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Introduction

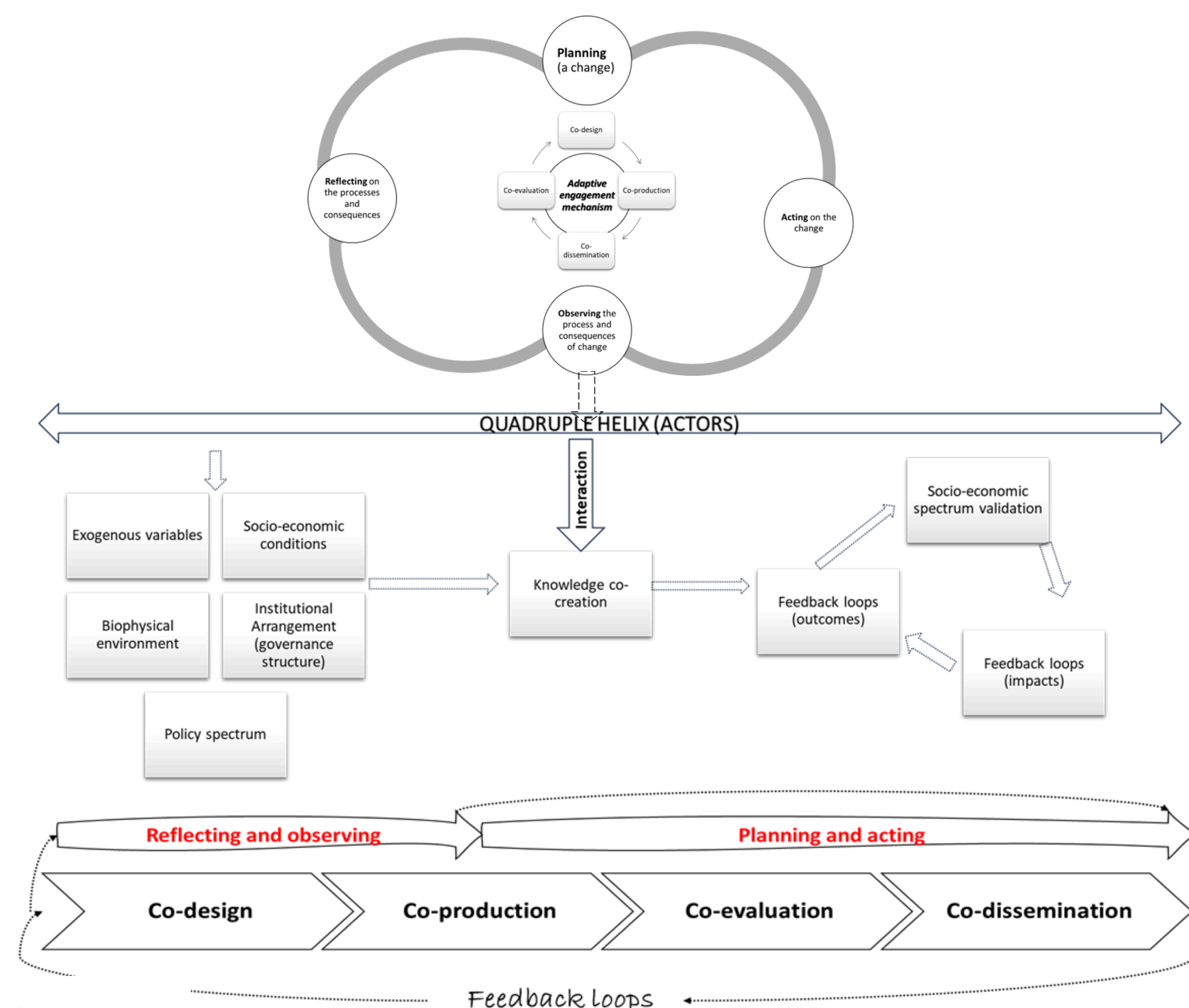
Climate change is reshaping forest systems, but decision-making still lacks integrated socio-economic and governance insights.

Stakeholder engagement generates rich knowledge, yet remains underused in structured analytical frameworks.

Since current approaches rely on fragmented socio-economic data and underutilize stakeholder knowledge, limiting their relevance for real-world decision-making, this study, **addresses this gap by developing and applying an Adaptive Participatory Engagement Framework (APEF) that transforms stakeholder-derived insights into validated and comparable socio-economic indicators.**

Objectives

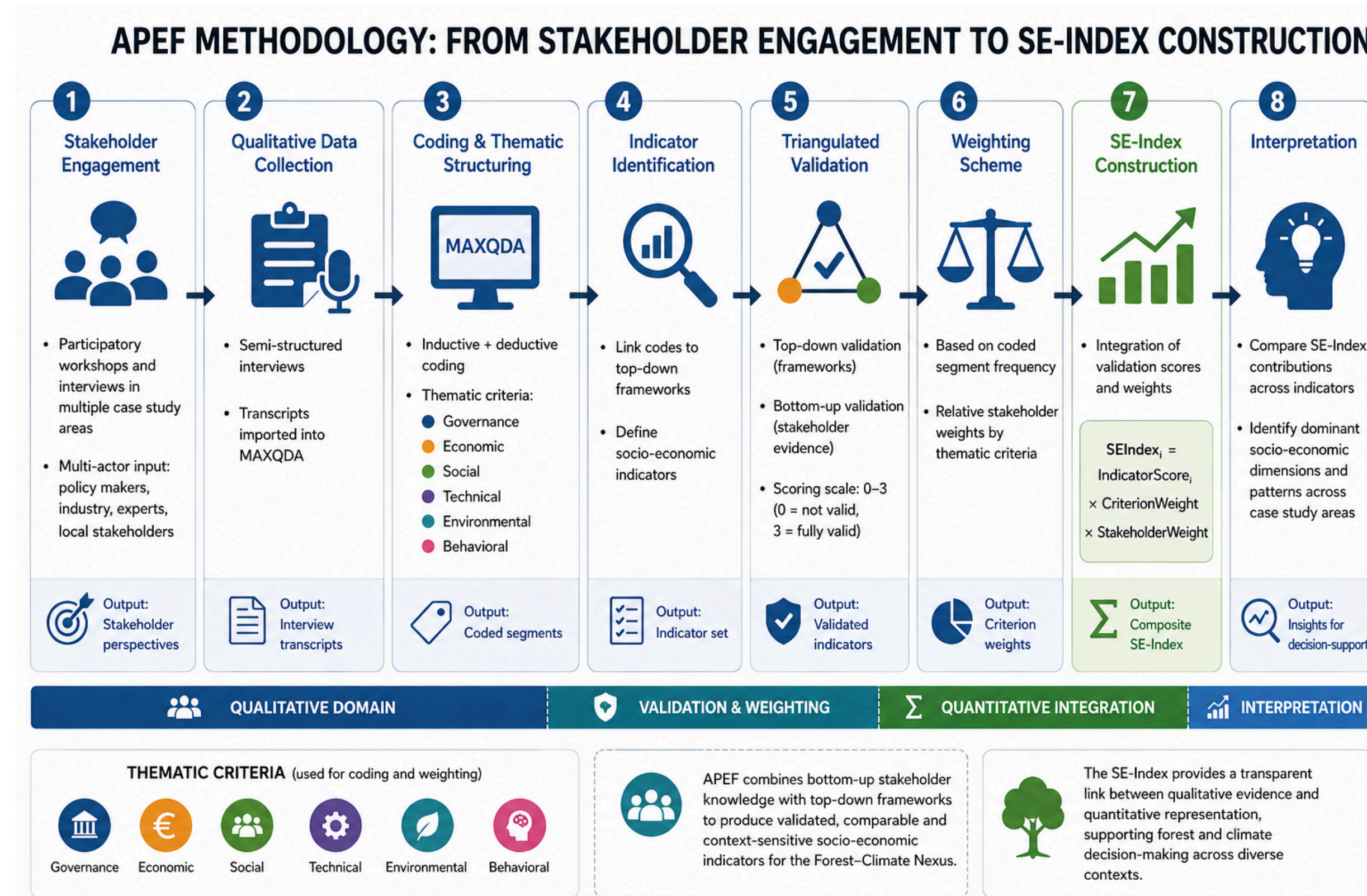
The **aim of this research is to develop and operationalize an Adaptive Participatory Engagement Framework (APEF) and to demonstrate how stakeholder knowledge can be transformed into validated socio-economic indicators through qualitative analysis.** The framework integrates PAR, a four-stage co-creation process, and governance analysis to ensure methodological comparability across Europe while remaining sensitive to local socio-ecological and institutional conditions within the F–C Nexus. In pursuing this aim, the study investigates: (1) how an adaptive participatory engagement framework can be designed and applied across diverse European forestry contexts; (2) how stakeholder engagement processes can generate qualitative evidence on socio-economic and governance dimensions of forest management; and (3) how stakeholder-derived knowledge can be systematically analyzed through qualitative methods and triangulated to identify and validate socio-economic indicators for decision-support applications.



Conceptual framework and Methodology

The **methodology** combines participatory engagement with qualitative analysis to systematically capture stakeholder knowledge across diverse forestry contexts. Stakeholder inputs are collected through workshops and semi-structured interviews in multiple case study areas, then coded using a structured framework to identify key socio-economic and governance themes. These themes were organized into thematic criteria (e.g., governance, economic, social, technical), forming the basis for defining a consistent set of socio-economic indicators aligned with existing policy and analytical frameworks.

These indicators are subsequently validated through a triangulated approach, integrating stakeholder-derived evidence (bottom-up) with established frameworks (top-down). Validation scores were assigned and combined with weights derived from the frequency of coded segments, reflecting stakeholder relevance. The final step integrates validation scores and weights into a composite SE-Index, allowing qualitative insights to be translated into comparable, quantitative outputs for analysis and decision-support.



Results

(1) Application of the APEF across diverse contexts:

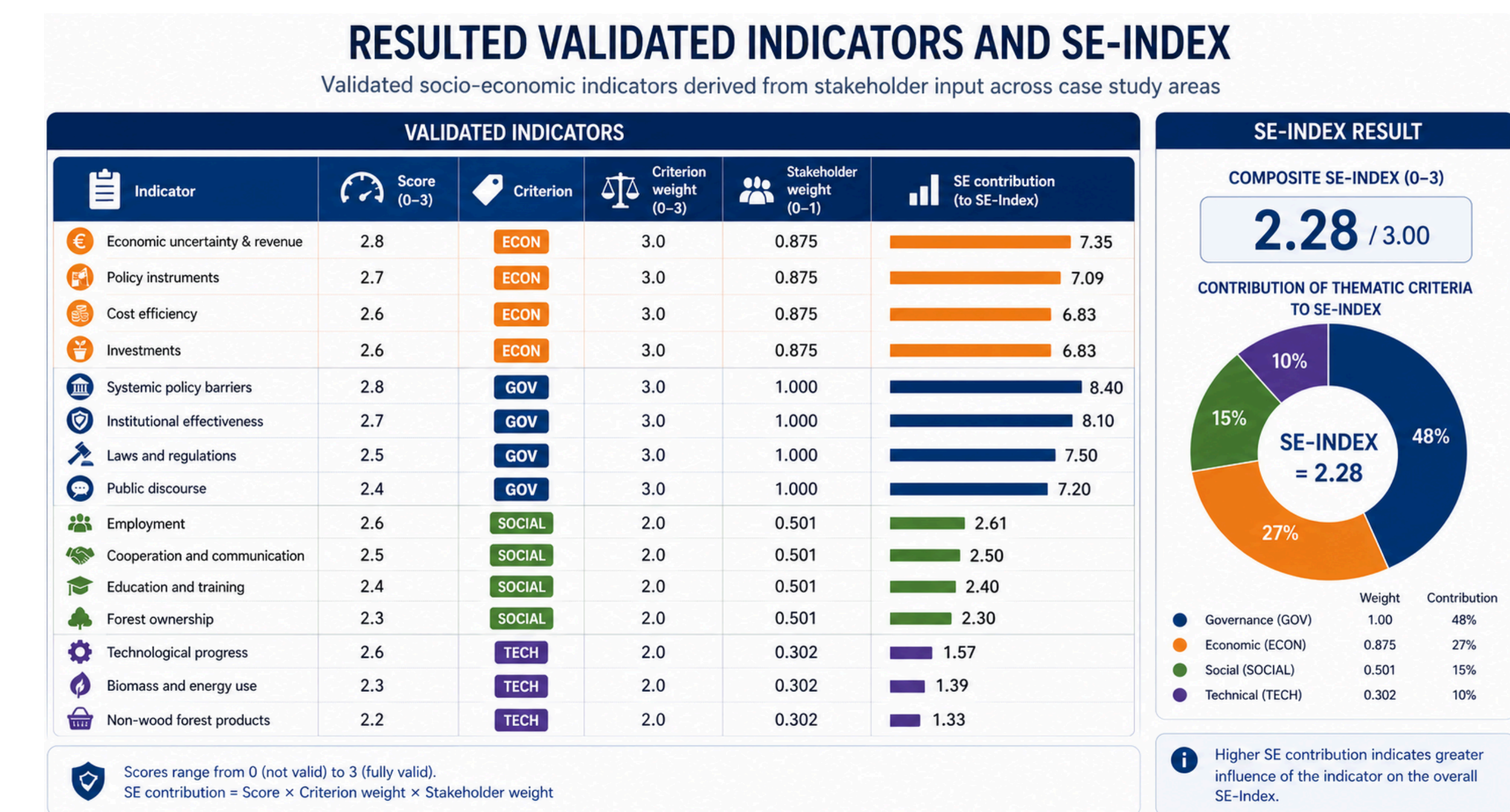
- The framework enabled consistent data collection and analysis across multiple case study areas.
- Governance (1415 segments) and economic dimensions (1238) dominate stakeholder-derived evidence.
- Variation across case studies highlights context-specific socio-economic configurations

(2) Stakeholder engagement as a source of evidence:

- Stakeholder input provides robust qualitative evidence on governance barriers, economic constraints, and management challenges.
- Behavioral responses (708 segments) reveal how uncertainty and risk are perceived and interpreted.
- Social and technical dimensions are consistently present but less influential.

(3) Validation and quantification of indicators (SE-Index):

- Triangulated validation produces consistent, cross-context comparable indicators.
- Governance indicators generate the highest SE-Index contributions, followed by economic indicators.
- The SE-Index translates qualitative insights into measurable outputs for decision-support.



Conclusions

The **Adaptive Participatory Engagement Framework (APEF)** structures stakeholder engagement and translates qualitative insights into comparable socio-economic indicators within the Forest–Climate Nexus. Applied across multiple case study areas, it enables cross-context comparability while preserving differences in governance systems, socio-economic conditions, and forest management settings.

Stakeholder engagement generates consistent evidence on the factors shaping forest management decisions, with governance and economic dimensions emerging as the most prominent. Governance-related aspects dominate both in empirical representation and contribution to the composite index, while economic factors remain closely linked to institutional contexts. Social and technical dimensions are consistently present but less influential, and behavioral responses provide additional insight into how stakeholders perceive and respond to uncertainty.

Through qualitative coding and triangulated validation, stakeholder knowledge is translated into structured and validated indicators. The integration of validation scoring, stakeholder weighting, and aggregation within the SE-Index links qualitative evidence to quantitative outputs, supporting comparison across case study areas. While this approach enhances transparency and decision-support relevance, it remains sensitive to limitations related to representing stakeholder influence, indicating directions for further methodological refinement.

