b) Only four weeks per year were sampled from two newspapers. This strategy may omit important floods, droughts, pollution incidents, and policy debates occurring outside the selected periods. The authors should provide a stronger justification and assess the sensitivity of the results to the sampling strategy, for example by comparing the fixed-period and randomly selected samples.

Response: We agree and have added a separate evaluation of the fixed-period and random-period components.

The corrected sample sizes are 319 articles from the fixed-period component and 325 from the randomly selected periods. The revised manuscript compares their thematic and framing distributions directly.

Accordingly, the revised Results now read:

“The sensitivity analysis compared the 319 fixed-period articles with the 325 randomly sampled articles. To examine sensitivity to the sampling design, thematic and framing distributions were evaluated separately for the fixed-period and randomly selected samples. The results reveal similar distributions across the two sampling designs, with the largest difference observed for Natural Hazards (23.1% in the random sample vs. 33.7% in the fixed-period sample), while Water Policy (25.1% vs. 26.6%), Water for Urban Use (17.0% vs. 17.5%), and Water Quality (15.9% vs. 13.8%) remained comparable. The comparison indicates which long-term patterns

are common to both sampling components and which categories, particularly event-sensitive topics such as Natural Hazards, are more strongly affected by the selected sampling periods. These results are used to identify which conclusions are robust across sampling components and which require greater caution.”

2-c) Although two researchers independently coded the articles, no quantitative measure of inter-coder reliability is reported. Statistics such as Cohen’s kappa or Krippendorff’s alpha should be provided. The decision rules for overlapping themes and ambiguous tone categories should also be clarified.

Response: We appreciate this valuable suggestion. We have now reported the intercoder reliability statistics and expanded the coding protocol to explain how overlapping themes and ambiguous classifications were handled.

Accordingly, Section 2.3 now reads:

“Independent coding produced an initial agreement of 88.0% for thematic classification (Cohen’s $\kappa = 0.850$) and 83.1% for tonal classification ($\kappa = 0.726$). Remaining disagreements were reviewed by a third independent coder. Each article received one primary thematic classification based on its dominant focus. When more than one category was potentially applicable, the principal issue, dominant problem framing, and emphasis of the headline and article body were used to determine the primary theme. Tone was similarly assigned according to the dominant evaluative framing rather than the presence of isolated development- or environment-related terms.”

3) The analysed data represent newspaper discourse rather than direct observations of public perception. Changes in media discourse may also be influenced by policy changes, government regulations, or management decisions. Although this limitation is acknowledged in Section 4.4, the distinction should be maintained consistently throughout the manuscript. For example, Section 2.5 refers to the coding categories as measures of “social values,” while Lines 244–246 interpret the results as a “broad societal reorientation.” Similar claims regarding “public attention” and “public priorities” appear in the Results and Discussion. These statements should refer more precisely to changes in newspaper discourse or media framing unless supported by independent survey, behavioural, or institutional evidence.

Response: We thank the reviewer for emphasizing this distinction. We fully agree and have conducted a manuscript-wide revision to distinguish newspaper discourse from public perception, societal values, behavioral change, and other latent social constructs.

Where conclusions are based solely on the newspaper corpus, the revised manuscript now refers to media discourse, framing, and discourse-level transitions. HSS-derived quantities are

described as proxies that may provide information about latent social processes rather than direct measurements of those processes.

Accordingly, the revised Discussion now reads:

“The observed changes represent long-term evolution in newspaper discourse and media framing and should not be interpreted as direct measurements of public perception, societal values, or behavior. Newspaper discourse may nevertheless provide useful indirect evidence concerning how water-related issues are publicly framed and circulated over long periods. In the HSS framework, such evidence is therefore treated as an imperfect observation of latent social processes rather than as the processes themselves. Interpretation must account for editorial selection, newspaper orientation, changing readership, sampling design, and the possibility that media framing may respond to institutional and political processes as well as to public concerns.”

The revised Conclusion similarly now reads:

“The key contribution of HSS is not that newspaper discourse directly measures public perception, but that historical media records can be systematically converted into interpretable and temporally resolved discourse indicators. These indicators provide empirical discourse-based information that may help constrain representations of latent social dynamics in sociohydrological analysis, provided that their mediated nature and associated uncertainty are explicitly recognized.”